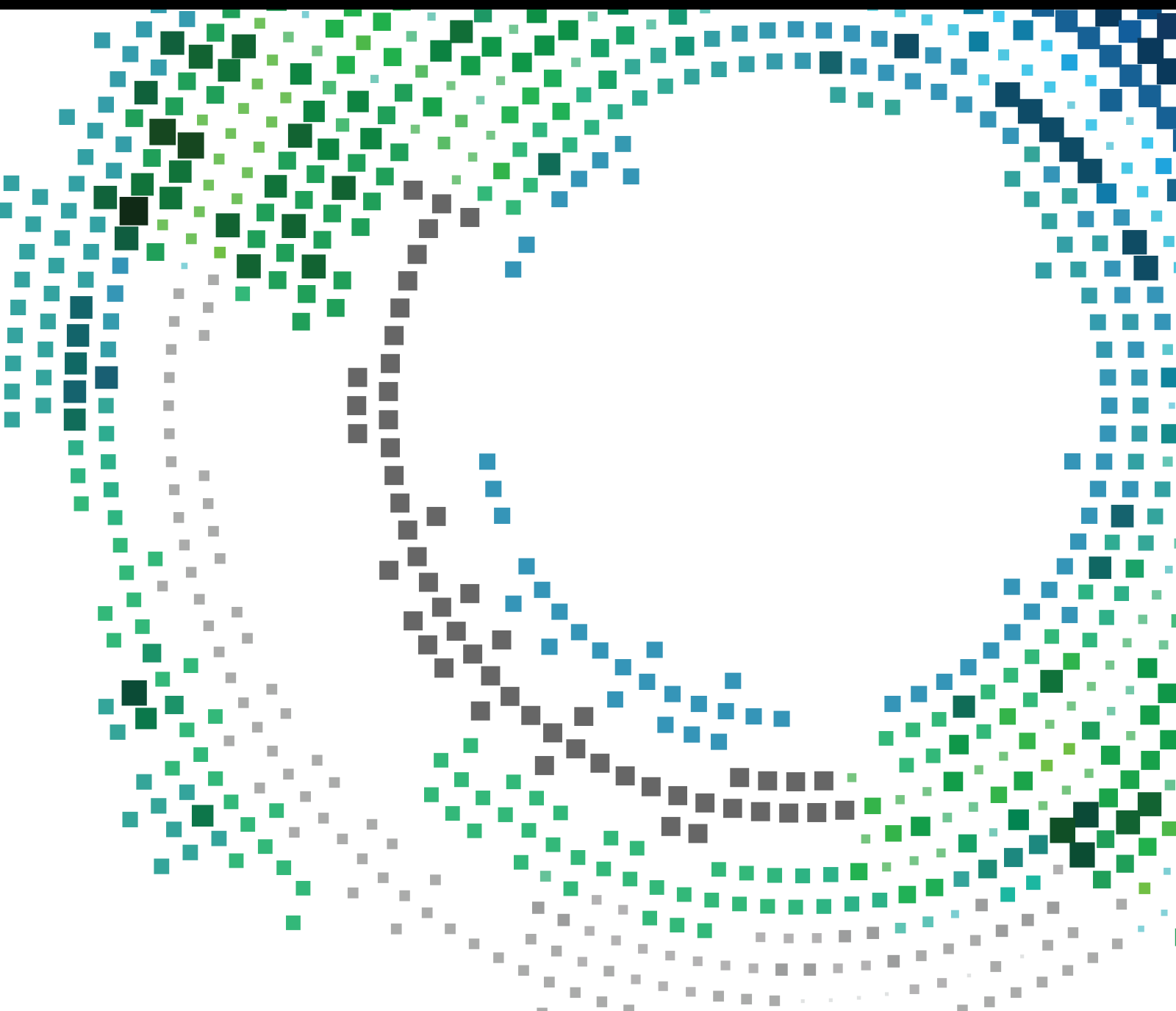


# Novel Approaches to Mobile Application Testing

Lead Guest Editor: Sikandar Ali

Guest Editors: Zhongguo Yang and Sadaqat Ur Rehman





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Mobile Information Systems

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


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## Research Article

# Detection of Touchscreen-Based Urdu Braille Characters Using Machine Learning Techniques

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Revolution in technology is changing the way visually impaired people read and write Braille easily. Learning Braille in its native language can be more convenient for its users. This study proposes an improved backend processing algorithm for an earlier developed touchscreen-based Braille text entry application. This application is used to collect Urdu Braille data, which is then converted to Urdu text. Braille to text conversion has been done on Hindi, Arabic, Bangla, Chinese, English, and other languages. For this study, Urdu Braille Grade 1 data were collected with multiclass (39 characters of Urdu represented by class 1, Alif (ا), to class 39, Bri Yay (ب). Total ( $N = 144$ ) cases for each class were collected. The dataset was collected from visually impaired students from The National Special Education School. Visually impaired users entered the Urdu Braille alphabets using touchscreen devices. The final dataset contained ( $N = 5638$ ) cases. Reconstruction Independent Component Analysis (RICA)-based feature extraction model is created for Braille to Urdu text classification. The multiclass was categorized into three groups (13 each), i.e., category-1 (1–13), Alif-Zaal (ا - ز), category-2 (14–26), Ray-Fay (ر - ف), and category-3 (27–39), Kaaf-Bri Yay (ک - ب), to give better vision and understanding. The performance was evaluated in terms of true positive rate, true negative rate, positive predictive value, negative predictive value, false positive rate, total accuracy, and area under the receiver operating curve. Among all the classifiers, support vector machine has achieved the highest performance with a 99.73% accuracy. For comparisons, robust machine learning techniques, such as support vector machine, decision tree, and  $K$ -nearest neighbors were used. Currently, this work has been done on only Grade 1 Urdu Braille. In the future, we plan to enhance this work using Grade 2 Urdu Braille with text and speech feedback on touchscreen-based android phones.

## 1. Introduction

Smart devices are the most powerful tool for improving people's living standards with visual disabilities [1]. Recent trends predict a drastic increase in smartphone users, with an expected increase of up to 9 billion by 2021 [2, 3]. There are various applications meant to assist visually impaired users, such as screen readers, sound and speech output devices, location finders, wearable devices for mobility, stereo vision-based systems, and virtual assistants [4–7]. Rapid growth in smartphone usage has changed the learning attitude of people [8]. People are increasingly turning to technology to explore new ideas. People learn by watching

videos, tutorials, and online courses on their smart devices [9]. Braille is a commonly used language for visually impaired people. Louis Braille designed it in 1821. Braille is comprised of six dots in the form of two columns and three rows [10]. Visually impaired people write on sheets with the help of a stylus and read by gliding their fingers over the raised dots. It is difficult for visually impaired people to write Braille using these devices. Some interfaces convert textbooks into Braille books, but this facility is limited to specific languages; there is no procedure for converting Urdu text into Braille [11]. Previously, visually impaired people could only use their phones to make phone calls and send and receive text messages [12]. But now, people with visual

impairments can read Braille with the help of a different screen reader software like Apple's VoiceOver [13]. Different applications such as NavTap, Braille Play [14], Braille Tap [15], Braille Key, TypeIn Braille [16], Perkinput [17], Braille Easy [18], Eyedroid [19], and DRISHYAM [20] were developed to facilitate Braille text entry using smart devices. Although audio feedback was provided for user assistance in these applications, they also used numerous difficult gestures to memorize and took more time to perform a specific task. Due to usability issues, visually impaired users are unable to access such applications. Research is in progress for making applications that are less time-consuming and more usable. For Braille to Natural language conversion, image processing techniques were applied on scanned Braille sheets. Braille has been converted into Arabic [21], English [22], Bengali [23], Hindi [24], Tamil, maths [25–27], and Odia [28] using these techniques, respectively. Braille is converted into Urdu and Hindi using deterministic Turing machines [29] and image segmentation algorithms [30].

Previously, Braille was translated into other languages using scanned sheets as input. Their conversions are hectic due to extensive writing on those sheets by the users. Several touchscreen-based applications provide text-to-speech conversion methods that assist visually impaired people with reading and writing. Most of these applications burden the user [31, 32], such as memorizing so many gestures, finding the position of dots on the screen, and no editing options. A position-free Braille text entry method was proposed to address these problems. That application was designed to put the least burden on the users while entering the English Braille alphabet. Visually impaired users can enter Braille characters by clicking anywhere on the screen, subsequently saved in an image format. For character recognition, deep learning techniques with the GoogLeNet inception model achieved more than 95% accuracy [33]. As per our knowledge, there are very few studies for Urdu Braille data, and none of them takes user input directly from the touchscreen. So, there is a strong need for an application that takes run-time Braille data and converts it into natural languages. Currently, there is no mechanism available for Braille to Urdu conversion using touchscreen-based devices. So, in this study, the front-end interface proposed by Sana et al. was used to collect the Urdu Braille dataset. Braille input was saved in an image format in the previous version of this application. Here, with some backend processing algorithm improvements, Urdu Braille input is saved in numerical data. Machine learning techniques such as DT, SVM, and KNN with RICA-based feature extraction methods are used for Braille to Urdu conversion on the new Urdu Braille dataset, see Figure 1.

The main contributions of this research are as follows:

- (a) Collection of Urdu Braille Grade 1 dataset using the application developed by Sana et al. from visually impaired students of the Special Education School, Manak Payyan, Pakistan [33]. There was no existing Urdu Braille dataset that was taken directly from touchscreen devices.

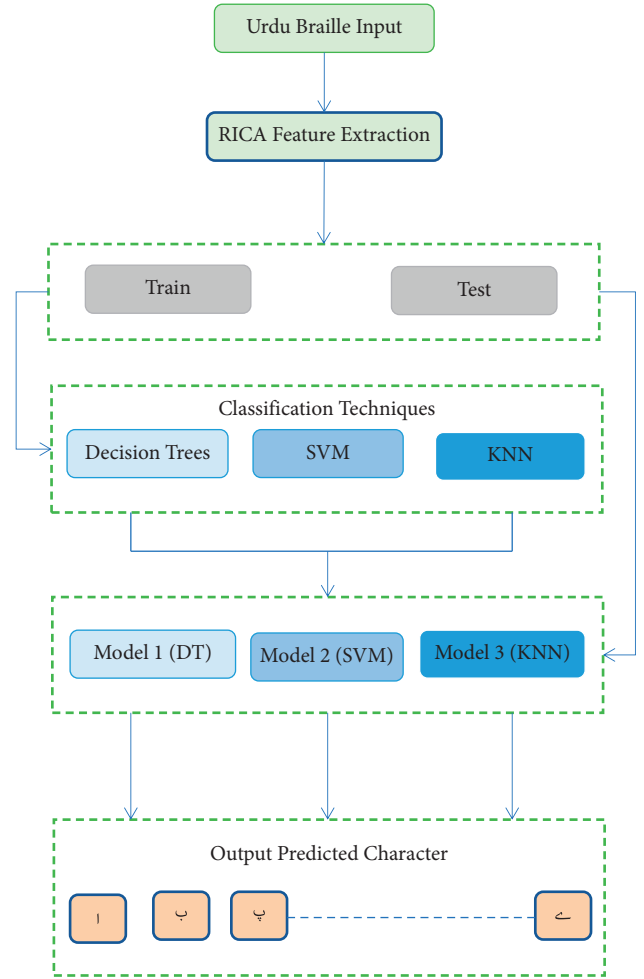


FIGURE 1: Schematic diagram for Braille to Urdu character prediction.

- (b) Enhancement in the backend processing mechanism of Sana et al. has been proposed.
- (c) Predication of Urdu character from Braille input is made with robust machine learning techniques, such as decision tree (DT), support vector machine (SVM), and  $K$ -nearest neighbor (KNN), using RICA-based feature extraction method.
- (d) Evaluation of proposed mechanism on the collected Urdu dataset is made based on true positive rate (TPR), true negative rate (TNR), positive predicted value (PPV), negative predicted value (NPV), false positive rate (FPR), total accuracy (TA), and area under the curve (AUC).
- (e) A comparative analysis with previous studies using scanned input-based data of different national and regional languages has been performed.

This study comprises the following sections: Section 2 provides materials and methods, information regarding the dataset, and its collection procedure. In Section 3, the results are presented in detail. Discussion is provided in Section 4, and finally, conclusions and future work are presented in Section 5.

## 2. Materials and Methods

**2.1. Dataset.** The front-end android-based application proposed was used to collect the Urdu dataset for this study [33]. On the android-based touchscreen, visually impaired users enter Urdu Braille characters. The dataset is collected from the National Special Education School Center (NSEC) “Manak Payyan.” The age of the participants was between 12 and 19 years, and these students were either completely or partially blind. At this level, Urdu Grade 1 Braille data were collected, which included 39 distinct characters.

The final dataset comprises 5637 Urdu Braille characters collected using an android-based touchscreen device. Machine learning techniques are utilized to convert Braille to Urdu text using this dataset. All the ambiguous data were eliminated after checking the values against each alphabet manually.

**2.2. Backend Processing Mechanism.** An improved backend processing mechanism is proposed in this study. In work done earlier, the dataset consisting of images corresponding to each character was used.

In the current study using the position-free interface, values of “x” and “y” coordinating against each dot are stored in a database. Braille is composed of six-dot patterns, and each Braille character is represented by the activation and deactivation of these dots. For example, if a Braille character has two active dots, the proposed system will save the value of “x” and “y” coordinates of active dots, and the remaining four inactive dots will be assigned a “0” value. Initial data were stored in the form of a .txt file separated by a comma. To avoid ambiguity in the dataset, the researcher manually checked the dataset, commas were removed, and each extracted dot was stored in a .csv file. Figures 2(a) and 2(b) show a visually impaired user entering Dal “ڍ” and Toyn “ٹ” using a touchscreen-based Braille interface.

The algorithm for Braille input coordinate extraction is shown in Figure 3.

Since the only coordinate location of active dots is saved in the dataset for each character instead of the whole image, thus, this approach reduces the storage requirements. In previous schemes, the single image saved in the database was 4 to 8 KB in size. For multiple instances, these requirements get multiplied by the number of cases, whereas with the new approach, a text file containing 144 different samples of a single character took only 9 to 10 KB space.

**2.2.1. Feature Extraction.** Different feature extraction techniques were applied earlier to predict Braille to text conversion for other languages. Jha and Parvathi extracted HOG features using Braille to Hindi text conversion [24]. Similarly, Li et al. have used the traditional feature extraction method using KNN, Naïve Bayes, etc., for recognizing Braille characters [34]. Moreover, Li et al. used a histogram of oriented gradients (HOG) with SVM to convert Braille characters into English, Sinhala, and Odia [35, 36]. This study extracts RICA-based features using DT, SVM, and KNN classifiers for converting Braille to Urdu text. This

feature extraction method extracts more features than the actual dimensions of the input dataset. This algorithm also has the ability for faster execution of preprocessing steps.

**2.2.2. RICA Feature Extraction Method.** Reconstruction independent component analysis (RICA) is not a supervised learning technique, so it does not utilize the class label information. RICA algorithm was introduced to address the limitations of the ICA algorithm. This technique delivered more promising results than ICA. A lot of algorithms have been presented in recent years to learn sparse features.

A sparse filter can differentiate many artificial and natural signals, and this feature plays a vital role in different machine learning techniques.

The unlabeled data are given as input

$$\{y^i\}_{i=1}^n, \quad y^i \in \mathbb{R}^m. \quad (1)$$

For calculating independent components, the problem of optimization of standard ICA [37] can be defined mathematically as

$$\min_X \frac{1}{n} \sum_{i=1}^n h(Xy^i), \quad (2)$$

$$\text{subject to } XX^U = I,$$

where  $h(\cdot)$  represents a nonlinear penalty function,  $X \in S^{L \times m}$  is a matrix,  $L$  represents the vectors count, and  $I$  defines the identity matrix. Additionally,  $XX^U = I$  is employed to prevent the vectors in  $X$  from being degenerated. For this purpose, a smooth penalty function can be used, i.e.,  $h(\cdot) = \log(\cosh(\cdot))$  [27].

However, some constraints related to orthonormality block the standard independent component analysis from learning on an overcomplete basis. Consequently, the defect, as mentioned above, prevents ICA from scaling into high-dimensional data. Hence, for the replacement of orthonormality constraints in ICA, soft reconstruction cost is used in RICA. After this substitution, the following unconstrained problem can be used to represent RICA filtering:

$$\min_X \frac{\lambda}{n} \sum_{i=1}^n \left( \|X^U X y^i - y^i\|_2^2 + \sum_{i=1}^n \sum_{k=1}^l h(X_k y^i) \right). \quad (3)$$

In the above-stated equation,  $\lambda > 0$  exhibits the tradeoff between sparsity and reconstruction error rates. After performing swapping orthonormality constraints with reconstruction cost, in this way, even on unwhitened data, RICA can learn sparse representations when  $X$  is overcomplete. However, penalty  $h$  can yield sparse representations and is not invariant [38]. Therefore, RICA [39] swapped it by an additional pooling penalty represented by L2, simultaneously promoting pooling features to cluster correlated features. Moreover, for feature learning, L2 pooling also encourages sparsity. L2 pooling [40, 41] represents a two-layered network; the 1st layer is  $(\cdot)^2$  with square nonlinearity, and in the 2nd layer,  $\sqrt{(\cdot)}$  square root nonlinearity,



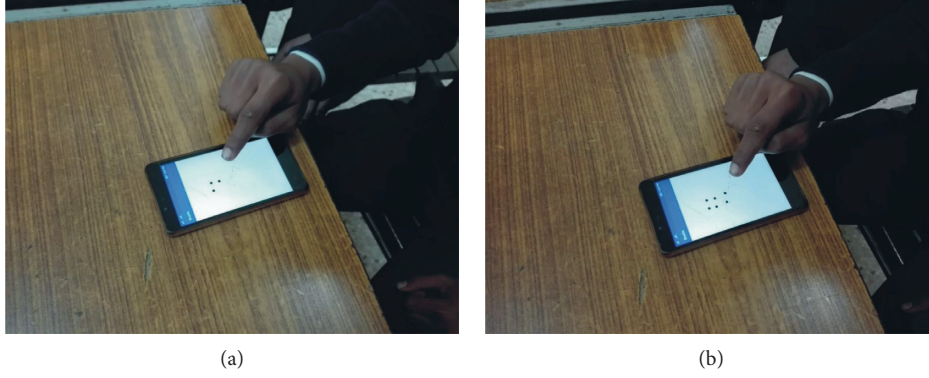


FIGURE 2: (a) A visually impaired student entering Urdu character Dal “ا.” (b) A visually impaired student entering Urdu character Toyn “ا”.

**ALGORITHM** *Braille Input Coordinate Extraction*

1. **Step 1:** Initialize Variables;  $minX$ ,  $minY$ ,  $maxX$ ,  $maxY$ ,  $x$  &  $y$
2.  $minX=20$
3.  $minY=20$
4.  $maxX=scrnwidth - 20$
5.  $maxY=scrnheight - 20$
6. **Step 2:** Draw Point
7.     **If** ( $x_i \geq (scrnwidth - 30)$ )
8.          $x_i = maxX$ ;
9.     **If** ( $y_i \geq (scrnheight - 30)$ )
10.          $y_i = maxY$ ;
11. **else**
12.     **If** ( $x_i \leq 20$ )
13.          $x_i = minX$ ;
14.     **If** ( $y_i \leq 20$ )
15.          $y_i = minY$ ;
16. Get ( $x_i, y_i$ ) //Draw circle at  $x_i$  and  $y_i$  with radius 15 pixels
17. Repeat **Step 2** [7-16] for each “ActiveDot”
18. **Step 3:** Check swipe direction
19.     **If** event: swipe left to right
20.         SaveCoordinate ( $x_i, y_i$ ) ; //for each Active Dot
21.         SaveCoordinate (0,0); //for each Inactive Dot
22.     **else** event: swipe right to left
23.         ClearScreen();

FIGURE 3: Proposed algorithm for Braille input coordinate extraction.

$$h(Xy^i) = \sum_{k=1}^L \sqrt{\varepsilon + H_k \cdot ((Xy^i) \odot (Xy^i))} \quad (4)$$

Pooling matrix  $H \in P(L \times L)$  where  $H_k$  denotes a row of that pooling matrix set to constant weights, i.e., 1 for every element in matrix  $H$ , element-wise multiplication is defined by  $\odot$ , and  $\varepsilon > 0$  is a small constant. RICA is a linear method that investigates the sparse representation only in the actual data space. RICA method is unable to use the association between class label information and training samples.

**2.3. Classification.** A process for categorizing classes according to the extracted features is known as classification. There are different machine learning techniques, such as supervised, unsupervised, reinforcement, ensemble, neural networks, and deep learning [42]. Machine learning approaches such as DT, KNN, and SVM based on RICA-based feature extraction methods are applied for character prediction. 70%–30% data are used for training and validation purpose [43].

**2.3.1. Decision Tree.** A DT is a machine learning technique that is used for prediction. DT is popular because it does not require too many computations [44]. DT classifiers have a tree-like structure that divides the dataset into several subsets. This classifier trains the model by applying simple decision rules on training data [45]. The model is then used to forecast the desired values, read the dataset, and categorize them into classes [8].

The following equations can be used to design DT algorithms mathematically.

$$\begin{aligned} \bar{X} &= \{X_1, X_2, X_3, \dots, X_m\}^T, \\ X_i &= \{x_1, x_2, x_3, \dots, x_{ij}, \dots, x_{in}\}, \\ S &= \{S_1, S_2, \dots, S_i, \dots, S_m\}. \end{aligned} \quad (5)$$

In this study, train and test data are divided, with a 70%–30% ratio. Training data are used to build a model, and test data are used to check the model’s validity. A multiclass approach is used to predict Braille to Urdu text using DT. The DT is tuned using the default parameters.

**2.3.2. KNN.** KNN is the most common and simple non-parametric technique used for regression and classification models in machine learning. The Euclidian distance formula [46] is used to calculate the distance between the samples.

$$EU_{a,b} = \sqrt{\sum_{i=1}^n (a_i - b_i)^2}, \quad (6)$$

where  $a$  and  $b$  represent the number of samples.

$$a_i - b_i, \quad (7)$$

where  $a_i - b_i$  are the  $i^{\text{th}}$  dimension feature dimensions of samples, and  $n$  represents the total number of feature dimensions.

The number of nearest neighbors determines the output value while using KNN. If the value of  $K = 1$ , the object can be classified and assigned to the nearest neighbor of that single class [45].

Here, KNN is used to classify Braille to Urdu text.  $K = 3$  is selected, distance metrics as Euclidean distance, and distance weight as equal weight.

**2.3.3. SVM.** For pattern and character recognition, SVM is the most well-known machine learning classification technique. SVM is a supervised machine learning technique used in biomedical image processing, computer vision, speech recognition, etc. [47]. SVM builds a hyperplane in high-dimensional spaces to obtain a better classification. If the achieved hyperplane has the highest functional margin, the classifier will give good performance [48]. The greater the margin, the lower the risk of generalized error. SVM finds the hyperplane that provides the most significant minimum distance for the training data. SVM can produce more generalized outcomes. SVM is a twofold classifier that converts data into a hyperplane that depends upon high-dimensional data.

Let us consider a hyperplane  $x \cdot w + b = 0$ , where  $w$  is normal.

Linearly separable data are represented as follows:

$$\{x_i, y_i\}, x_i \in \mathbb{R}^N, y_i \in \{-1, 1\}, \quad i = 1, 2, \dots, N, \quad (8)$$

where  $y_i$  is the twofold class label.

When we achieve maximum margin by maximizing, the objective function value of

$$E = \|w\|^2 \text{ gives}$$

$$\begin{aligned} x_i \cdot w + b &\geq 1, \text{ for } y_i = +1, \\ x_i \cdot w + b &\leq -1, \text{ for } y_i = -1. \end{aligned} \quad (9)$$

By removing the discrepancies from the above equations, now we have

$$(x_i \cdot b + b) y_i \geq 1, \text{ for all } i. \quad (10)$$

If data cannot be linearly separated, then a slack variable  $\Xi_i$  is used to identify misclassifications.

Thus, in this scenario, an objective function is defined as

$$E = \frac{1}{2} \|w\|^2 + C \sum_i L(\Xi_i), \quad (11)$$

subject to

$$(x_i \cdot b + b) y_i \geq 1 - \xi_i, \text{ for all } i. \quad (12)$$

Here,  $C$  and  $L$  represent hyperparameters and cost functions, respectively. Cost functions are used to detect outliers. The dual formulation with  $L(\Xi_i) = \Xi_i$  is

$$\alpha = \max_{\alpha} \left( \sum_{i,j} \alpha_i \alpha_j y_i y_j x_i x_j \right), \quad (13)$$

subject to

$$0 \leq \alpha_i \leq C,$$

$$\sum_i \alpha_i y_i = 0. \quad (14)$$

Here,

$$\alpha = \{\alpha_1, \alpha_2, \alpha_3, \dots, \alpha_i\},$$

$$w_0 = \sum_i \alpha_i x_i y_i. \quad (15)$$

Kernel trick is used to handle nonlinearly separable data [49]. The nonlinear mapping function from the input space is transformed into a higher dimensional feature space. Polynomial, Gaussian, and radial-based functions are the most popular kernels.

SVM polynomial kernels:

$$K(x_i, y_i) = \exp\left(\frac{-1}{2} \frac{\|x_i - y_i\|^2}{\sigma^2}\right). \quad (16)$$

SVM Gaussian polynomial kernels:

$$K(x_i, y_i) = \exp\left(\frac{-1}{2} \frac{\|x_i - y_i\|^2}{\sigma^2}\right). \quad (17)$$

SVM fine Gaussian kernels:

$$K(x_i, y_i) = \exp\left(\frac{-1}{2} \frac{\|x_i - y_i\| \|x_i - y_i\|}{\sigma^2}\right). \quad (18)$$

Dual formation of a nonlinear case is shown as

$$\alpha^* = \max_{\alpha} \left( \sum_i \alpha_i + \sum_{i,j} \alpha_i \alpha_j y_i y_j K(x_i, y_j) \right), \quad (19)$$

subject to

$$0 \leq \alpha_i \leq C,$$

$$\sum_i \alpha_i y_i = 0. \quad (20)$$

Grid search is the famous evaluation metric used for SVM evaluation. Optimal parameters are carefully selected by setting the grid range and step size. Only one parameter, “ $c$ ,” a soft margin constant, is used in a linear kernel, whereas the SVM Gaussian kernel and SVM fine Gaussian kernel contain two training parameters, cost “ $c$ ” and sigma, which can be used to control the nonlinearity of the degree. RICA feature extraction method was employed in the study with 70% data for training and 30% for testing. In this study, a polynomial kernel with default parameters is used.

**2.4. Performance Evaluation Metrics.** To predict Urdu Braille characters, true positive rate (TPR), true negative rate (TNR), positive predicted value (PPV), negative predicted



value (NPV), false positive rate (FPR), and total accuracy (TA) are used to evaluate Urdu Braille character prediction.

**2.4.1. True Positive Rate.** TPR is also called sensitivity or recall. TPR indicates how many correct alphabets are classified as true. Mathematically, it is written as

$$\frac{\text{recall}}{\text{sensitivity}} = \frac{\text{TP}}{\text{TP} + \text{FN}} \quad (21)$$

**2.4.2. True Negative Rate.** TNR is also called specificity. This metric defines the number of negative predicted values that are correctly identified. It can be expressed mathematically as

$$\text{specificity} = \frac{\text{TN}}{\text{TN} + \text{FP}} \quad (22)$$

**2.4.3. Positive Predictive Value.** A test predicted positive results when it is true positive. Mathematically, it can be presented as

$$\text{precision (PPV)} = \frac{\text{TP}}{\text{TP} + \text{FP}} \quad (23)$$

**2.4.4. Negative Predictive Value.** NPV shows a test result in negative prediction, and the subject also has a negative value. Mathematical representation is given as follows:

$$\text{negative predictive value (NPV)} = \frac{\text{TN}}{\text{TN} + \text{FN}} \quad (24)$$

**2.4.5. Total Accuracy.** Total accuracy is defined by adding all true positives and all true negatives and dividing it by all true negatives, false positives, true positives, and false negatives.

$$\text{accuracy} = \frac{\text{TP} + \text{TN}}{\text{TN} + \text{FP} + \text{TP} + \text{FN}} \quad (25)$$

**2.4.6. ROC.** It measures the proportions of all true positives and all true negatives. They are calculated by plotting the ROC curve against the true positive and false positive values. TPR is plotted along the x-axis, whereas FPR is plotted along the y-axis. The area under the curve (AUC) value lays between 0 and 1. A value >0.5 shows separation. A value greater than 0.5 indicates separation. In this study, Braille Urdu characters, which are predicted true when they belong to the true class, have values 1 or approaching 1.

### 3. Results

Urdu Braille characters are predicted from a newly collected dataset from touchscreen devices. The performance is computed using RICA feature extraction methods and machine learning algorithms such as DT, KNN, and SVM. TPR, TNR, PPV, NPV, TA, FPR, and

AUC were the performance metrics employed in the evaluation.

Figures 4(a)–4(c) show AUC values using DT for category-1 (class 1–class 13), Alif-Zaal (ا - ذ), category-2 (class 14–class 26), Ray-Fay (ر - ف), and category-3 (class 27–class 39), Qaaf-Bri Yay (ق - پ), respectively. By extracting RICA features, the highest performance attained from category-1 (class 1–class 13), Alif-Zaal (ا - ذ), is Braille class 6 with 99.9% TA and with 0.9979 AUC value, as shown in Figure 4(a). They were followed by other classes such as Alif, Bay, Hay, and Khay (ا, ب, ح, خ) yielding accuracies of (99.90%), with AUC (0.9995, 0.9914, 0.9895), respectively. Other classes such as Chay and Zaal (چ, ذ) also achieved better accuracies of 99.85% and 97.76% with AUC (0.9884 and 0.9887, respectively). Other performance measures, such as TPR and TNR, yield performance (TPR >94%) and (TNR >98%). From category-2 (14–26), Ray-Fay (ر - ف) shows the highest performance for class 18, 21, 14, and 15, i.e., Seen, Zuuad, Ray, Rray, Fay, Toyn, and Ghaen (س, ص, ظ, ر, ز, ف, ط) with accuracies of (99.95%, 99.95%, 99.85%, 99.85%, 99.80%, 99.64%, and 99.64%), with AUC (0.9899, 0.9997, 0.9992, 0.9495, 0.9615, 0.9495, and 0.9683, respectively) with TPR >90% and TNR >99%, as shown in Figure 4(b). For category-3 (27–39), Qaaf-Bri Yay (ق - پ), maximum TA of 100% is achieved for class 35 (Gol Hy), 37 (Hamza), and 28 (Kaaf) (گ, ه, ک) with AUC value of (0.9553, 1, 0.9995). These results are followed by Gaaf, Meem, and Hy (ج, م, ہ) with TA of (99.75%, 99.85%, and 99.75%) (with AUC value of (0.0732, 0.8125, and 0.9553) TPR >94%, and TNR >99%, except for class 31, i.e., TPR = 62.50%, as shown in Figure 4(c). Amongst all, the highest separation (AUC = 1) was seen for the Urdu Braille characters Gol Hy and Hamza (گ, ه). AUC value of other Urdu Braille characters such as Alif, Bay, Pay, and Tay (ا, ب, پ, ت) are above 99% indicating good classification. Detailed results are presented in Table 1.

The maximum accuracy obtained by using KNN for category (1–13), Alif-Zaal (ا - ذ), is for class 2, 4, 5, and 13, i.e., Bay, Tay, Ttay, and Zaal (ب, ت, ط, ذ) with TA (99.95%, 99.85%, 99.80%, and 99.75%) and AUC (0.9997, 0.9992, 0.9990, and 0.9896, respectively), as shown in Figure 5(a). For category-2 (14–26), (Ray-Fay) (ر - ف), highest TA of 100% is achieved for class 15, 18, and 23, followed by 26, 21, 14, and 19, i.e., Rray, Seen, and Zoyn (ظ, س, ز). Fay and Zuad (ف, ض) achieved a TA of 99.95%, while Ray and Sheen (ر, ش) had TAs of 99.90% and 99.75%, respectively, with AUC (1, 1, 1, 0.9884, 0.9922, 0.9995, and 0.9800) with TPR >96% and TNR >99%, as shown in Figure 5(b). Similarly, highest TA achieved for category-3 (27–39), (Qaaf-Bri Yeh) (ق - پ), is for class 35, 37, 31, 30, 27, and 28, i.e., Gol Hy, Hamza, Meem, Laam, Qaaf, and Kaaf (گ, ه, م, ل, ق, ک) with TA (99.69%, 100%, 100%, 99.80%, 99.75%, and 99.69%), with AUC (1, 1, 0.7143, 0.9457, 0.9873, and 0.9578, respectively) along with TPR >42% for Meem (م), TPR = 100% for Gol Hy (گ), Hamza (ه), and TNR = 100% for Gol Hy, Hamza, and Meem (گ, ه, م), as shown in Figure 5(c). Overall findings indicate that Braille characters such as گ, ه, م, ل, ق, ک got the highest AUC value of 1 that shows 100% separation among all classes.

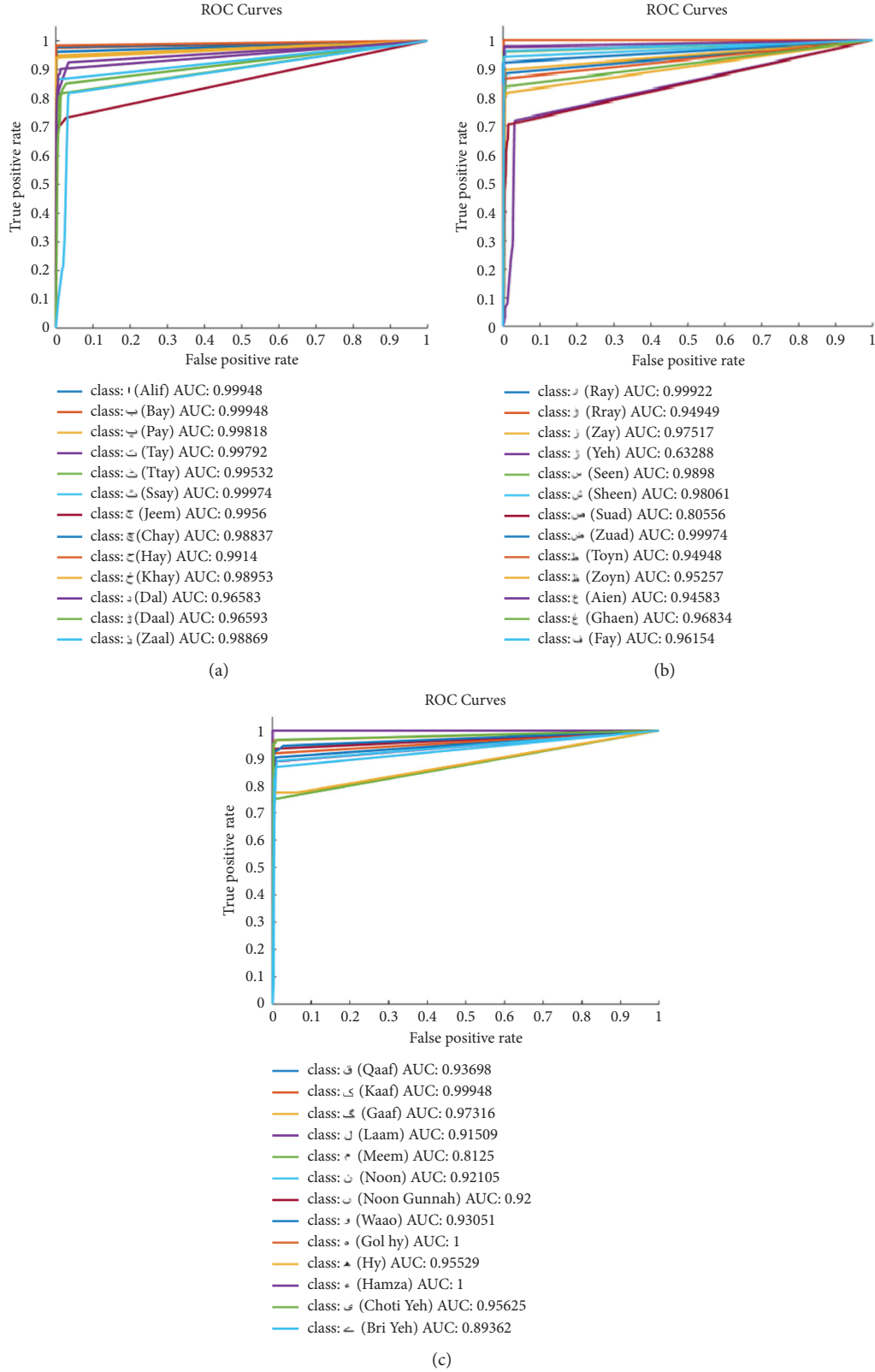


FIGURE 4: (a) ROC curve for category-1 (ا - ز) using DT. (b) ROC curve for category-2 (ر - ف) using DT. (c) ROC curve for category-3 (ق - بـ) using DT.



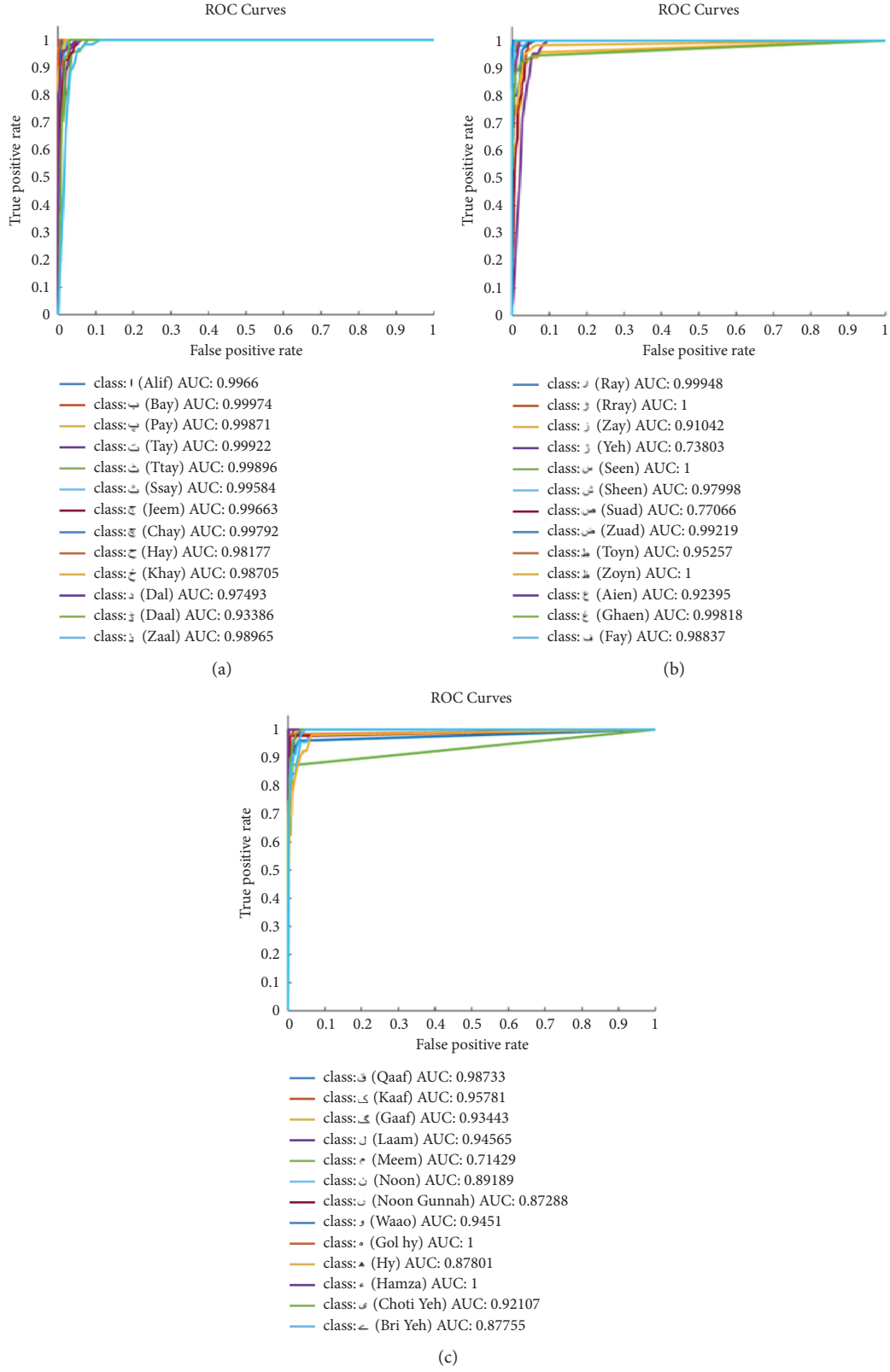


FIGURE 5: ROC to predict Urdu Braille characters. (a) ROC curve for category-1 (ا - ذ) using KNN. (b) ROC curve for category-2 (ر - ف) using KNN. (c) ROC curve for category-3 (ق - ٻ) using KNN.

TABLE 2: KNN classifier results for Grade 1 Urdu alphabets.

Serial #	Urdu characters	English equivalent	TPR (%)	TNR (%)	PPV (%)	NPV (%)	FPR (%)	Total accuracy (%)	AUC
1	ا	Alif	100.0	99.32	80.00	100.0	0.68	99.34	0.9966
2	ب	Bay	100.0	99.95	97.50	100.0	0.05	99.95	0.9997
3	پ	Pay	100.0	99.74	86.11	100.0	0.26	99.75	0.9987
4	ت	Tay	100.0	99.84	93.02	100.0	0.16	99.85	0.9992
5	ٹ	Ttay	100.0	99.79	88.89	100.0	0.21	99.80	0.9990
6	ث	Ssay	100.0	99.17	71.43	100.0	0.83	99.18	0.9958
7	ج	Jeem	100.0	99.33	71.11	100.0	0.67	99.34	0.9966
8	چ	Chay	100.0	99.58	84.62	100.0	0.42	99.59	0.9979
9	ح	Hay	96.72	99.63	89.39	99.89	0.37	99.54	0.9818
10	خ	Khay	97.62	99.79	91.11	99.95	0.21	99.75	0.9871
11	د	Dal	95.45	99.53	82.35	99.90	0.47	99.44	0.9749
12	ذ	Daal	87.50	99.27	71.43	99.74	0.73	99.03	0.9339
13	ز	Zaal	100.0	97.93	43.66	100.0	2.07	97.96	0.9896
14	ر	Ray	100.0	99.90	96.00	100.0	0.10	99.90	0.9995
15	ڑ	Rray	100.0	100.0	100.0	100.0	0.00	100.0	1.0000
16	ز	Zay	83.33	98.75	59.32	99.63	1.25	98.42	0.9104
17	ژ	Yeh	48.08	99.53	73.53	98.60	0.47	98.17	0.7380
18	س	Seen	100.0	100.0	100.0	100.0	0.00	100.0	1.0000
19	ش	Sheen	96.15	99.84	94.34	99.90	0.16	99.75	0.9800
20	ص	Suad	54.24	99.89	94.12	98.60	0.11	98.52	0.7707
21	ض	Zuad	98.44	100.0	100.0	99.95	0.00	99.95	0.9922
22	ط	Toyn	90.57	99.95	97.96	99.74	0.05	99.69	0.9526
23	ظ	Zoyn	100.0	100.0	100.0	100.0	0.00	100.0	1.0000
24	ع	Aien	85.42	99.37	77.36	99.63	0.63	99.03	0.9240
25	غ	Ghaen	100.0	99.64	86.00	100.0	0.36	99.64	0.9982
26	ف	Fay	97.67	100.0	100.0	99.95	0.00	99.95	0.9884
27	ق	Qaaf	97.73	99.74	89.58	99.95	0.26	99.69	0.9873
28	ک	Kaaf	91.67	99.90	95.65	99.79	0.10	99.69	0.9578
29	گ	Gaaf	86.89	100.0	100.0	99.58	0.00	99.59	0.9344
30	ل	Laam	89.13	100.0	100.0	99.74	0.00	99.75	0.9457
31	م	Meem	42.86	100.0	100.0	99.80	0.00	99.80	0.7143
32	ن	Noon	78.38	100.0	100.0	99.59	0.00	99.59	0.8919
33	ں	Noon Gunnah	74.58	100.0	100.0	99.22	0.00	99.24	0.8729
34	و	Wao	89.83	100.0	100.0	99.69	0.00	99.69	0.9492
35	ہ	Gol Ha	100.0	100.0	100.0	100.0	0.00	100.0	1.00
36	ھ	Hy	75.76	99.84	89.29	99.59	0.16	99.44	0.8780
37	ء	Hamza	100.0	100.0	100.0	100.0	0.00	100.0	1.0000
38	ی	Choti Yeh	84.38	99.84	96.43	99.20	0.16	99.08	0.9211
39	ے	Bri Yeh	75.51	100.0	100.0	99.38	0.00	99.39	0.8776

(97.04%), (83.00%), (92.21%), and (95.8%), respectively. For Naive Bayes, DT, and KNN, TPR and PPV showed no significant value. Better results were seen with SVM, sequential model, and GoogLeNet inception model. The maximum performance with the lowest error rate was achieved by SVM with RICA-based feature extraction method with TPR (93.96%), TNR (99.85%), PPV (94.51%), NPV (99.87%), TA (99.73%), and FPR (0.14%). After SVM, the results using DT showed the second best performance. The obtained results show TPR (90.98%), TNR (99.78%), PPV (92.21%), NPV (99.78%), TA (99.57%), and FPR (0.21%). At last, performance achieved using KNN is TPR (90.2%), TNR (99.72%), PPV (89.75%), NPV (99.77%), TA (99.5%), and FPR (0.28%). Table 3 compares the findings of Sana et al. with the current study [33]. More promising results have been achieved with an improved backend processing system for dataset collection; we have achieved more promising results in total accuracy and space used.

#### 4. Discussion

To improve the living quality for visually challenged persons, Braille must be converted to natural language. Braille to natural language conversion has been done in many studies. Most of the studies translated scanned Braille documents into standard English or the other way around. Jha and Parvathi conducted a study that used an SVM classifier trained by extracting features using the histogram of oriented gradient (HOG) feature extraction method to translate handwritten Odia and Hindi text into Braille. Converting Odia [36] and Hindi [25] using this classification technique, 99% and 94.5% accuracies were achieved, respectively, into Braille. Using the same technique, 99% and 80% accuracies were achieved for converting handwritten English and Sinhala documents into Braille text [35]. An SVM classifier trained on HAAR feature extraction methods is used to convert handwritten English sheets, with a classification error of less than 10% [50]. English to Braille conversion was

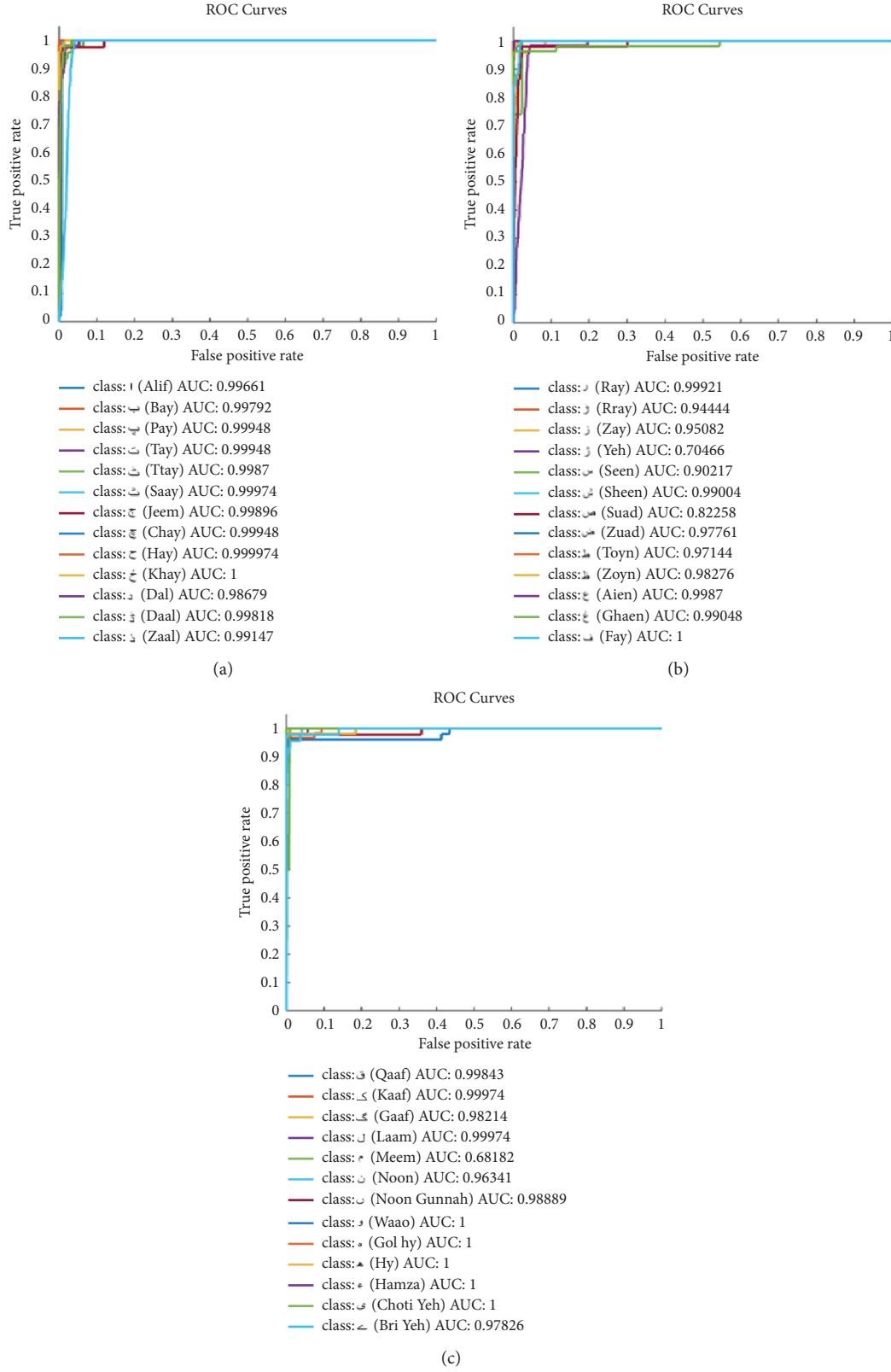


FIGURE 6: ROC to predict Urdu Braille characters. (a) ROC curve for category-1 (ا - ذ) using SVM. (b) ROC curve for category-2 (ر - ف) using SVM. (c) ROC curve for category-3 (ق - ے) using SVM.



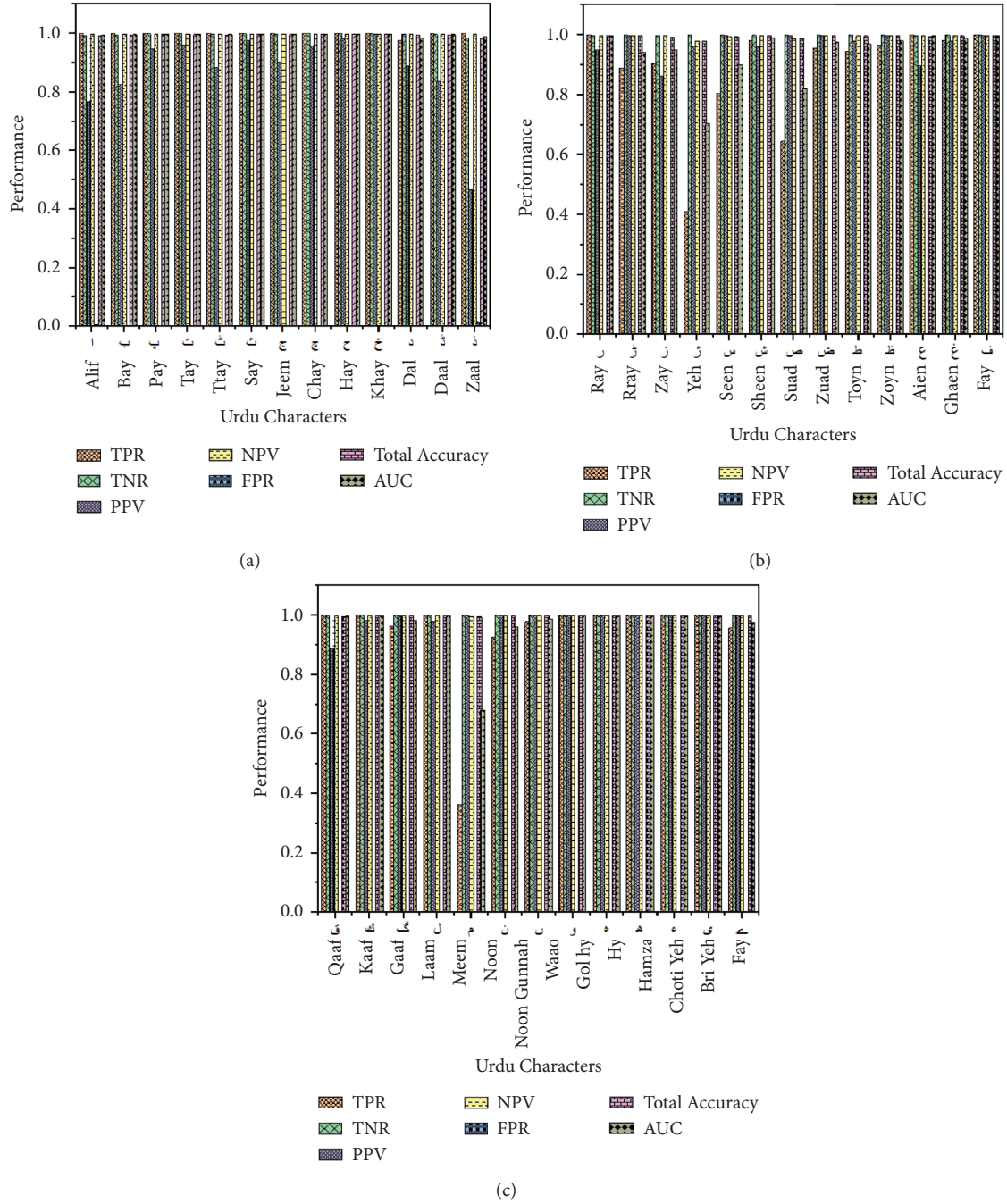


FIGURE 7: Performance metrics showing results obtained for the SVM classifier. (a) Performance metrics for category-1 (Alif - ز) using SVM. (b) Performance metrics for category-2 (Ray - Fay) using SVM. (c) Performance metrics for category-3 (Qaaf - Fay) using SVM.

taken place by taking input from a gesture-based touchscreen using KNN for classification. The distance between two dots was computed using Bayesian touch distance, which yielded a 97.4 percent accuracy [51]. Another study was carried out to recognize scanned Braille characters using KNN, Naïve Bayes, random forest, and SVM depicting that 63%, 53%, 65%, and 69.6% accuracies were achieved [34], as shown in Table 4.

For Braille to Urdu character recognition, RICA-based features are extracted, and robust machine learning

algorithms such as DT, SVM, and KNN are used. A new Urdu Braille dataset was collected from visually impaired students using a newly built touchscreen-based free Braille input application. Main findings achieved for DT algorithm with category-1 (1-13), Alif-Zaaf (Alif - ز), the highest detection performance was obtained with Braille class 6 (ٹ) with TA (99.95%) and AUC (0.9979). These results were followed by other classes such as (خ, ح, ب, ل) yielding accuracies of (99.90%), with AUC (0.9995, 0.9995, 0.9914, and 0.9895), respectively. Other performance indicators, such as TPR and

TABLE 3: Comparative analysis of Braille to natural language conversion using Naïve Bayes, DT, SVM, KNN, sequential model, and GoogLeNet model.

Deep learning scheme for character prediction with position-free touchscreen-based Braille input method [33]						
Classification techniques used	TPR (%)	TNR (%)	PPV (%)	NPV (%)	TA (%)	FPR (%)
Naïve Bayes	NaN	96.64	NaN	99.38	96.38	3.36
DT	NaN	98.82	NaN	98.23	97.20	1.18
KNN	NaN	98.60	NaN	98.11	97.04	1.40
SVM	68.67	99.16	76.75	98.72	83.00	0.84
Sequential model	90.76	99.63	91.07	99.2	92.21	0.36
GoogLeNet model	95.89	99.83	96.61	99.83	95.8	0.16
Detection of Urdu Braille characters based on reconstruction independent component analysis (RICA) features using robust machine learning techniques						
DT	90.98	99.78	91.21	99.78	99.57	0.22
KNN	90.2	99.72	89.75	99.77	99.5	0.28
SVM	93.96	99.85	94.51	99.87	99.73	0.15

TABLE 4: Comparative analysis with previous literatures.

Supported languages	Techniques used	Feature extraction/ algorithms/others	Accuracy (%)	References
Hindi	SVM	HOG features	94.5	[24]
Chinese	Image segmentation techniques	Image segmentation techniques	79.63	[52]
Chinese	DNN	DNN	90.47	[53]
	MLP		86	
	RBF	SDAE	80	
	SoftMax		92	
	MLP		64	
Simple Braille recognition	RBF		55	[34]
	SoftMax		65	
	KNN	Traditional feature extraction	63	
	Naïve Bayes		53	
	Random forest		65	
	SVM		69.6	
Tamil	Nil	Image segmentation technique	99.2	[28]
Hindi			98.8	
Sinhala	SVM	HOG feature extraction method	80	[35]
Arabic	Newly designed Braille letter recognition and transcription scheme for Braille to Arabic text conversion	Image segmentation	99	[21]
Odia	SVM	HOG features	99	[36]
Korean	CNN model	-----	99.6	[54]
		VGG-16	94.62	
Bangla	Deep neural network	ResNet-50	93.58	[55]
		DenseNet-121	94.08	
Grade 1 Urdu Braille	Decision tree		99.57	
	KNN	RICA feature extraction method	99.50	Newly proposed coordinate-based model
	SVM		99.73	

TNR, show that performance (TPR >94%) and (TNR >98%) are achieved. Similarly, category-2 (14–26), Ray to Fay (ف - ر), for DT shows the best results for class 18, 21, 14, and 15, i.e., Seen, Zuuad, Ray, and Rray (ر, ض, ر, ئ) with accuracies of 99.95%, 99.95%, 99.85%, and 99.85%, with AUC (0.9899, 0.9997, 0.9992, and 0.9495 respectively) with TPR = 100% and TNR >99%. For category-3 (27–39), Qaaf-Bri Yeh (ق - ب), highest TA is achieved for class 35, 37, and 28, i.e., Gol Hy and Hamza (ه, ع) with (100%) TA. TA of Kaaf is 99.90%, with AUC (1, 1, and 0.9995), respectively, with TPR >94% and TNR >99%. By employing KNN, the

highest TA achieved for category (1–13), Alif-Zaal (ا - ذ), is for class 13, 2, and 4, i.e., Bay and Tay (99.85% and 99.85%), with AUC (0.9997 and 0.9992, respectively). For category-2 (14–26), (Ry-Fy) (ر - ف), highest TA is achieved for class 15, 18, 23, 26, and 21, i.e., Rray, Seen, and Zoyn (ر, ض, ز) TA = 100% followed by Fay and Zuad (ف, ض) with TPR (99.95%) with AUC (1, 1, 1, 0.9884, and 0.9922) with TPR = 100% and TNR >99%. Similarly, for category-3 (27–39) (Qaaf-Bri Yeh) (ق - ب), highest TA was achieved for class 35, 37, and 31, i.e., Gol Ha, Hamza, and Meem (ه, ع, م) TA (100%, 100%, and 99.80%), with AUC (1, 1, and 0.7143)



with TPR >42% for Meem (م) and TPR = 100% for Gol Hy (و) and Hamza (ع) and TNR = 100% for Hay, Hamza, and Meem (م, و, ع). Moreover, performance evaluation for SVM category (1–13), Alif-Zaal (ا - ز), shows highest accuracies for class 10, 6, 9, and 8, i.e., Khay, Ssay, Hay, and Chy (خ, ج, ث, ح) with TA (100%, 99.95%, 99.95%, and 99.90%), with AUC (1, 0.9997, 0.9997, and 0.9995, respectively) with TPR = 100% and TNR >99%. For category-2 (14–26) (Ray-Fay) (ف - ر), highest performance was achieved for class 26, 15, 23, and 25, i.e., Fay, Rray, Zoyn, and Ghaen (ظ, غ, ز, ف) with TA achieved (100%, 99.95%, 99.90%, and 99.90%) with AUC (1, 0.9444, 0.9828, and 0.9905). Similarly, for category-3 (Qaaf-Bri Yeh) (ق - ب), the highest TA is achieved for class 34, 35, 36, 37, and 38, i.e., Waao, Hy, Gol Hay, Hamza, and Choti Yeh (ق, ه, و, ح, ع, ي) all achieved the highest TA of (100%), with AUC (1) with TPR = 100% and TNR = 100%.

## 5. Conclusions and Future Work

Braille is a growing means of communication for people with visual impairments. More than 150 million people continue to use Braille around the world for several reasons. Literacy is one of the powerful cases that show Braille's importance for learning how to read and write. With the advent of technology, Braille is more accessible to visually impaired users. Various studies have been carried out to convert Braille into a natural language. However, most studies have used handwritten scanned sheets to translate Braille into natural languages such as Arabic, Hindi, Tamil, Odia, Chinese, Korean, Bangla, English, and Gujarati, and vice versa [21, 28, 36, 52–57]. As per our knowledge for Urdu Braille recognition, no such study has been found so far. In this research, the Urdu Braille dataset is collected using a touchscreen-based android application [33]. This application is easy to use and less burdensome for visually impaired people. Robust machine learning techniques include SVM with polynomial kernels, DT with default parameters, and KNN with  $K = 3$  for Urdu Braille character recognition. The dataset was divided into 70%–30% for training and validation. Performance metrics used to evaluate these classifiers' performance are PPV, NPV, FPR, FNR, FPR, TA, and AUC. The RICA-based feature extraction method is used for Urdu Braille character recognition. The highest performance using DT classifier shows that class 35, Gol Hy (و), and class 37, Hamza (ع), achieved a maximum separation AUC (1) with TA, TPR, TNR = 100%, and FPR = 0%. Similarly, the highest performance using KNN shows that class 15, 18, 23, 35, and 37, i.e., Rray, Seen, Zoyn, Gol Hy, and Hamza (س, ز, ع, ه, ط) attained the highest separation AUC (1) with TPR, TNR, TA = 100%, and FPR = 0%. Furthermore, using SVM, the highest performance was achieved by class 10, 26, 34, 35, 36, 37, and 38, i.e., Khay, Fay, Waao, Hy, Gol Hy, Hamza, and Choti Yeh (خ, ف, و, ح, ه, ع, ي) with highest separation AUC (1) with TPR, TNR, TA = 100%, and FPR = 0%. SVM has the highest TA of all classifiers with TA (99.73%), TPR (93.96%), TNR (99.85%), PPV (94.51%), NPV (99.87%), and FPR (0.14%).

RICA features are extracted, and robust machine learning techniques are used to recognize Urdu Braille

characters. We intend to expand this dataset in the future to include other languages such as English and maths with advanced Braille levels. The performance will then be evaluated using convolutional neural network (CNN) and transfer learning techniques such as GoogleNet inception model and LSTM. By implementing these models, performance of the system will further improve. Along with this, we will be more focused on providing error detection and voice feedback services for visually impaired users.

## Data Availability

This dataset is not publicly available. But it could be provided on request.

## Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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## References

- [1] Y. Lee and J. Lee, "A checklist for assessing blind users' usability of educational smartphone applications," *Universal Access in the Information Society*, vol. 18, no. 2, pp. 343–360, 2019.
- [2] Tech. rep, "Ericsson Mobility Report," 2019. <https://www.ericsson.com/en/mobility-report/reports/november-2019>.
- [3] S. O'Dea, "Smartphone users 2020 | Statista," Smartphone users worldwide 2016–2021. 2020. <https://www.statista.com/statistics/330695/number-of-smartphone-users-worldwide-2020>.
- [4] W. Grusseneyer and E. Folmer, "Accessible touchscreen technology for people with visual impairments: a survey," *ACM Trans. Access. Comput.*, vol. 9, no. 2, pp. 1–31, 2017.
- [5] S. Akram, A. Mahmood, I. Ullah et al., "Construction and analysis of a novel wearable assistive device for a visually impaired person," *Applied Bionics and Biomechanics*, vol. 2020, Article ID 6153128, 11 pages, 2020.
- [6] A. A. Díaz-toro, S. E. Campaña-bastidas, and E. F. Caicedo-bravo, "Vision-based system for assisting blind people to wander unknown environments in a safe way," *Journal of Sensors*, vol. 2021, Article ID 6685686, 18 pages, 2021.
- [7] V. Iyer, K. Shah, S. Sheth, and K. Devadkar, "Virtual assistant for the visually impaired," in *Proceedings of the 2020 5th International Conference on Communication and Electronics Systems (ICCES)*, Coimbatore, India, December 2020.
- [8] K. Taylor and L. Silver, *Smartphone Ownership Is Growing Rapidly Around the World, but Not Always Equally*, Pew Research Center, Washington, DC, USA, 2019, <https://www.pewresearch.org/global/2019/02/05/Smartphone-Ownership-Is-Growing-Rapidly-Around-the-World-But-Not-Always-Equally/>.
- [9] S. Shokat, R. Riaz, S. S. Rizvi, K. Khan, F. Riaz, and S. J. Kwon, "Analysis and evaluation of braille to text conversion methods," *Mobile Information Systems*, vol. 2020, Article ID 3461651, 13 pages, 2020.

- [10] J. Rantala, R. Raisamo, J. Lylykangas et al., "Methods for presenting braille characters on a mobile device with a touchscreen and tactile feedback," *IEEE Transactions on Haptics*, vol. 2, no. 1, pp. 28–39, 2009.
- [11] R. K. Virinchi, "Design and analysis of a system to read braille with remote cloud architecture," in *Proceedings of the IEEE 17th India Council International Conference (INDICON)*, New Delhi, India, September 2020.
- [12] B. Leporini, M. C. Buzzi, and M. Buzzi, "Interacting with mobile devices via VoiceOver," in *Proceedings of the 24th Australian Computer-Human Interaction Conference on-OzCHI '12*, Melbourne, Australia, May 2012.
- [13] M. Li, M. Fan, and K. N. Truong, "BrailleSketch," in *Proceedings of the 19th International ACM SIGACCESS Conference on Computers and Accessibility*, Baltimore, ML, USA, June 2017.
- [14] T. Guerreiro, P. Lagoá, P. Santana, D. Gonçalves, and J. Jorge, "NavTap and BrailleTap: non-visual texting interfaces," in *Proceedings of the Rehabilitation Engineering and Assistive Technology Society of North America Conference (Resna)*, Baltimore, ML, USA, January 2008.
- [15] J. Oliveira, T. Guerreiro, H. Nicolau, J. Jorge, and D. Gonçalves, "BrailleType: unleashing braille over touch screen mobile phones," in *Proceedings of the IFIP Conference on Human-Computer Interaction*, Lisbon, Portugal, December 2011.
- [16] N. S. Subash, S. Nambiar, and V. Kumar, "BrailleKey: an alternative Braille text input system: comparative study of an innovative simplified text input system for the visually impaired," in *Proceedings of the 4th International Conference on Intelligent Human Computer Interaction: Advancing Technology for Humanity, IHCI 2012*, Kharagpur, India, June 2012.
- [17] S. Azenkot, J. O. Wobbrock, S. Prasain, and R. E. Ladner, "Input finger detection for nonvisual touch screen text entry in Perkinput," in *Proceedings of the Graphics Interface*, Toronto Ontario Canada, May 2012.
- [18] B. Šepić, A. Ghanem, and S. Vogel, "BrailleEasy: one-handed braille keyboard for smartphones," *Studies in Health Technology and Informatics*, vol. 217, pp. 1030–1035, 2015.
- [19] M. Shabnam and S. Govindarajan, "Gesture recognition algorithm: braille-coded gesture patterns for touch screens: eyedroid," *Indian J. Sci. Technol.*, vol. 9, no. 33, pp. 1–17, 2016.
- [20] H. Gautam and P. Gaur, "DRISHYAM\_ real-time text to braille conversion and realisation," in *Proceedings of the IEEE 17th India Council International Conference (INDICON)*, New Delhi, India, May 2020.
- [21] S. D. Al-Shamma and S. Fathi, "Arabic Braille Recognition and transcription into text and voice," in *Proceedings of the 2010 5th Cairo International Biomedical Engineering Conference*, Cairo, Egypt, June 2010.
- [22] P. R. Kumar, "Braille language converter for visually impaired people," *Int. J. Intellect. Adv. Res. Eng. Comput.*, vol. 6, no. 2, pp. 2229–2232, 2018.
- [23] L. Nahar, A. Jaafar, E. Ahamed, and A. B. M. A. Kaish, "Design of a braille learning application for visually impaired students in Bangladesh," *Assistive Technology*, vol. 27, no. 3, pp. 172–182, 2015.
- [24] V. Jha and K. Parvathi, "Braille transliteration of Hindi handwritten texts using machine learning for character recognition," *Int. J. Sci. Technol. Research*, vol. 8, no. 10, pp. 1188–1193, 2019.
- [25] A. Bier and Z. Sroczynski, "Rule based intelligent system verbalizing mathematical notation," *Multimedia Tools and Applications*, vol. 78, no. 19, pp. 28089–28110, 2019.
- [26] M. Maćkowski, P. Brzoza, M. Żabka, and D. Spinczyk, "Multimedia platform for mathematics' interactive learning accessible to blind people," *Multimedia Tools and Applications*, vol. 77, no. 5, pp. 6191–6208, 2018.
- [27] J. Yook, K. Kim, B. C. Son, and S. Park, "A translating program usability analysis of alternative multimedia mathematics materials for the blind," *Multimed. Tools Appl.*, Springer, Berlin, Germany, 2020.
- [28] S. Padmavathi, K. S. S. Manojna, and S. S. Reddy, "Conversion of braille to text in English, Hindi and Tamil languages," *International Journal of Computer Science, Engineering and Applications*, vol. 3, no. 3, pp. 19–32, 2013.
- [29] M. A. Fahiem, "A deterministic turing machine for context sensitive translation of braille codes to Urdu text," in *Combinatorial Image Analysis*, Springer, Berlin Heidelberg, 2008.
- [30] U. Beg, K. Parvathi, and V. Jha, "Text translation of scanned Hindi document to braille via image processing," *Indian Journal of Science and Technology*, vol. 10, no. 33, pp. 1–8, 2017.
- [31] G. Kouroupetroglou, A. Pino, and P. Riga, "A methodological approach for designing and developing web-based inventories of mobile Assistive Technology applications," *Multimedia Tools and Applications*, vol. 76, no. 4, pp. 5347–5366, 2017.
- [32] S. Priyadarsini, P. Ajit, K. Nayak, and S. Champati, "A survey on speech synthesis techniques in Indian languages," *Multimedia Systems*, vol. 26, pp. 453–468, 2020.
- [33] S. Shokat, R. Riaz, S. S. Rizvi, A. M. Abbasi, and S. J. Kwon, "Deep learning scheme for charcater prediction with position-free touch screen-based Braille input method," *Human Centric Computing and Information Sciences*, vol. 10, no. 1, pp. 1–24, 2020.
- [34] T. Li, X. Zeng, and S. Xu, "A Deep learning method for braille recognition," in *Proceedings of the 2014 International Conference on Computational Intelligence and Communication Networks*, Bhopal, India, November 2014.
- [35] W. K. I. L. I. Perera and T. D. S. H. Wanniarachchi, "Optical braille recognition based on Histogram of oriented gradient features and support-vector machine," *International Journal of Engineering Science*, vol. 8, no. 10, pp. 19192–19195, 2018.
- [36] V. Jha and K. Parvathi, "Machine learning based braille transliteration of Odia language," *International Journal of Innovative Technology and Exploring Engineering*, vol. 9, no. 5, pp. 1866–1871, 2020.
- [37] Y. Yanhui Xiao, Z. Zhenfeng Zhu, Y. Yao Zhao, Y. Yunchao Wei, and S. Shikui Wei, "Kernel reconstruction ICA for sparse representation," *IEEE Transactions on Neural Networks and Learning Systems*, vol. 26, no. 6, pp. 1222–1232, Jun. 2015.
- [38] A. Hyvärinen, J. Hurri, and P. O. Hoyer, *Natural Image Statistics*, Springer London, London, UK, 2009.
- [39] Q. Le, A. Karpenko, J. Ngiam, and A. Y. Ng, "ICA with reconstruction cost for efficient overcomplete feature learning," in *Advances in Neural Information Processing Systems*, Springer, Berlin, Germany, 2011.
- [40] Y.-L. Boureau, J. Ponce, and Y. LeCun, "A theoretical analysis of feature pooling in visual recognition," in *Proceedings of the 27th International Conference on Machine Learning (ICML-10)*, Haifa, Israel, September 2010.
- [41] Y. LeCun, "Learning invariant feature hierarchies," in *Proceedings of the European Conference on Computer Vision*, Berlin, Heidelberg, June 2012.
- [42] M. Hu, W. Li, K. Yan, Z. Ji, and H. Hu, "Modern machine learning techniques for univariate tunnel settlement

- forecasting: a comparative study,” *Mathematical Problems in Engineering*, vol. 2019, Article ID 7057612, 12 pages, 2019.
- [43] I. Rasheed, V. Gupta, H. Banka, and C. Kumar, “Urdu Text Classification: a comparative study using machine learning techniques,” in *Proceedings of the 2018 Thirteenth International Conference on Digital Information Management (ICDIM)*, Coimbatore, India, May 2018.
- [44] T. Shaikhina, D. Lowe, S. Daga, D. Briggs, R. Higgins, and N. Khovanova, “Decision tree and random forest models for outcome prediction in antibody incompatible kidney transplantation,” *Biomedical Signal Processing and Control*, vol. 52, pp. 456–462, 2019.
- [45] L. Hussain, I. A. Awan, W. Aziz et al., “Detecting congestive heart failure by extracting multimodal features and employing machine learning techniques,” *BioMed Research International*, vol. 2020, Article ID 4281243, 19 pages, 2020.
- [46] Q. Ning, Z. Ma, and X. Zhao, “dForml(KNN)-PseAAC: detecting formylation sites from protein sequences using K-nearest neighbor algorithm via Chou’s 5-step rule and pseudo components,” *Journal of Theoretical Biology*, vol. 470, pp. 43–49, 2019.
- [47] A. Gammernan, V. Vovk, H. Boström, and L. Carlsson, “Conformal and probabilistic prediction with applications: editorial,” *Machine Learning*, vol. 108, no. 3, pp. 379–380, 2019.
- [48] M. Achirul Nanda, K. Boro Seminar, D. Nandika, and A. Maddu, “A comparison study of kernel functions in the support vector machine and its application for termite detection,” *Information*, vol. 9, no. 1, p. 5, 2018.
- [49] A. Tharwat, “Parameter investigation of support vector machine classifier with kernel functions,” *Knowledge and Information Systems*, vol. 61, no. 3, pp. 1269–1302, 2019.
- [50] J. Li, X. Yan, and D. Zhang, “Optical braille recognition with haar wavelet features and support-vector machine,” in *Proceedings of the International Conference on Computer, Mechatronics, Control and Electronic Engineering*, Changchun, China, December 2010.
- [51] H. Udupola and S. R. Liyanage, “Braille messenger: adaptive learning based non-visual touch screen input for the blind community using braille,” in *Proceedings of the International Conference on Innovations in Info-Business and Technology, 2017*, Ozo, Colombo, Sri Lanka, October 2018.
- [52] X. Wang, Y. Yang, H. Liu, and Y. Qian, “Chinese-braille translation based on braille corpus,” *International Journal of Advanced Pervasive and Ubiquitous Computing*, vol. 8, no. 2, pp. 56–63, 2016.
- [53] X. Wang, J. Zhong, J. Cai, H. Liu, and Y. Qian, “CBConv: service for automatic conversion of Chinese characters into braille with high accuracy,” in *Proceedings of the 21st International ACM SIGACCESS Conference on Computers and Accessibility*, New York, NY, USA, April 2019.
- [54] S. Lee, S. Jung, and H. Song, “CNN-based drug recognition and braille embosser system for the blind,” *Journal of Computing Science and Engineering*, vol. 12, no. 4, pp. 149–156, 2018.
- [55] T. R. Abir, T. S. Bin Ahmed, M. T. Rahman, and S. Jafreen, *Handwritten Bangla Character Recognition to Braille Pattern Conversion Using Image Processing and Machine Learning*, BRAC University, Dhaka, Bangladesh, 2018.
- [56] M. Gadag and V. Udayashankara, “Efficient approach for English braille to text conversion,” *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, vol. 5, no. 4, pp. 3343–3348, 2016.
- [57] H. Parekh, S. Shah, F. Patel, and H. Vyas, “Gujarati braille text recognition: a review,” *International Journal of Computer Science & Communication*, vol. 7, no. 1, pp. 19–24, 2019.

## Research Article

# Logical Intelligent Detection Algorithm of Chinese Language Articles Based on Text Mining

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With the advent of the big data era and the rapid development of the Internet industry, the information processing technology of text mining has become an indispensable role in natural language processing. In our daily life, many things cannot be separated from natural language processing technology, such as machine translation, intelligent response, and semantic search. At the same time, with the development of artificial intelligence, text mining technology has gradually developed into a research hotspot. There are many ways to realize text mining. This paper mainly describes the realization of web text mining and the realization of text structure algorithm based on HTML through a variety of methods to compare the specific clustering time of web text mining. Through this comparison, we can also get which web mining is the most efficient. The use of WebKB datasets for many times in experimental comparison also reflects that Web text mining for the Chinese language logic intelligent detection algorithm provides a basis.

## 1. Introduction

At present, no matter at home or abroad, there are few research studies on the use of intelligent detection algorithms in detecting Chinese article logic. Text mining is one of the frontier research topics in the field of artificial intelligence; it is a computer technology that processes text based on text data and mathematical statistical analysis [1], combines machine learning and natural language processing [2], extracts information and knowledge contained in text, and selects and extracts samples from text information [3], providing users with easy-to-understand knowledge. For us, Chinese is Mandarin, which we will use in our daily life and study. For example, the words and articles written in books or paper are all Chinese, just like this passage I am writing now. If I read it out, it is actually Chinese, that is, natural language [4]. Of course, it is still Chinese without reading it. As long as people who know this language are working, studying, and living in Chinese, no one can leave it. Putonghua is the standard Chinese language in China and local dialects and national languages of all ethnic groups, that is, local Chinese languages can be translated into standard Putonghua Chinese language.

Whenever and wherever and regardless of any nation and country, our Chinese language can become a common language. There is no natural language understanding problem in interpersonal communication between people [5], but when we communicate with computers, we cannot. How should computers understand our Chinese language and realize text mining from it? At present, we can realize text mining through a series of methods such as information retrieval [6], natural language processing [7], and text information extraction [8]. Comparing web mining with traditional data text mining, we can find that the objects of web mining are distributed and a large number of web documents. Secondly, web text mining is logically a graph composed of document nodes and hyperlinks [9]. Because web documents are unstructured or meaningless, the purpose of data mining may be limited to structured data in the database and use relational tables to store structures [10] for knowledge discovery. Proper usability must be based on the preprocessing of web documents. Therefore, developing new web text mining [11] or preprocessing [12] web files to obtain document features [13] is the focus of web text mining research through three clustering algorithms of



HTML [14] to achieve the realization of logical intelligent detection algorithm and through the dataset [15] to achieve the comparison of experimental data.

Text information mining has always been a research hotspot of scholars. Text information mining based on machine learning, deep learning, and natural language processing technology has also been widely used, such as text information recognition, emotion analysis based on text information, and text similarity detection; at present, there is little research on logic detection and recognition based on text information; especially, for Chinese text, sentence is complex and has multimeaning, logic and grammar are difficult, and sentence composition is complex. How to carry out intelligent recognition of Chinese article logic through text information will be a very useful research topic.

There are few research studies on the use of intelligent detection algorithms in detecting Chinese article logic. The main contributions of this paper are as follows. We proposed a logical similarity degree and mining algorithm of web text and three HTML text clustering-based algorithm (hierarchical method, partition method, and grid method); the use of WebKB datasets for many times in experimental comparison also reflects that the proposed method for the Chinese language logic intelligent detection algorithm provides a basis.

## 2. Web Text Mining and Classification

Text mining is a combination of computer linguistics, statistical analysis, machine learning, and information retrieval technology. From text information to sample selection and extraction, this is a process of creating understandable knowledge. Web text mining [16, 17] is a process of discovering and extracting potentially useful and hidden information from web files and documents. It analyzes and predicts the content trend of web document set. Although web text mining is similar to flat text mining, tags in web document provide additional information to improve web text mining performance. This is the main research content of excavating teaching materials.

Web mining is a challenging subject. It realizes the web structure and rules of the web access model and realizes the dynamic search of web content. Generally speaking, web mining can be simply divided into three categories, as shown in Figure 1.

## 3. The Process of Text Mining

The process of text mining is shown in Figure 2. At first, it is the information source of the text, and the final result is the way users acquire knowledge.

**3.1. Text Preprocessing.** Text mining is the first step of text mining. The writing process may account for 80% of the whole system work.

Compared with traditional structured data, structured files are limited or unstructured. Although it is structured, it will still focus on the form of the document, rather than the

content and unstructured of the document. Therefore, data mining is necessary, and it should adopt certain standards.

Most web pages on the Internet are composed of HTML documents or XML documents. In text preprocessing, the first thing to do is to use the web page information extraction module to remove the tags unrelated to text mining, then convert them into TXT text in a unified format, and store them in a folder for subsequent processing. Compared with English text preprocessing, Chinese text preprocessing will be more complicated because the Chinese original word is not a word; the amount of information of this word is relatively low, and there is no inherent separator (such as space) between words in sentences. It can be seen that Chinese texts also need entries.

**3.2. Representation of Text.** The Boolean logic model, vector space model, latent semantic index, and probability model are commonly used in text representation [18].

The basic idea of the vector space model is to use word bags to represent texts [19, 20]. A key assumption of this expression is that each feature word will correspond to a dimension of the feature space, independent of the order in which the sentences appear in the article. Text is represented as a vector in Euclidean space.

Its core concepts can be described as follows:

- (1) Feature items: each word constitutes a document. Document =  $d(t_1, t_2, t_k, t_n)$ , where  $t_k$  represents the  $k$ th feature and will be used as a dimension.
- (2) Weight of feature items: in the text, each feature element is given a weight to indicate the importance of the feature element in the text.
- (3) Vector space model (VSM): after clearing the order information between feature elements, the text is expressed as a vector, which is a point in feature space.

As represented by the text  $D$ ,  $V(d_i) = W_{i1}, W_{i2}, W_{ik}, W_{im}$ .

$W_{ik} = f(t_k c_j)$  is a weight function reflecting the importance of feature  $t_k$  in determining whether document  $d_i$  belongs to class  $c_j$ .

- (4) Similarity: all documents can be mapped to the space of this text vector. Document information allocation is a vector matching problem in vector positioning. In multidimensional space, the distance between points is measured by the cosine angle between vectors, that is, the similarity between documents. Assuming that the target document is  $U$  and the unknown document is  $V_i$ , the larger the included angle, the higher the similarity of documents. The similarity calculation formula is as follows:

$$\text{similarity}(V_i, U) = \cos(V_i, U) = \frac{V_i \times U}{V_i \cdot U} \quad (1)$$

$$= \sum_{k=1}^m w_{ik} \cdot w_i \sum_{k=1}^m w_{ik}^2 \sum_{k=1}^m w_k^2$$

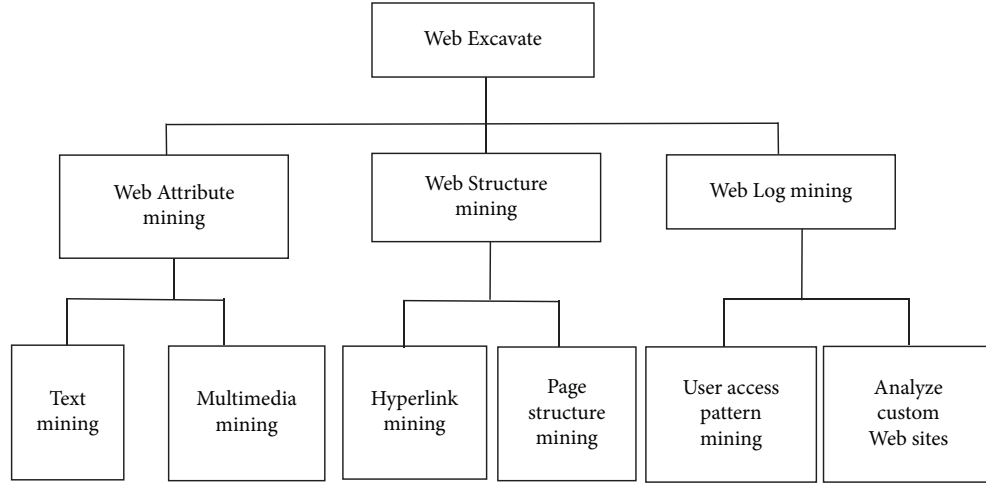


FIGURE 1: Classification graph of web mining.

Weights are generally functions of attribute elements displayed in documents. The frequency with which the feature  $t_k$  appears in the document  $d_i$  is represented by  $f_{ik}$  ( $DI$ ), and there are several weight functions:

- (1) The simplest Boolean form:

$$w_{ik} = \begin{cases} 1, & \text{if } tf_k(d_i) > 0, \\ 0, & \text{otherwise.} \end{cases} \quad (2)$$

The text vector consists of 0 and 1.

- (2) Word frequency type:

$$w_{ik} = tf_k(d_i). \quad (3)$$

- (3) Square root type:

$$w_{ik} = tf_k(d_i)^{1/2}. \quad (4)$$

- (4) Logarithmic type:

$$w_{ik} = \lg(tf_k(d_i) + 1). \quad (5)$$

- (5) TF-IDF formula:

$$w_{ik} = tf_k(d_i) \cdot \lg_{N_k}^N + 0.5. \quad (6)$$

After normalization, it is

$$w_{ik} = \sum_{j \in d_i} \frac{w_{ij}}{w_{ij}^2}. \quad (7)$$

The purpose of normalization is to make different texts have the same length. After the text is segmented by the word segmentation program, the stop word list is first used to delete the words that are not helpful to the classification. We can also use the strategies of feature word correlation analysis, clustering, synonym, and synonym combination and finally express it as the above text vector.

**3.3. Feature Set Subtraction.** Feature set reduction has three goals. First, to improve the running efficiency and speed of the program; The second point is that tens of thousands of dimensional features have different importance for text classification [21]: some features held in common by all categories make little contribution to the classification required by texts and the features of other specific categories account for a relatively large proportion, while the features of other categories account for a small proportion. The third is to prevent them from overfitting. For each class, the attributes that have little contribution to classification are deleted, and the feature set reflecting the class is filtered out. An effective feature set must have the following two characteristics intuitively:

- (1) Completeness: it really reflects the content of the target document
- (2) Differentiation: it can clearly distinguish our target document from other documents

When using vector space method to represent documents, the dimension of text feature vector often reaches tens of thousands of dimensions. Even if the stop words in the stop word list are deleted and the low-frequency words are deleted by zip rules, tens of thousands of dimensional features will still remain. Finally, only the best feature is usually selected to execute various text mining operations through it, so it is very important to further reduce the number of features.

Generally speaking, feature subset extraction is to evaluate each feature in the set function. The method is to create an evaluation function, receive the evaluation of each feature, then sort all the functions after evaluation, and select a predefined number of best features as feature subsets. The evaluation function of text feature selection is extended from the perspective of information theory. It is used to mark each individual feature entry, which is a good reflection of the correlation between the entry and the different types.

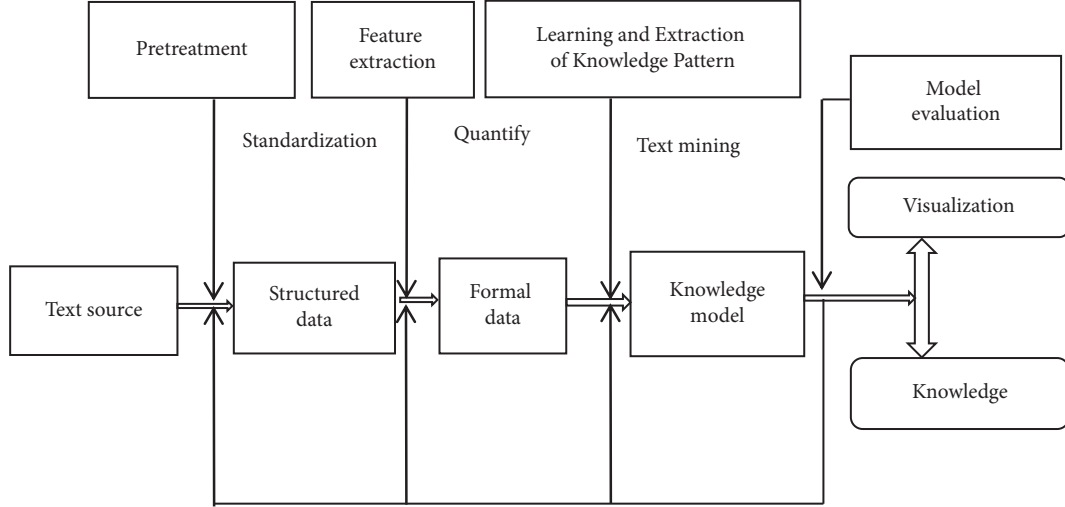


FIGURE 2: Schematic diagram of the text mining process.

Commonly used evaluation functions include document frequency, information gain, expected cross entropy, mutual information, word weight, text evidence weight, and probability ratio.

#### 4. Logical Intelligent Detection Algorithm of Chinese Language Articles

Articles are written languages that reflect objective things and constitute chapters [22]. It is the product of a certain social life and is reflected in people's thoughts. In this case, the study must be inseparable from the general logic (hereinafter referred to as logic) that studies the logical form and law of thinking. In a certain sense, logic is related to the merits and demerits of an article, and logic determines the life of an article.

**4.1. Logical Similarity Degree and Mining Algorithm of Web Text.** The calculation of text similarity [23] and logic based on HTML structure belongs to web text mining, which depends on the logical structure feature, which is to calculate the text similarity from the nesting and path of tag structure, so as to obtain whether the logic of Chinese language is reasonable or not.

Tags are the smallest parts in HTML. Using tags to measure the similarity of web texts, the similarity is judged mainly by considering the proportion of the number of tag pairs to the total number of tags. The calculation formula is as follows:

$$\text{Sim}(T_1, T_2) = \frac{N(T_1) \cap N(T_2)}{N(T_1) \cup N(T_2)}, \quad (8)$$

where  $T_1$  and  $T_2$  are two HTML document trees and  $N(T_1)$  and  $N(T_2)$  are the set of tag elements of the two document trees. In this way, the depth of tags should be combined, and the deeper the tags, the more they can reflect HTML document information.

Therefore, when calculating text similarity, each tag element should be weighted.

The path matching method reflects the similarity between HTML texts by comparing the ratio of the same path in two HTML texts to all the paths in these two HTML texts. Path refers to the sequence from root node to leaf node. Costa Gianni and others first proposed path matching and used Jaccard coefficient [24] to express text similarity. The calculation formula is as follows:

$$\text{Sim}(T_1, T_2) = 1 - \frac{|\text{Path}(T_1) \cap \text{Path}(T_2)|}{\text{Max}(\text{Path}(T_1), \text{Path}(T_2))}. \quad (9)$$

It can be seen from the formula that the greater the Jaccard coefficient, the smaller the similarity. However, this method has its limitations, and most of them are applied by partial matching in practical applications.

Whether it is text similarity calculation based on tag structure or tag path matching, the effect is not very ideal in the subsequent processing, but its operation efficiency is high, so it is also widely used.

Through the calculation of similarity, we can also get the value of logical reliability. The Chinese text with high similarity will have relatively high logical reliability, and at the same time, it will have the value of being mined.

**4.2. HTML Text Clustering Algorithm.** Text clustering algorithms are based on the hierarchical method, the partition method, and the grid method, each of which has its own advantages. At present, K-Means algorithm is widely used because of its simplicity and high efficiency, in order to fully consider the topic information of web text.

**4.2.1. Clustering Algorithm Based on Partition.** K-means algorithm is a basic partition algorithm [25]. On this basis, the  $k$ -means+ algorithm is improved. This is the basic principle in the initialization process. The central point of view is that the distance between the central points of each cluster can solve this shortcoming as much as possible. In the

clustering process, the center point of each cluster is randomly initialized to a certain extent. Firstly, the algorithm randomly selects a data point ( $n = 1$ ) as the initial point of the first cluster, then selects the initial cluster center of  $n + 1$  point of the data point of the first  $n$  data point, and calculates the distance between samples and the cluster center as follows:

$$d(x) = \sqrt{\sum_{i=1}^m (x_i - c_i)^2}. \quad (10)$$

**4.2.2. Hierarchical Clustering Algorithm.** The hierarchical structure of hierarchical clustering algorithm begins with a single object in the cluster; these objects are associated with other objects in the cluster, and they are located in one or more clusters in the cluster. This is an aggregate, which is a part of the Agnes hierarchy, which is the internal structure of an aggregate and produces an inverted binary tree in the process of merging. On the contrary, all objects are treated as a cluster first and then divided into multiple clusters according to a certain similarity law, and then, this partition step is repeated until each object cannot be partitioned, or a certain termination condition is reached; then, further partition is stopped. The above is the split hierarchical clustering (DIANA) process.

The HTML tag nesting contains a hierarchy, and the HTML text of a simple point can be represented by a tree diagram, as shown in Figure 3.

Web pages are represented as a subset of root-to-connection paths in the corresponding DOM (Document Object Model) tree, and Figure 3 shows the values of the four parts that need to be considered in the DOM tree. A collection of links is commonly referred to as such a DOM Root-to-link path and all the parent paths (upper level paths) that share the path. In the figure, a page is specially described through its set of links. For example, the left branch can be represented as HTML-HEAD-TITLE-title, where title is the value of the TITLE tag. Based on this, the commonly used

algorithm is clustering hierarchical clustering algorithm (AHC), which merges two most similar clusters in each generation. The three most commonly used merging strategies are single link, full link, and average link, in which the distance between clusters is calculated as the nearest distance, the farthest distance, and the average distance between objects, respectively. In HTML text clustering, the partition method and the hierarchical method are used. The characteristic of structured clustering algorithm is that it defines the similarity measure for document grouping. One of the basic methods to calculate document similarity is the tag-only method, which measures the number of common tags between each pair of documents. However, for documents with little difference in the number of structural responses, this method is poor in estimating the similarity between documents. Using full link, average link, or partial methods (such as  $k$ -means), the same results are obtained in terms of clustering quality.

PathHP (HTML Pattern Path) is proposed on the basis of Apriori algorithm. In PathHP, if the characteristic  $f$  is the maximum frequent path, it is called a pattern. If the document in  $D$  contains at least minsup percentage, where minsup is the minimum support parameter defined by the user, and  $f$  is not a subpath of any other frequent path:

$$\text{frequent}(f) \iff \exists_{D'} \forall_{d' \in D'} f \in d' \wedge \frac{|D'|}{|D|} \geq \text{minsup},$$

$$\text{pattern}(f) \iff \text{frequent}(f) \wedge \exists_f (\text{frequent}(f) \wedge f(\omega f)). \quad (11)$$

The algorithm first sets the initial value of minsup to  $1/k$  (where  $k$  is the expected number of clusters). Next, input dataset  $D$  for maximum frequent path mining is set. Before the number of paths found is greater than or equal to the expected number of clusters, minsup is divided by 2 and the mining process restarts. The resulting pattern set  $P$  is then grouped into  $K$  profiles using the complete link AHC algorithm, and the pattern similarity measure is defined as

$$\text{sim}(p1, p2) = \frac{\sum_{d \in D} \min\{m(p1, d), m(p2, d)\}}{\sum_{d \in D} m(p1, d) + m(p2, d) - \min\{m(p1, d), m(p2, d)\}}. \quad (12)$$

Finally, each document is assigned to the profile with the highest connection strength. In PathHP, we define the connection strength calculation formula of document  $d$  to meta as follows:

$$\text{str}(d, \pi_i) = \frac{\sum_{p \in \pi_i} m(p, d)}{|\pi_i|}. \quad (13)$$

Therefore, the negative influence caused by the size of  $\pi_i$  will be eliminated.

## 5. Experimental Analysis

**5.1. Introduction of Dataset.** WebKB data are used in the experimental dataset. The original dataset should be decompressed under Linux system, and the decompressed experimental data are shown in Table 1.

WebKB includes web page texts of computer science departments of four universities, which are Course Faculty Student class pages and so on; to develop a probabilistic, symbolic knowledge base that mirrors the content of the



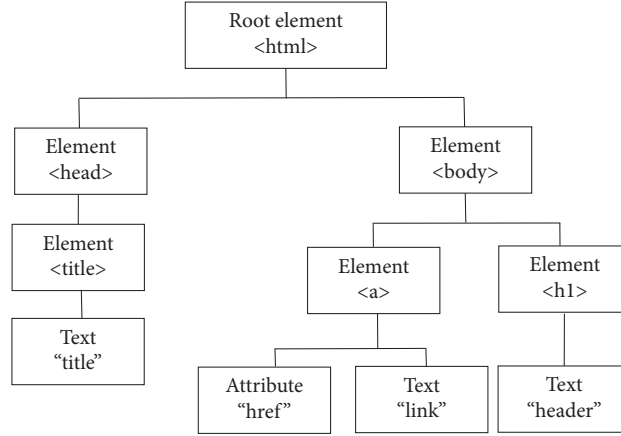


FIGURE 3: HTML DOM tree diagram.

TABLE 1: WebKB datasheet.

WebKB	Course	Department	Faculty	Project	Staff	Student	Other	Total
Cornell	44	1	34	20	21	128	619	867
Texas	38	1	46	20	3	148	571	827
Washington	77	1	31	21	10	126	939	1205
Wisconsin	85	1	42	25	12	156	942	1263
Misc	686	178	971	416	89	1080	639	4113

World Wide Web is used. This will make text information on the web available in computer-understandable form, enabling much more sophisticated information retrieval and problem solving. MISC contains pages from other universities; WebKB dataset is usually used for classification and clustering tasks. In the experiment, in order to process data effectively, it is divided into two datasets; one is to remove the web pages in misc files, a total of 4162 HTML files, and the other is to remove 8275 HTML files of WebKB as a whole (in fact, 8282 files, 7 duplicate files are removed), which are recorded as WebKB4162 and WebKB8275, respectively.

**5.2. Experimental Results and Evaluation.** Because clustering is not based on knowledge to judge the classification, most of the time we cannot evaluate the clustering results. Commonly used evaluation strategies are evaluating the differences of data objects in categories, such as purity and recall rate; there are also differences between evaluation classes, mainly calculating entropy. The specific performance of the evaluation strategy is shown in Figure 4.

F-Score is a clustering evaluation method used in this paper, which depends on accuracy and recall rate. Accuracy is also called accuracy, and recall rate refers to the maximum percentage of the correctly classified text in the total number of classified network texts. Recall rate refers to the percentage of correctly classified texts in the total number of online texts. These two indicators can also reflect whether the logic of Chinese articles is reasonable and clear. The accuracy precision is calculated by the following formula:

$$\text{precision} = \frac{\sum_i x_i}{\sum_i x_i + \sum_i y_i}, \quad i = 1 \dots k, \quad (14)$$

where  $X$  is the number of web texts that are correctly clustered,  $y$  is the number of web texts that are incorrectly clustered into other classes, and  $k$  is the number of clustering clusters. The recall rate recall formula is calculated as follows:

$$\text{recall} = \frac{\sum_i x_i + \sum_i y_i}{|T|}, \quad i = 1 \dots k, \quad (15)$$

where  $T$  is the total number of texts in the dataset. Although these evaluation methods are derived from supervised learning, they can be used when evaluating experimental results because all the web text data used contains tags with original categories. A web text may belong to both Class A and Class B. Calculate the likelihood that a document  $T$  in Class A belongs to Class B. The selected correlation calculation formula is as follows:

$$\text{Association degree}(T_y) = \frac{\sum Y/X}{|T|}, \quad (16)$$

where  $T$  is the total number of Web texts,  $x$  represents the number of categories in which web texts  $T_y$  belong, and  $y$  represents the number of similar categories of  $T_y$ . Figure 5 shows the class time of WebKB8275 dataset.

Although there is a certain gap in clustering time between knowledge base clustering and traditional vector space model, it is better than the latter in clustering accuracy and recall rate.

Time spent for text mining using an HTML clustering algorithm versus text mining without an algorithm or using another algorithm is shown in Figure 6.

WebKB4162 removes the data in misc, and only the relevant data of web texts of computer departments of Cornell, Texas, Washington, and Wisconsin are retained in

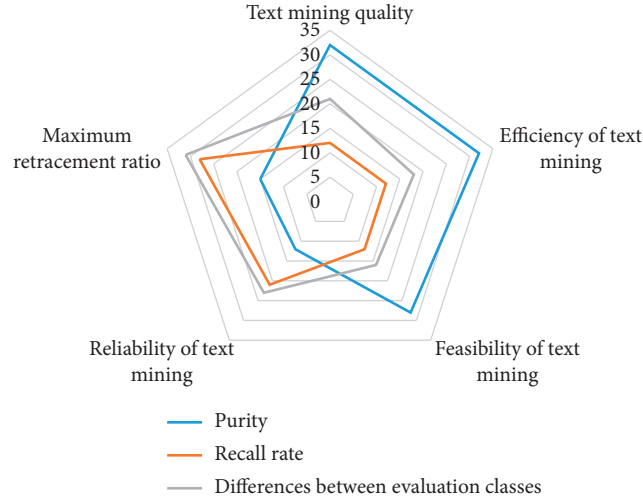


FIGURE 4: Specific performance of evaluation index.

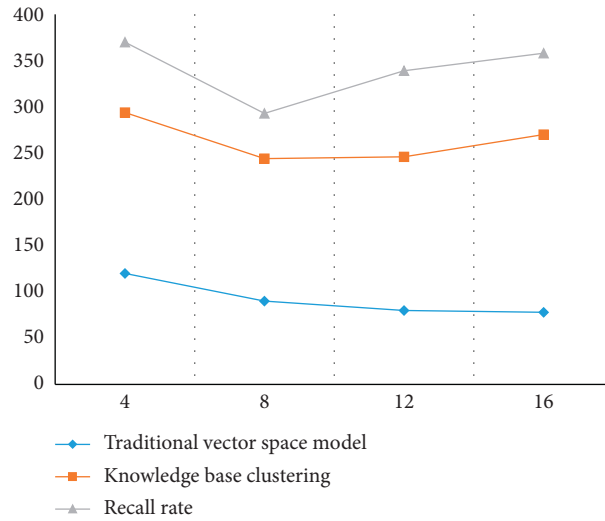


FIGURE 5: WebKB8275 dataset class time.

the dataset. The time comparison between knowledge base clustering and vector space model clustering is shown in Figure 7. Clustering based on knowledge base will have obvious difference in running time when  $K$  is different, but the way of the vector space model basically does not have obvious difference in running time when  $K$  is different.

Through the above process, the representation description logic reduces the dimension of web text and discovers its potential semantic relationship, which improves

the efficiency of data clustering in description knowledge base and the reliability of mining Chinese language logic. Compared with the traditional vector space computing method, the knowledge representation based on description logic knowledge base has certain advantages in the accuracy of clustering problems. Because of the existence of its reasoning algorithm, it has disadvantages in running time. The specific operational efficiency of different web mining operations is shown in Figure 8.

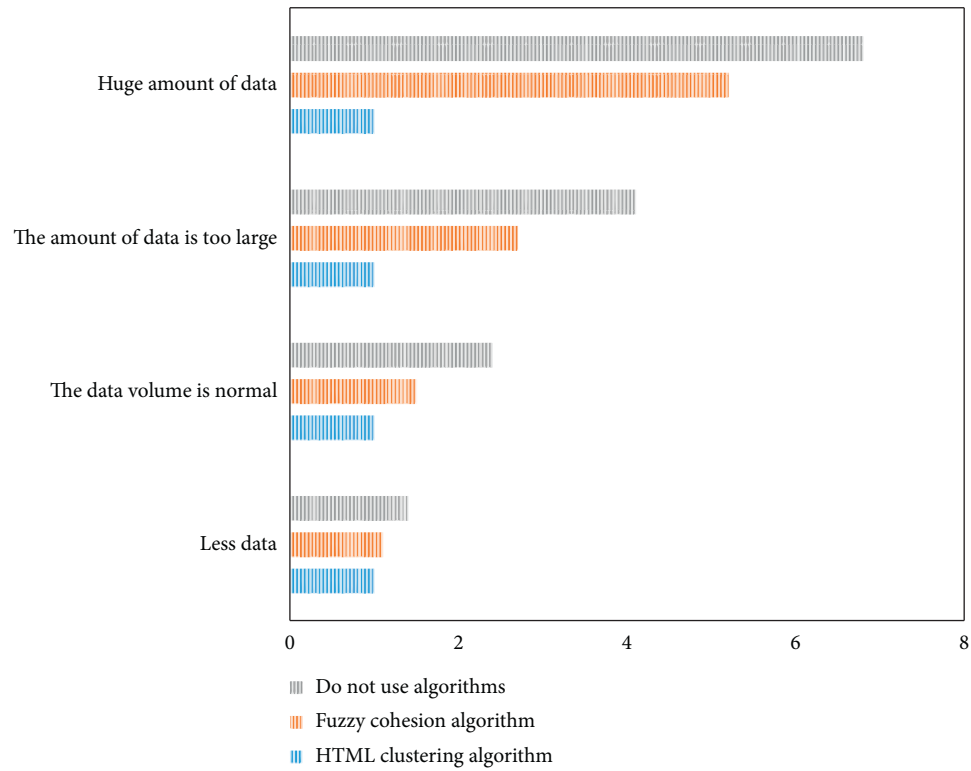


FIGURE 6: Time spent on text mining in various cases.

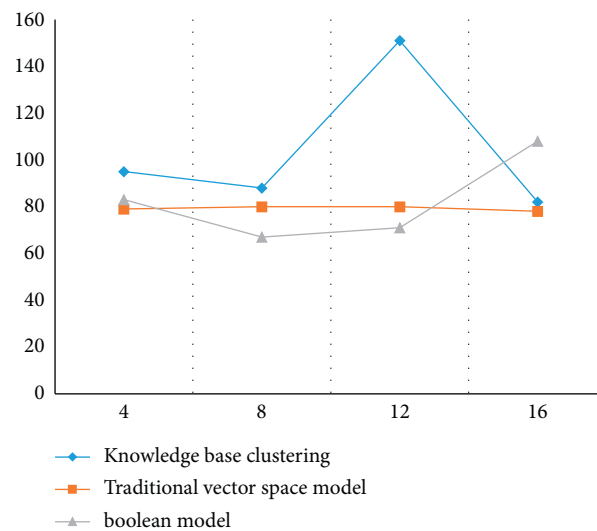


FIGURE 7: WebKB4162 clustering time.

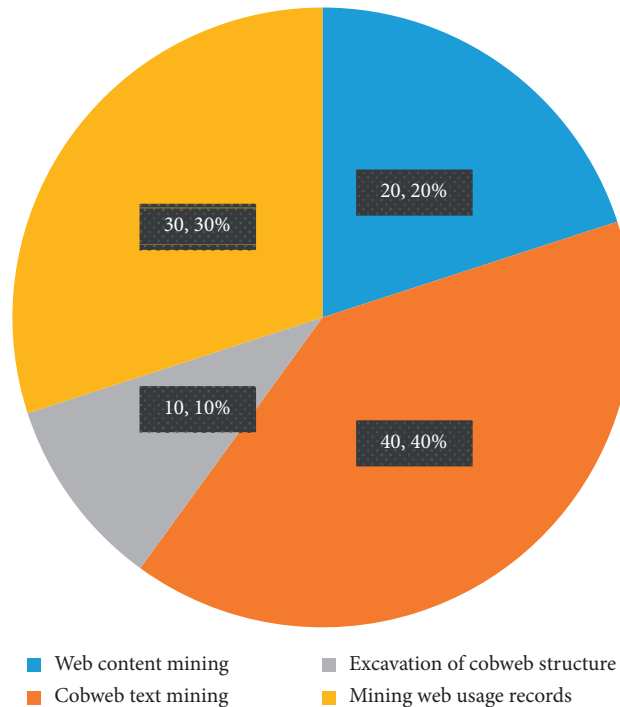


FIGURE 8: Percentage of different web mining operation efficiencies.

## 6. Conclusion

With the development of the Internet, the communication between computers and people no longer depends solely on binary. Nowadays, the ways of communication are more and more diverse, just like text mining is a technology introduced in China, and the algorithm of using text mining to realize the logical intelligent detection of Chinese language can better help us save manpower. This paper proposed a logical similarity degree and mining algorithm of Web Text and three HTML text clustering-based algorithm (hierarchical method, partition method, and grid method), and the use of WebKB datasets for many times of experimental comparison also reflects that the proposed method for the Chinese language logic intelligent detection algorithm provides a basis. This intelligent algorithm not only solves the problem of Chinese language logic but also realizes text mining. If this algorithm is used well, I think it should help us in all aspects. Data mining is a new solution in text and data mining. Chinese text mining is a complex text information system, and it is an art data mining, is the core of data mining, and is the foundation and structure of data mining. In a study on data banking, our data control mining technology is not suitable for text analysis. Data control mining technology is suitable for text analysis, which is an effective text retrieval method. In the popular research of WWW, it is a new network information retrieval method. War in network text is the key to text retrieval. The effect and running efficiency of the intelligent detection algorithm of Chinese language article logic realized by web text mining will only be better.

## Data Availability

The experimental data used to support the findings of this study are available from the corresponding author upon request.

## Conflicts of Interest

The authors declare that they have no conflicts of interest regarding this work.

## References

- [1] Y. Hao, Y. Huang, and Y. Feng, "Research on the application of big data technology in information statistics research system," *Journal of Physics: Conference Series*, vol. 1865, no. 4, Article ID 042112, 2021.
- [2] P. Cui, *Research on the Intelligent Recognition Method of Academic Document Content Based on Text Mining*, Beijing Jiaotong University, Beijing, China, 2019.
- [3] W. Xue and Y. Lu, "Research on text mining technology," *Journal of Beijing Union University*, vol. 19, no. 4, pp. 59–63, 2005.
- [4] G. Yang, "Natural language understanding," *Foreign Language Teaching and Research: Foreign Languages Bimonthly*, vol. 3, pp. 26–29, 1987.
- [5] X. Liu, "Summary of natural language understanding," *Statistics and Information Forum*, vol. 2, pp. 5–12, 2007.
- [6] J. C. Wang, R. Xiao, Z. X. Sun, and F. Y. Zhang, "Web information retrieval research progress," *Computer Research and Development*, vol. 38, 2001.
- [7] K. Liu and B. Guo, *Natural Language Processing*, Science Press, Beijing, China, 1991.

- [8] X. Li and M. Zhuang, "Free text information extraction technology," *Information Science*, vol. 7, pp. 48–54, 2004.
- [9] J. Wang, J. Pan, and F. Zhang, "Research on web text mining technology," *Computer Research and Development*, vol. 37, no. 5, pp. 513–520, 2000.
- [10] B. Liao, J. Yu, H. Sun, and M. Nian, "Energy-saving algorithm of distributed storage system based on storage structure reconfiguration," *Computer Research and Development*, vol. 1, pp. 5–20, 2013.
- [11] X. Xiao and Y. Gao, "Web text mining," *Computer Knowledge and Technology*, vol. 9, pp. 822–823, 2007.
- [12] M. Liu, X. Wang, and Y. Huang, "Data preprocessing in data mining," *Computer Science*, vol. 4, pp. 56–59, 2000.
- [13] F. Jiang, G. Li, and X. Yue, "Research method of document feature extraction based on semantics," *Computer Science*, vol. 43, no. 2, pp. 254–258, 2016.
- [14] J.-G. Sun, J. Liu, and L. Zhao, "Clustering algorithms research," *Journal of Software*, vol. 19, no. 1, pp. 48–61, 2008.
- [15] F. Chen and L. Hu, "Research and implementation of a text data integration method," *Journal of Northeast Normal University*, vol. 48, no. 1, pp. 78–83, 2016.
- [16] X. Xie, Y. Fu, H. Jin, Y. L. Zhao, W. Z. Cao, and H. Jin, "A novel text mining approach for scholar information extraction from web content in Chinese," *Future Generation Computer Systems*, vol. 111, pp. 859–872, 2020.
- [17] J. Schedlbauer, G. Raptis, and B. Ludwig, "Medical informatics labor market analysis using web crawling, web scraping, and text mining," *International Journal of Medical Informatics*, vol. 150, Article ID 104453, 2021.
- [18] X. Wu, Z. Wu, and Y. Feng, "A text category detection and information extraction algorithm with deep learning," *Journal of Physics: Conference Series*, vol. 1982, no. 1, Article ID 012047, 2021.
- [19] A. Karim and M. A. Yaqin, "Implementasi vector space model untuk meningkatkan kualitas pencarian dan penentuan derajat hadits pada kitab-kitab hadits," *Jurnal Telekomunikasi dan Komputer*, vol. 10, no. 1, pp. 1–10, 2020.
- [20] C. Ke, Z. Jiang, H. Zhang, Y. Wang, and S. Zhu, "An intelligent design for remanufacturing method based on vector space model and case-based reasoning," *Journal of Cleaner Production*, vol. 277, Article ID 123269, 2020.
- [21] H. Azarbonyad, M. Dehghani, M. Marx, and J. Kamps, "Learning to rank for multi-label text classification: combining different sources of information," *Natural Language Engineering*, vol. 27, no. 1, pp. 1–23, 2020.
- [22] B. B. Bogomolov, V. S. Boldyrev, A. M. Zubarev, V. P. Meshalkin, and V. V. Men'shikov, "Intelligent logical information algorithm for choosing energy- and resource-efficient chemical technologies," *Theoretical Foundations of Chemical Engineering*, vol. 53, no. 5, pp. 709–718, 2019.
- [23] S. Wu, F. Liu, and K. Zhang, "Short text similarity calculation based on jaccard and semantic mixture," in *Bio-Inspired Computing: Theories and Applications. BIC-TA 2020. Communications in Computer and Information Science*, L. Pan, S. Pang, T. Song, and F. Gong, Eds., vol. 1363, pp. 37–45, Springer, Berlin, Germany, 2021.
- [24] E. Y. Puspaningrum, B. Nugroho, A. Setiawan, and N. Hariyanti, "Detection of text similarity for indication plagiarism using winnowing algorithm based K-gram and jaccard coefficient," *Journal of Physics: Conference Series*, vol. 1569, no. 2, pp. 1–6, 2020.
- [25] A. Ahmad and S. S. Khan, "initKmix-A novel initial partition generation algorithm for clustering mixed data using  $k$ -means-based clustering," *Expert Systems with Applications*, vol. 167, no. 2, Article ID 114149, 2020.

## Research Article

# Using the Internet of Things Mobile to Keep the User's Back Straight While Sitting

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Spine and neck pain is the most common type of pain experienced by people whose work requires sitting for long hours during the day. Therefore, many of them resort to dealing with this matter in several ways, and these methods differ in their effectiveness and negative effects. In this paper, we designed a device to alert the user to the need to adjust their sitting and to generate an alert when they are sitting inappropriately. When trying this device, the results were promising and accurate in terms of the results of the sequential reading of the movement of the flexible sensor, which helps the system to give alerts at the right time in the event of curvature of the spine, in addition to the ease of use of this device.

## 1. Introduction

The term Internet of Things (IoT) is a relatively recent term and refers to the new generation of the Internet that allows information exchange and understanding between different and interconnected devices. These devices may be sensors, tools, various artificial intelligence tools, and others [1]. It is also a modern technical method that aims to connect the things represented by sensors and various devices and connect them to the Internet to transfer data between these devices without human intervention if these things are within the geographical scope of the Internet [2, 3].

The phrase “Internet of Things” was coined in the late 1990s by businessman Kevin Ashton. He was one of the phrase members that connected things over the Internet; also, he first utilized this phrase in his presentation in 1999, and this term remained accompanying him ever since [4]. Only a few years ago, we started to see the true potential of the IoT, the concept of wireless Internet development became more prevalent, embedded sensors developed

tremendously, and people started to understand the technology that could also be personal as a professional tool [5].

What distinguishes the IoT is that it allows the person to be free from the place, that is, the person can control the tools without having to be in a specific place to deal with a specific device [6]. It is noteworthy that the IoT lists below many of the daily things that can be integrated with it, and the principle of work is applied to them, such as industrial machines, wearable devices, and many others. It must be noted that the coming period of technological life will be buzzing with it as it is the best way to make life more efficient [7].

The domain of implementation of IoT technology is extremely big in daily life and has entered into several main areas and is among the most important of these areas that can be integrated with communications, health care, factories, companies, and education [7].

The applications of the IoT in the medical field are among the largest and most significant applications. IoT has decentralized healthcare services from healthcare

institutions to lateralized sites such as homes and workplaces, making it one of the most widely used advancements in e-Health today. It can monitor patients remotely and record their conditions in electronic records, and it can also be applied in wearable systems to help control many healthy habits including patients' sleep patterns [8].

Furthermore, this domain is constantly confronted with significant interoperability issues. For example, the safe, secure, and successful sharing of clinical data between healthcare organizations or research institutes can offer significant operational challenges. Such clinical data exchanges necessitate extensive, trustworthy, and healthy engagement amongst the parties involved. The nature of clinical data, sensitivity, data-sharing agreements, processes, complex patient matching algorithms, ethical policies, and governing norms are all potential barriers in this process.

IoT technology works without the need for the intervention of the human factor; it works to communicate between more than one device or machine automatically and freely, or between a device and a person, and these devices have the freedom to exchange data and information and take action to act on it as well without asking for help or approval from the human factor.

The last industrial revolution has been considered as the technology of the IoT. Examples of commercial utilize the IoT: agriculture with pinpoint accuracy [9], intelligent parking [10], and management of water usage [11]. In addition, much research into the usage of IoT for constructing intelligent systems has been performed in different fields such as grids that are intelligent [12], crash-avoiding cars [13], and monitoring structural health [14].

Despite the fact that the aforementioned sectors appear to be drastically different from healthcare, the research undertaken within them supports the viability of an IoT-based healthcare system. Existing systems in other disciplines have demonstrated that remote object monitoring, data collecting, and reporting can be accomplished.

The entry of the IoT in the field of health is a golden opportunity and really important to meet the challenges of chronic diseases and also to prevent diseases before they occur. A patient's treatment by using IoT applications includes the use of built-in sensors and actuators. Invasive monitoring systems depend on the IoT aid in the continuous monitoring and tracking of a patient's physiological condition. Radio-frequency identification (RFID) technology was utilized to track the activity of medical practitioners and other healthcare providers washing their hands in one of Ohio's premier hospitals. The deployment of IoT-based technology helped enterprises minimize infection-related death tolls while also lowering financial losses [15, 16]. The mechanisms of applying the IoT in the medical field differed from the development of healthcare systems and medical devices by reducing the duration of hospitalization, clinic visits, and death rates, which leads to obtaining the best clinical results [17]. The use of IoT in the development of medical devices meets the needs of a variety of healthcare fields. Figure 1 shows a variety of medical-related IoT-driven devices. The following section describes the methodology of this study in terms of study objectives and their importance.

In this study, we designed a smart device for people who use computers for long hours during the day, especially programmers, so as to keep their backbone straight. The device is installed on a person's backbone; if a person bends his backbone for more than two minutes, the person is alerted by vibration for half a second.

The rest of this paper is organized as follows. In Section 2, system description is presented. Then, in Section 3, the components of the system are analyzed and presented. In Section 4, system implementation is presented. After that, Section 5 represents the results. Finally, the conclusion is presented in Section 6.

## 2. Study Description

Many people whose work requires sitting, especially programmers, suffer from a curvature of the backbone because of their wrong sitting, and then, these people begin to feel pain in the neck area and between the shoulders, fatigue, and exhaustion in the event of any activity or work, and if they continue to sit wrong for a long period, it will cause a twist in the backbone [30]. Therefore, many of these people resort to wearing back corset, which is used as a support tool to reduce the development of the situation for the worse. However, this corset has many negative effects because of which people use this corset less; the most important of it is as follows. (1) It works to stabilize the muscles (not moving). (2) Wearing the corset for long periods (for more than two or three hours) leads to a weakening of muscle strength [31]. Figure 2 shows the picture of a medical corset brace [32].

In this study, in the absence of a real tool that contributes and urges the practice of correct sitting, the device that we designed depends on alerting people and reminding them to adjust their sitting. In addition, with the passage of time in which this device is used, it contributes to training on a correct sitting. During the period of design of this device, we made sure to use low-cost materials so that anyone in society can own this device and to benefit all people who suffer from frequent curvature of the spine.

## 3. The Components of the System

This system contains six pieces electronics:

- (i) Arduino UNO (Figure 3): it is considered as a microcontroller board consisting of a 16 MHz ceramic resonator, reset button, 6 analog inputs, 14 digital I/O pins, USB connection facilitation, a power Jack, and ICSP header [33]. To operate the system, we use a USB cable or battery or power it with an AC-to-DC adapter to connect it to a computer [33, 34].
- (ii) Flex sensor (Figure 4): it measures the amount of bending or deflection. It is installed on a specific surface, and bending the surface changes the resistance of the sensor element [35–37]. We need two from it.
- (iii) Vibration sensor (buzzer) (Figure 5): it is an auditory signaling device that can be



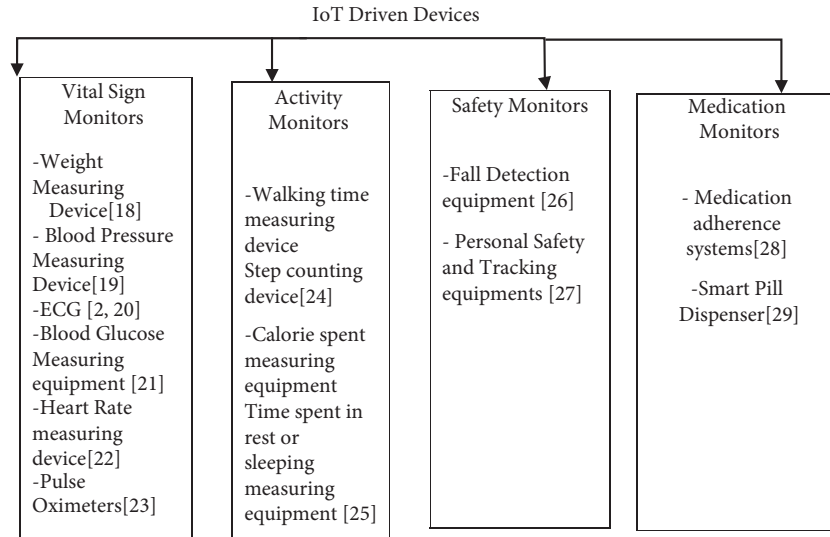


FIGURE 1: IoT medical devices [18–29].



FIGURE 2: Medical corset brace [32].

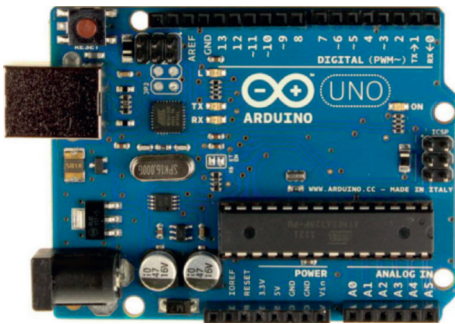


FIGURE 3: Arduino UNO [34].

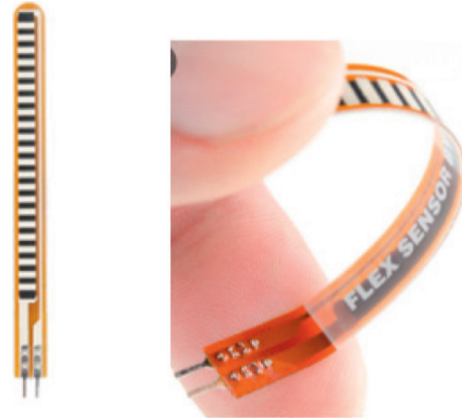


FIGURE 4: Flex sensor [35]



FIGURE 5: Vibration sensor (buzzer) [38].

electromechanical, mechanical, or piezoelectric in nature [38, 39]. We need two from it.

- (iv) Female-female jumper wires (Figure 6): it is normally used to interconnect the components of an Arduino UNO with sensors [40].
- (v) USB cable (Figure 7): it is used to connect the UNO with PC [41].
- (vi) Breadboard (Figure 8): it is a building block for electronics prototyping [42].

Figure 9 shows the design of our project. We used the fritzing program and download it (<https://fritzing.org/>

download/) to experimentally design and draw this project. Figure 10 shows the algorithm used to implement this system.



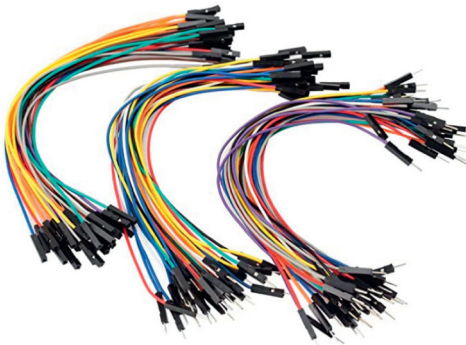


FIGURE 6: Female-male jumper wires [40].



FIGURE 7: USB cable [41].

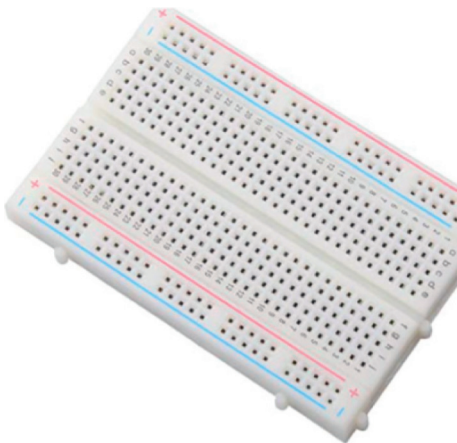


FIGURE 8: Breadboard [42].

#### 4. System Implementation

The first flex sensor is installed longitudinally and the vibration sensor is next to it, on the upper part of the spine, as shown by the orange arrow in Figure 9. The second flex sensor is installed longitudinally on the bottom of the spine and the second vibration sensor next to it, as shown by the green arrow in Figure 9, so that both flex sensors take

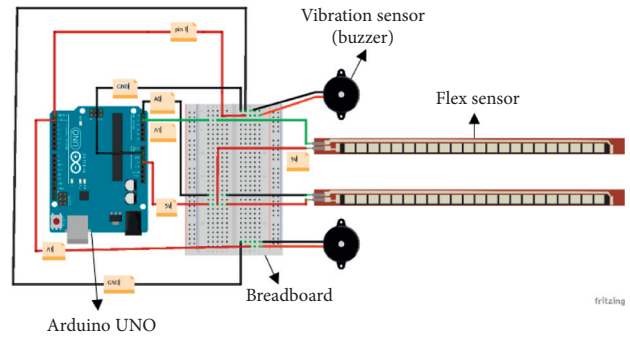


FIGURE 9: Project design.

```

Read analog from both flex sensors
Void loop () {
  if (flexSensorReading1<=13) {
    Turn on the top of vibration sensor
    Delay the process for one minute
    Turn off the top of vibration sensor
  }
  if (flexSensorReading2<=13) {
    Turn on vibration sensor on the bottom
    Delay the process for one minute
    Turn off the bottom of vibration sensor
  }
  Delay the loop for nine minutes
}

```

FIGURE 10: Algorithm of our system.

consecutive readings of the areas to which they are installed. If the user bends his backbone, see Figure 11, the vibration sensor starts, which is giving a shake for half a second to warn the person that he must adjust his seat.

#### 5. Results

To carry out this experiment, we used Arduino software to get these results and downloaded it from <https://www.arduino.cc/en/guide/windows>. Arduino is programmed based on successive readings of the flex sensor. The vibration sensors work based on the reading of flex sensors.

The Arduino is programmed according to the following two levels:

- (i) Level 1 (flex sensor reading  $\leq 13$ ): alarm will work
- (ii) Level 2 (flex sensor reading  $= 33$ ): alarm will not work

Figure 12 shows the output window of the serial monitor, which displays the alerts. In the beginning, the system displays the reading of flex sensors (in top and bottom). After that, if the reading of flex sensors is less than or equal to 13 that means the backbone is curved at 100 degrees, the vibration sensors are working for half second to remind the user of the device to adjust his sitting and shows “alarm working” message on the serial monitor, but if the reading of flex sensors is 33, this means the backbone is straight and the vibration sensors are not working.

According to Figure 12, for example,



FIGURE 11: The places of install the flex sensors [43]. Note: this device is considered a prototype.

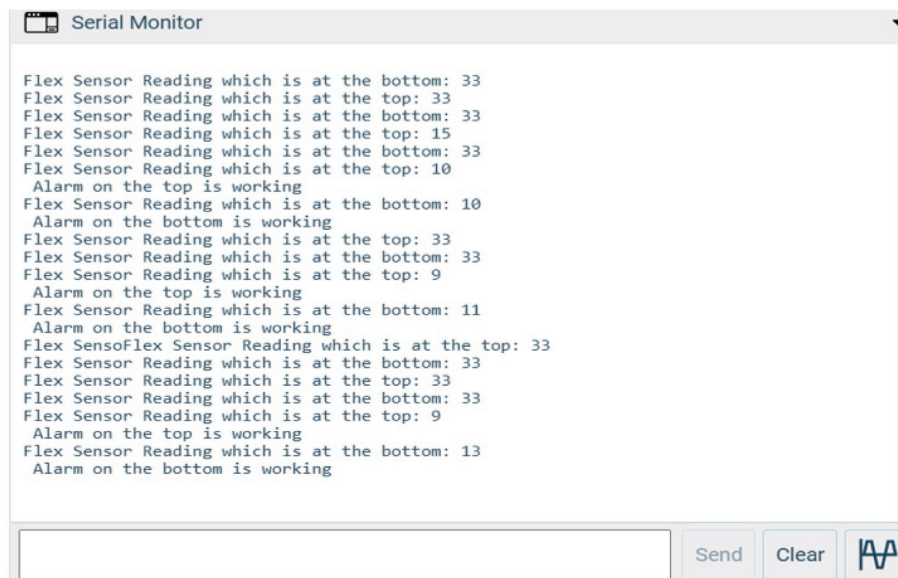


FIGURE 12: The output.

- (i) The first five readings of the flex sensors (in top and bottom)  $> 13$ : alarm did not work
- (ii) The sixth reading of the flex sensors  $\leq 13$ : the alarm worked and gave a message on the serial screen stating that the sensor was turned on

## 6. Conclusion

Many people whose work requires sitting for long periods suffer from pain in the neck and spine. Therefore, many of these people resort to wearing back corsets, which are used as a support tool to reduce the development of the situation for the worse. However, this corset has many negative effects, including that it stabilizes the muscles (not moving), and wearing it limits muscle function. In this study, a smart alert system is designed to alert the person through an alarm so that this design helps to train the person to sit correctly. To build this device, we needed to use two flex sensors, two vibration sensors, UNO, breadboard, and wires. Also, we have used Arduino software to program this device. The

most important features of this device are that it is easy to use and of low cost; the accurate reading of the bending sensors and giving the right alert to the user of this device helped us in the success of this device. This system is considered a prototype [32–43].

## Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

## Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

## References

- [1] F. Xia, L. T. Yang, L. Wang, and A. Vinel, "Internet of things," *International Journal of Communication Systems*, vol. 25, no. 9, pp. 1101–1102, 2012.

- [2] A. Iftexhar and X. Cui, "Blockchain-based traceability system that ensures food safety measures to protect consumer safety and COVID-19 free supply chains," *Foods*, vol. 10, no. 6, p. 1289, 2021.
- [3] K. Ashton, "That 'internet of things' thing," *RFID Journal*, vol. 22, no. 7, pp. 97–114, 2009.
- [4] S. Gul, S. Ahmad, M. Yasir et al., "A survey on role of internet of things in education," *International Journal of Computer Science and Network Security*, vol. 17, no. 5, pp. 159–165, 2017.
- [5] M. Kassab, J. DeFranco, and P. Laplante, "A systematic literature review on Internet of things in education: benefits and challenges," *Journal of Computer Assisted Learning*, vol. 36, no. 2, pp. 115–127, 2020.
- [6] F. Wortmann and K. Flüchter, "Internet of things," *Business & Information Systems Engineering*, vol. 57, no. 3, pp. 221–224, 2015.
- [7] D. K. A.-R. Al-Malah, H. H. K. Jinah, and H. T. S. ALRikabi, "Enhancement of educational services by using the internet of things applications for talent and intelligent schools," *Periodicals of Engineering and Natural Sciences*, vol. 8, no. 4, pp. 2358–2366, 2020.
- [8] M. Maksimović, V. Vujović, and B. Perišić, "A custom Internet of Things healthcare system," in *Proceedings of the 2015 10th Iberian Conference on Information Systems and Technologies (CISTI)*, pp. 1–6, IEEE, Águeda, Portugal, June 2015.
- [9] UON England, "Smart farm," 2017, <http://www.une.edu.au/research/research-centres-institutes/smart-farm>.
- [10] S. Parking, "Smarteye, smartrep, and RFID technology—Westminster city council—London," 2017, <http://www.smartparking.com/keep-up-to-date/case-studies/3-500-vehicledetection-sensors-and-epermit-technology-in-the-city-of-westminsterlondon>.
- [11] Sensus, "Smart water—smarter at every point," 2017, <http://www.sensus.com/internet-of-things/smart-water>.
- [12] S. Tan, D. De, W.-Z. Song, J. Yang, and S. K. Das, "Survey of security advances in smart grid: a data driven approach," *IEEE Communications Surveys & Tutorials*, vol. 19, no. 1, pp. 397–422, 2016.
- [13] K. M. Alam, M. Saini, and A. E. Saddik, "Toward social internet of vehicles: concept, architecture, and applications," *IEEE access*, vol. 3, pp. 343–357, 2015.
- [14] C. Arcadius Tokognon, B. Gao, G. Y. Tian, and Y. Yan, "Structural health monitoring framework based on Internet of Things: a survey," *IEEE Internet of Things Journal*, vol. 4, no. 3, pp. 619–635, 2017.
- [15] B. S. Babu, K. Srikanth, T. Ramanjaneyulu, and I. L. Narayana, "IoT for healthcare," *International Journal of Science and Research*, vol. 5, no. 2, pp. 322–326, 2016.
- [16] J. Sun, F. Khan, J. Li, M. D. Alshehri, R. Alturki, and M. Wedyan, "Mutual authentication scheme for the device-to-server communication in the internet of medical things," *IEEE Internet of Things Journal*, vol. 8, 2021.
- [17] B. Singh, S. Bhattacharya, C. Chowdhary, and D. Jat, "A review on internet of things and its applications in healthcare," *Journal of Chemical and Pharmaceutical Sciences*, vol. 10, no. 1, pp. 447–452, 2017.
- [18] P. Singh, "Internet of things based health monitoring system: opportunities and challenges," *International Journal of Advanced Research in Computer Science*, vol. 9, no. 1, pp. 224–228, 2018.
- [19] P. D. P. Adi and A. Kitagawa, "ZigBee radio frequency (RF) performance on raspberry pi 3 for internet of things (IoT) based blood pressure sensors monitoring," *International Journal of Advanced Computer Science and Applications*, vol. 10, no. 5, pp. 18–27, 2019.
- [20] T. N. Gia, M. Jiang, A.-M. Rahmani, T. Westerlund, P. Liljeberg, and H. Tenhunen, "Fog computing in healthcare internet of things: a case study on ecg feature extraction," in *Proceedings of the 2015 IEEE International Conference on Computer and Information Technology; Ubiquitous Computing and Communications; Dependable, Autonomic and Secure Computing; Pervasive Intelligence and Computing*, pp. 356–363, IEEE, Liverpool, UK, October 2015.
- [21] J. J. Rodrigues Barata, R. Munoz, R. D. De Carvalho Silva, J. J. P. C. Rodrigues, and V. H. C. De Albuquerque, "Internet of Things based on electronic and mobile health systems for blood glucose continuous monitoring and management," *IEEE Access*, vol. 7, pp. 175116–175125, 2019.
- [22] N. Xiao, W. Yu, and X. Han, "Wearable heart rate monitoring intelligent sports bracelet based on Internet of things," *Measurement*, vol. 164, Article ID 108102, 2020.
- [23] Y. Xie, Y. Gao, Y. Li, Y. Lu, and W. Li, "Development of wearable pulse oximeter based on internet of things and signal processing techniques," in *Proceedings of the 2017 European Modelling Symposium (EMS)*, pp. 249–254, IEEE, Manchester, UK, November 2017.
- [24] T. Huiqiang, "Analysis of fluctuation factors of healthy exercise based on machine data mining and Internet of things," *Environmental Technology & Innovation*, vol. 23, Article ID 101647, 2021.
- [25] N. S. Ashfar, J. A. Lurthier, and L. A. James, "FX calories calculator & fitness advisor," *International Journal on Cybernetics & Informatics*, vol. 10, 2021.
- [26] A. Alarifi and A. Alwadain, "Killer heuristic optimized convolution neural network-based fall detection with wearable IoT sensor devices," *Measurement*, vol. 167, Article ID 108258, 2021.
- [27] R. Rogers, "Internet of things-based smart healthcare systems, wireless connected devices, and body sensor networks in COVID-19 remote patient monitoring," *American Journal of Medical Research*, vol. 8, no. 1, pp. 71–80, 2021.
- [28] X. Toh, H.-X. Tan, H. Liang, and H.-P. Tan, "Elderly medication adherence monitoring with the Internet of Things," in *Proceedings of the 2016 IEEE International Conference on Pervasive Computing and Communication Workshops (PerCom Workshops)*, pp. 1–6, IEEE, Sydney, Australia, March 2016.
- [29] M. V. Moise, A.-M. Niculescu, and A. Dumitraşcu, "Integration of Internet of Things technology into a pill dispenser," in *Proceedings of the 2020 IEEE 26th International Symposium for Design and Technology in Electronic Packaging (SIITME)*, pp. 270–273, IEEE, Pitesti, Romania, October 2020.
- [30] J. Hesse, "Medical back belt with neuromuscular electrical stimulation," in *Smart Textiles and Their Applications*, pp. 115–125, Elsevier, Amsterdam, Netherlands, 2016.
- [31] O. Available, <https://www.thecorsetcenter.com/7-pros-and-cons-to-corsets/>.
- [32] 7-Doctores, [Online]. Available: <https://7drs.com/%D8%A2%D8%AB%D8%A7%D8%B1-%D8%A7%D8%B3%D8%AA%D8%AE%D8%AF%D8%A7%D9%85-%D9%85%D8%B4%D8%AF%D8%A7%D8%AA-%D8%A7%D9%84%D8%B8%D9%87%D8%B1-%D8%A7%D9%84%D8%B9%D8%B4%D9%88%D8%A7%D8%A6%D9%8A%D8%A9/>.
- [33] A. UNO, [Online]. Available: <https://www.jsumo.com/arduino-uno-r3-clone-with-usb-cable-usb-chip-ch340>.
- [34] F. sensor, [Online]. Available: <https://www.teachmemicro.com/use-flex-sensor/>.
- [35] buzzer, [Online]. Available: <https://www.pcboard.ca/minipiezo-buzzer>.

- [36] F.-M. J. Wires, [Online]. Available: <https://www.amazon.com/Female-Female-Jumper-Wires-pcs/dp/B079QPFMPT>.
- [37] U. C. f. UNO, [Online]. Available: <https://www.circuituncle.com/product/usb-cable-for-arduino-uno-mega/>.
- [38] N. S. Kumar, B. Vuayalakshmi, R. J. Prarthana, and A. Shankar, "IOT based smart garbage alert system using Arduino UNO," in *Proceedings of the 2016 IEEE Region 10 Conference (TENCON)*, pp. 1028–1034, IEEE, Singapore, November 2016.
- [39] A. Syed, Z. T. H. Agasbal, T. Melligeri, and B. Gudur, "Flex sensor based robotic arm controller using micro controller," *Journal of Software Engineering and Applications*, vol. 5, 2012.
- [40] M. Wedyan, A. Al-Jumaily, F. Alnajjar, P. M. Muhamed, and S. Shimoda, "A wearable robotics assistive device: design, technical solutions, and implementation," in *Proceedings of the 2017 International Conference on Electrical and Computing Technologies and Applications (ICECTA)*, pp. 1–5, IEEE, Ras Al Khaimah, UAE, November 2017.
- [41] J. Christian and N. Komar, "Prototipe sistem pendeteksi kebocoran gas LPG menggunakan sensor gas MQ2, board Arduino duemilanove, buzzer, dan Arduino GSM shield pada PT. Alfa retailindo (carrefour pasar minggu)," *Jurnal TICom*, vol. 2, no. 1, p. 92830, 2013.
- [42] Breadboard, [Online]. Available: [https://www.amazon.com/Qunqi-point-Experiment-Breadboard-5-5%C3%978-2%C3%970-85cm/dp/B0135IQ0ZC/ref=asc\\_df\\_B0135IQ0ZC?tag=bingshoppinga-20&linkCode=df0&hvadid=79989522876977&hvnetw=o&hvmqmt=e&hvbmt=be&hvdev=c&hvlocint=&hvlocphy=&hvtargid=pla-4583589111108674&psc=1](https://www.amazon.com/Qunqi-point-Experiment-Breadboard-5-5%C3%978-2%C3%970-85cm/dp/B0135IQ0ZC/ref=asc_df_B0135IQ0ZC?tag=bingshoppinga-20&linkCode=df0&hvadid=79989522876977&hvnetw=o&hvmqmt=e&hvbmt=be&hvdev=c&hvlocint=&hvlocphy=&hvtargid=pla-4583589111108674&psc=1).
- [43] I. O. backbone, [Online]. Available: <https://www.albayan.ae/balsam/news/2015-12-06-1.2522862>.



## Research Article

# Research on Fault Diagnosis Model of Generative Adss Based on Improved Semisupervised Diagnosis Algorithm

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With the advent of the era of big data and the rapid development of deep learning and other technologies, people can use complex neural network models to mine and extract key information in massive data with the support of powerful computing power. However, it also increases the complexity of heterogeneous network and greatly increases the difficulty of network maintenance and management. In order to solve the problem of network fault diagnosis, this paper first proposes an improved semisupervised inverse network fault diagnosis algorithm; the proposed algorithm effectively guarantees the convergence of generated against network model, makes full use of a large amount of trouble-free tag data, and obtains a good accuracy of fault diagnosis. Then, the diagnosis model is further optimized and the fault classification task is completed by the convolutional neural network, the discriminant function of the network is simplified, and the generation pair network is only responsible for generating fault samples. The simulation results also show that the fault diagnosis algorithm based on network generation and convolutional neural network achieves good fault diagnosis accuracy and saves the overhead of manually labeling a large number of data samples.

## 1. Introduction

With the advent of the era of big data and the rapid development of deep learning and other technologies, people can mine and extract key information from massive data by using complex neural network models with the support of powerful computing power [1]. Especially in the complex heterogeneous network environment, thousands of network nodes will generate a large amount of network operation information every day [2]. However, this also increases the complexity of heterogeneous networks and increases the operating costs of network maintenance and management for operators. Some scholars have proposed a self-organizing fault diagnosis algorithm for heterogeneous networks based on AdaBoost ensemble learning, by training Bayesian, decision tree, artificial neural network, and K nearest neighbor classifiers, combined their classification results to gradually approach the real classification results, and used SMOTE technology to deal with the problem of unbalanced data in cellular networks, avoiding the low classification accuracy of

a few classes and effectively improving the diagnostic accuracy of classifiers [3]. It is undeniable that intelligent diagnosis algorithms such as RNN, LSTM, and CNN have satisfactory accuracy, but the premise of this high accuracy is to manually add labels to all samples, which will undoubtedly increase the cost of fault diagnosis [4]. Some scholars have proposed a semisupervised generation countermeasure network algorithm based on Gini regularization, which improves the convergence speed and accuracy of the model by adding Gini regularization constraints to the unsupervised loss function of the discriminator. In this algorithm, Wellside data is used as marked data, and seismic data is used as unmarked data to identify lithology, which reduces drilling cost [5]. Some scholars have also proposed a semisupervised classification algorithm based on joint training of generating countermeasure networks [6]. Firstly, two GAN models are trained once with labeled data sets. Then the unlabeled data set is input into the discriminators of the two GAN models. If the two discriminators have the same discriminating results to a

certain sample, the corresponding category label, namely, pseudo-label sample, is added to the labeled data set, the above operation is repeated until no new pseudolabel sample is generated, and the new labeled data set is used to train GAN model to complete the final classification task. Although the algorithm makes full use of unlabeled data sets, it only generates pseudolabeled samples according to whether the output results of two GAN models are the same, and its credibility directly affects the classification effect of the final GAN model.

Soft fault is the most difficult problem in analog circuits. Researchers have found a method to classify the samples randomly generated in the soft fault interval by using semisupervised support vector machine algorithm and then extract the circuit fault response data by manifold learning algorithm. Through verification, the classification method can be used for circuit soft fault diagnosis, which is quite instructive for practical application [7]. Tag data is actually difficult to collect and costs a lot. In the intelligent fault diagnosis of convolutional neural network, it often depends on labeled data. Therefore, we want to use unlabeled data. A bearing intelligent fault diagnosis method based on semisupervised convolutional neural network is proposed, and then the semisupervised convolutional neural network model is used to analyze the bearing vibration signal. Experiments show that our semisupervised convolutional neural network can train the model with unlabeled samples and improve the performance of diagnosis. Its advantages are obvious compared with common methods [8]. With the development of society and the improvement of living standards, people have higher and higher requirements for air quality in building rooms. At present, we generally use air handling devices to realize the circulation and regulation of indoor air, which is particularly important for the accurate diagnosis and troubleshooting of air conditioning equipment. Although the data-driven diagnosis method widely used in practice has its flexibility and advantages, its further implementation of advanced supervised learning algorithm is not in line with the reality because it takes too much time and effort to obtain the wrong data label [9]. Therefore, we propose a semisupervised diagnosis method based on neural network, which adopts self-training strategy. Through a large number of experiments, we believe that it can improve the generalization performance of the model and play a positive role in the development of advanced data-driven fault diagnosis system tools in the future. The artificial data generated by the generated countermeasure network has high similarity with the real data. At the same time, it can be used as a tool for data enhancement in the task of image generation. We use the developed auxiliary classifier GAN framework to generate realistic raw data. The framework can effectively avoid the gradient disappearance problem, and the category label is used to assist the training model [10]. We use a set of evaluation methods to evaluate the quality of the generated samples and confirm their performance.

The contribution of this paper is as follows. (1) In view of the current network fault diagnosis problem of hard, at first, this paper puts forward a kind of based on improved the generation of a semisupervised against network fault

diagnosis algorithms, the proposed algorithm effectively guarantees the convergence of generated against network model and makes full use of a large amount of trouble-free tag data, and obtains a good accuracy of fault diagnosis. And then we use a diagnosis model for the further optimization. (2) The generate against network based combined with convolution neural network fault diagnosis algorithm achieves good accuracy of fault diagnosis and saves the overhead of manually marking a large number of data samples.

## 2. Fault Diagnosis Algorithm Based on Improved Generation Countermeasure Network

**2.1. System Model.** Aiming at the dense heterogeneous wireless network scenario with multilevel network structure composed of high-power Hong Jizhan and low-power micro base stations [11, 12], as shown in Figure 1, this paper proposes a network fault diagnosis model based on GAN to locate faults, so as to avoid losses caused by fault propagation.

In the selection of key performance parameters used to characterize the network condition, this paper adopts the feature selection algorithm combining Reliance and mutual information, and finally selects eight key performance indexes, RSRQ\_P, DCR, HO, RSRP\_P, ERAB\_S, SNR\_UL, SNR\_DL and LER, as the input parameters of the fault diagnosis model.

**2.2. Network Fault Diagnosis Model Based on Improved Semisupervised Generation Countermeasure.** Although the original GAN does not need classification labels in the training process, it generates false data similar to the real data, and its discriminator realizes the identification of true and false data, but it cannot classify the real data [13, 14]. Some scholars skillfully modify the discriminator of GAN and replace the output layer of discriminator network with Softmax classifier, so that it can classify real data. Assuming that the training data has  $K$  classes, the Softmax classifier has  $K + 1$  classes, where the  $K + 1$  class represents the false data generated by the generator, and the rest correspond to  $K$  classes in the training data, so that GAN can complete the semisupervised classification problem, and its network structure is shown in Figure 2.

The training network  $D$  maximizes the probability of sorting the labels of the training samples (maximizing  $\log D(x)$ ), and the training network  $G$  minimizes  $\log(1 - D(g(c)))$ ; that is, it maximizes the loss of  $D$ . In the training process, one party is fixed and the parameters of the other network are updated and iterated alternately to maximize the other party's error. Finally,  $G$  can estimate the distribution of sample data. Due to the change of discriminator structure, the loss function of semisupervised generation countermeasure network (SGAN) also changes accordingly. The loss function of generator  $G$  is shown in formula (1), where  $\hat{x} = G(z)$  is the data generated by the generator,  $p(\hat{x})$  is the probability distribution function of  $\hat{x}$ , and  $P_d(y = K + 1|\hat{x})$  represents the probability that the generated data  $\hat{x}$  is judged as  $K + 1$  class by discriminator  $D$ .



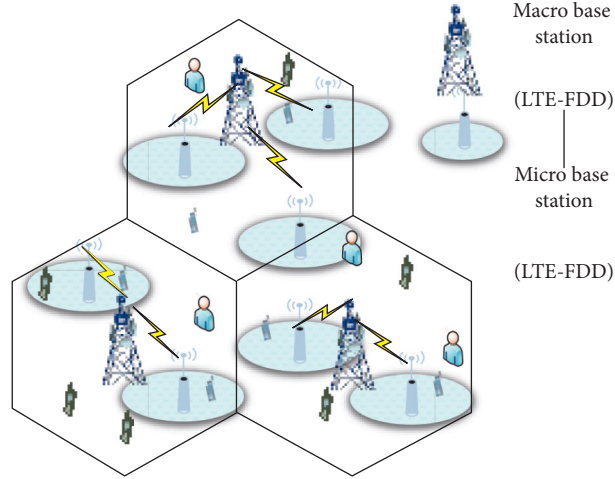


FIGURE 1: Two-tier heterogeneous wireless network model.

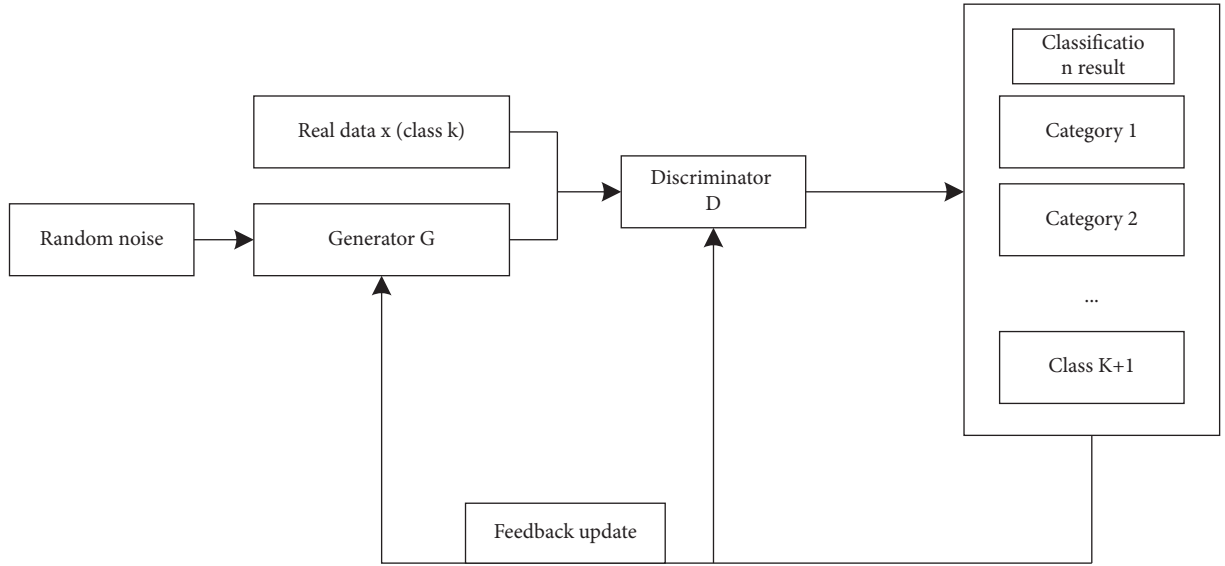


FIGURE 2: Semisupervised generation countermeasure network structure.

$$L_G = E_{\hat{x} \sim p(\hat{x})} [\log P_d(y = K + 1 | \hat{x})]. \quad (1)$$

The loss function of discriminator  $D$  can be divided into supervised loss and unsupervised loss, as shown in

$$\begin{aligned} L_D &= -E_{(x,y) \sim p(x,y)} [\log P_d(y|x)] \\ &\quad - E_{\hat{x} \sim p(\hat{x})} [\log P_d(y = K + 1 | \hat{x})] \\ &= L_{\text{sup}} + L_{\text{unsup}}, \end{aligned} \quad (2)$$

where  $X$  is the real data,  $Y$  is the category label of  $X$ ,  $P(X, Y)$  is the probability distribution obeyed by  $(X, Y)$ ,  $X$  is the data generated by the generator, and  $p(\hat{x})$  is the probability distribution obeyed by it. The loss function of the supervised part refers to the distance loss between the predicted result and the label when training the labeled part of data  $(x, y)$ , as shown in formula (3). The loss function of the unsupervised part refers to the loss when training the unlabeled part of data  $x$  and the generated data  $\hat{x}$ , that is, the loss function of the original GAN discriminator, as shown in formula (4).

$$L_{\text{sup}} = -E_{(x,y) \sim p(x,y)} [\log P_d(y|x)], y \in \{1, 2, \dots, K + 1\}, \quad (3)$$

$$L_{\text{unsup}} = -\left\{ E_{x \sim p(x)} [\log(1 - P_d(y = K + 1|x))] + E_{\hat{x} \sim p(\hat{x})} [\log P_d(y = K + 1|\hat{x})] \right\}. \quad (4)$$

Although SGAN can improve the performance of supervision tasks by learning additional unlabeled samples, the goal of gradient descent algorithm in SGAN is to find the minimum loss function point, instead of finding a Nash equilibrium that makes both the generator and the discriminator achieve the best performance. Especially when there are many input feature parameters, the difficulty of convergence of the model will greatly increase. Therefore, in this paper, two constraint functions, feature matching and compactness calculation, are added to the loss function of the generator network to stabilize the convergence of SGAN model and improve the final performance of the model. The model structure is shown in Figure 3.

Among them, the calculation formula of convolution operation is as follows:

$$y_{i,j}^{l+1,j+1} = \sum_{i=0}^H \sum_{j=0}^w f_{i,j} \cdot x_{i,j+1+j}^l \quad (5)$$

In this paper, a  $3 \times 3$  convolution kernel is adopted, and in order to prevent the omission of data information, the convolution step is set to 1; that is, the distance of each convolution kernel movement is a coordinate unit, so the output meets the following requirements:

$$\begin{aligned} 0 \leq i^{l+1} \leq H^l - H + 1 = H^{l+1}, \\ 0 \leq j^{l+1} \leq W^l - W + 1 = W^{l+1}. \end{aligned} \quad (6)$$

When SGAN trains generator  $G$ , originally, it only depends on reducing the distance loss between the output result of discriminator  $D$  and the real result. That is to say, the only goal is to increase the probability that the discriminator  $D$  regards false data as true data, so it is easy to cause the generator  $G$  to be overtrained on the current discriminator  $D$ , which leads to the great influence on the generator  $G$  when the parameters of the discriminator  $D$  change, so that the convergence fluctuation of the model is large, and it is difficult to reach the Nash equilibrium point of  $D$  and  $G$ . Therefore, in this paper, an objective function  $D(x, \hat{x})$  of the distance between the generated data and the real data is added to the loss function of the generator  $G$ , that is, the feature matching between the generated data and the real data, so as to make the generated data consistent with the real data as much as possible and avoid overtraining on the current discriminator. The main idea is that when the false data  $\hat{x}$  generated by the generator is input to the discriminant network and when the calculation result of each hidden layer in the discriminator is as similar as possible as the real data  $x$  is input into the discriminant network, then the L2 distance is calculated for each hidden layer result, and the distance of all layers is summed and averaged to obtain the objective function  $D(x, \hat{x})$ . The formula is as follows:

$$D(x, \hat{x}) = \frac{1}{l} \sum_{i=1}^l E_{x \sim p(x)} f_i(x) - E_{\hat{x} \sim p(\hat{x})} f_i(\hat{x}), \quad (7)$$

where  $f_i(\cdot)$  is the output of the  $i$ -th hidden layer of the discriminator,  $l$  is the number of hidden layers,  $x$  is the real data, and  $\hat{x}$  is the generated data.

In the loss function of the generator, we add the distance function between the compactness between the real samples and the compactness between the generated samples, so as to avoid the situation that the loss function tends to be unchanged and the algorithm cannot converge correctly when the model collapses.

In this paper, the definition of compactness modeling between samples is as follows: the distance between a single sample and each sample in a small batch data set is summed and averaged to characterize the compactness between the sample and the data set. Considering the differences in dimensions of each feature in the sample, the distance between the samples adopts standardized Euclidean distance, and the distance function between the compactness between the real samples and the compactness between the generated samples is

$$\begin{aligned} \text{dis} = |D_{\text{ral}} - D_{\text{fake}}| = \frac{1}{n} \sum_{r=1}^n f(\hat{x}) \\ - f(x_r)_{\text{normal}} - \frac{1}{n} \sum_{f=1}^n f(\hat{x}) - f(x_f), \end{aligned} \quad (8)$$

where  $\hat{x}$  is the input data of the discriminator,  $X_r$  and  $X_f$  are the samples of the small batch real data set and the small batch generated data set respectively,  $n$  is the size of the small batch data set, and  $f(\cdot)$  is the output of the hidden layer in the middle of the discriminator. The normalized Euclidean distance between two  $n$ -dimensional variables  $a$  ( $x_{11}, x_{12}, \dots, x_{1n}$ ) and  $b$  ( $x_{21}, x_{22}, \dots, x_{2n}$ ) is shown in formula 10, where  $s_k$  is the standard deviation of the  $k$ th component in Figure 4.

$$\text{dis}(a, b) = a - b_{\text{normal}} = \sqrt{\sum_{k=1}^n \left( \frac{x_{1k} - x_{2k}}{s_k} \right)^2}. \quad (9)$$

At this point, we have completed the improvement of SGAN, and the loss function of its final generator  $G$  is

$$L_G = E_{\hat{a} \sim p(\hat{a})} [\log P_d(y = K + 1 | \hat{x})] + \lambda * [D(x, \hat{x}) + \text{dis}]. \quad (10)$$

The specific training process of the improved SGAN is in Table 1.

In this paper, the structure of the generator and discriminator of the improved semisupervised generation countermeasure network is selected as CNN, the size of convolution kernel in convolution layer and deconvolution layer is  $3 \times 3$ , and the step size is 2. The results of each convolution and deconvolution are normalized in batches to avoid overfitting and improve the training speed of the model. The learning rate is set to 0.0001, and the cross-entropy loss function is selected as the model error function, which is helpful to improve the classification effect.

We also smooth the 0 and 1 data tags in the model to enhance the anti-interference ability of the network. However, in order to keep the optimal discriminant function of the discriminator unchanged and avoid the occurrence of pattern collapse, we keep the tags with a value of 0

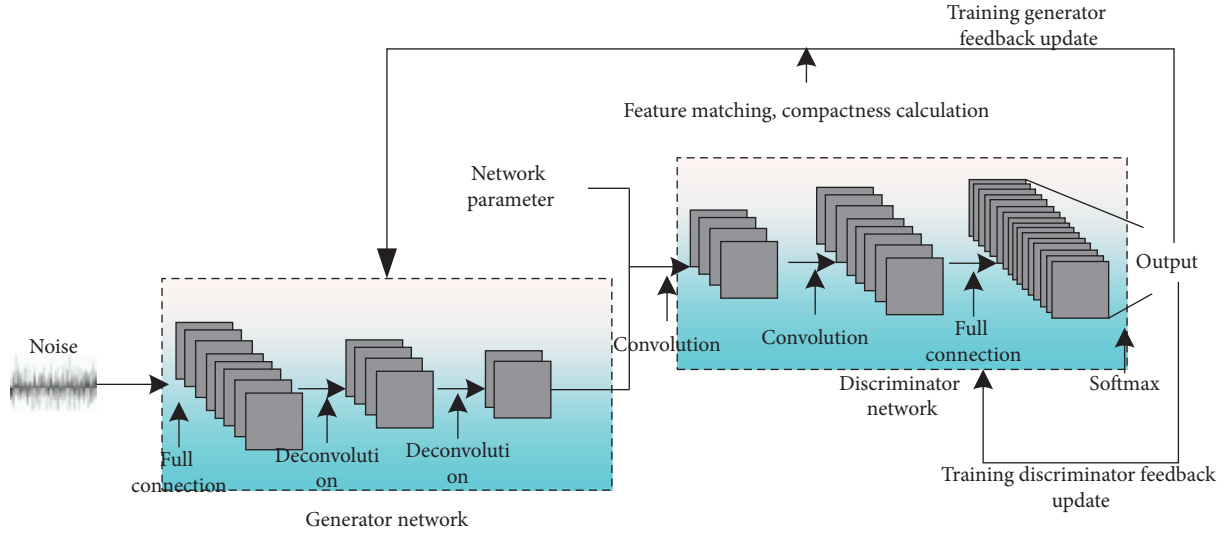


FIGURE 3: Fault diagnosis model based on improved generation countermeasure network.

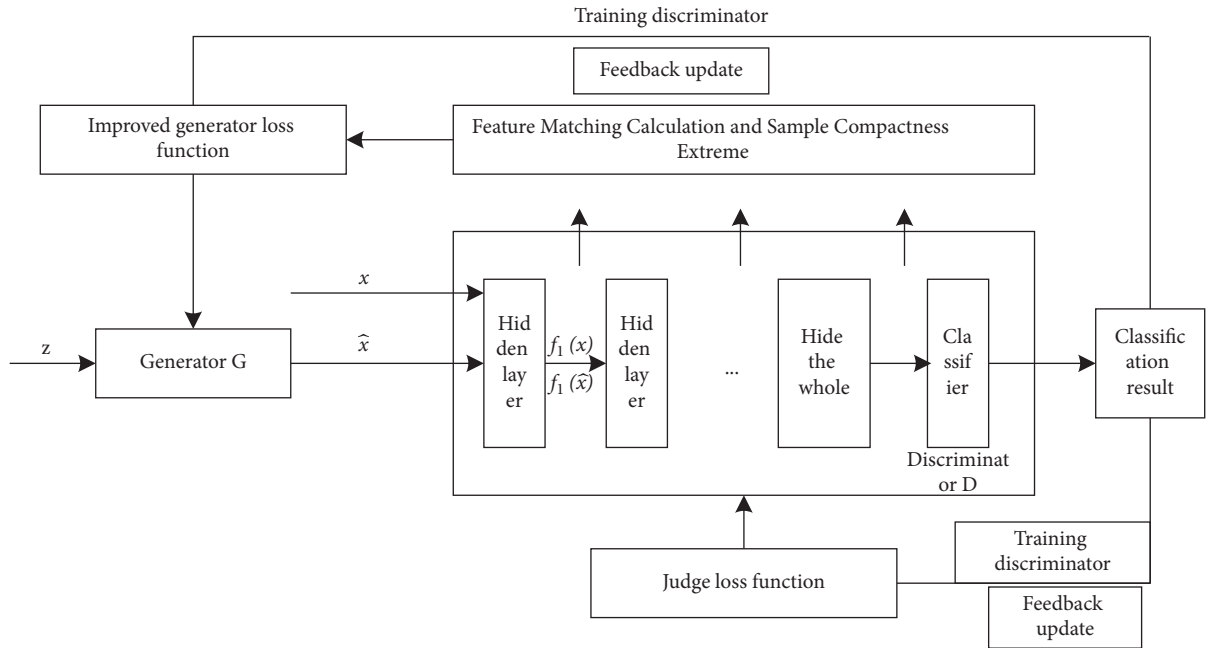


FIGURE 4: Algorithm flow chart of improved SGAN.

TABLE 1: Improved SGAN algorithm steps.

Algorithm: Improved SGAN model training based on small batch random gradient descent algorithm

Inputs:  $p(z)$ : Random noise distribution,  $p(x)$ : True data distribution,  $\lambda$ : Specific gravity coefficient,  $m$ : Iteration times

Output: Trained discriminator  $D$

For  $i = 1$  to  $m$  do

N Noise samples  $\{Z^{(1)}, Z^{(2)}, \dots, Z^{(n)}\}$  subject to  $P(z)$  distribution

N labeled samples obeying  $p(x)$  distribution  $\{(x^{(1)}, y^{(1)}), (x^{(2)}, y^{(2)}), \dots, (x^{(n)}, y^{(n)})\}$

N unlabeled samples following  $p(x)$  distribution  $\{\tilde{x}^{(1)}, \tilde{x}^{(2)}, \dots, \tilde{x}^{(n)}\}$

Keeping the parameters of generator  $G$  unchanged, update the parameters of discriminator  $D$  according to the following formula

$$\min_{\theta(D)} \frac{1}{n} \sum_{i=1}^n \{-\log P_d(y^{(i)} | x^{(i)}, y^{(i)} < K + 1) - \log(1 - P_d(y = K + 1 | G(z^{(i)})))\}$$

Keeping the parameters of discriminator  $D$  unchanged, update the parameters of generator  $G$  according to the following formula

$$\min_{\theta(G)} \frac{1}{n} \sum_{i=1}^n \{\log P_d(y = K + 1 | G(z^{(i)}))\}$$

end

unchanged, and only change the tags with a value of 1 to 0.9; that is, smooth the unilateral tags.

In addition, in order to strengthen the generalization ability of the model, we also set a trigger condition for model modification for the trained discriminator model [15, 16]. Every time the discriminator diagnoses the network fault, the data that is wrongly diagnosed will be stored in the database. When the stored data is larger than one-third of the training data, the retraining of the model will be triggered. The training data consists of the original training data and the data for diagnosing errors, thus completing the correction of the discriminator model. The flow chart is as follows in Figure 5.

### 3. Generate a Fault Diagnosis Model Combining Countermeasure Network with Convolution Neural Network

Although the semisupervised fault diagnosis algorithm based on improved generation countermeasure network proposed in the previous section solves the problem that the diagnosis model can identify network faults autonomously under the condition of a small amount of marked data and a large amount of unmarked data, two constraint functions are added to the loss function of the generator network to stabilize and accelerate the convergence of the model to achieve Nash equilibrium. However, with the increase of the input network characteristic parameters, the convergence of the model will become more and more difficult, so we consider reducing the complexity of the discriminator network in the model to accelerate the convergence of the model.

In the improved semisupervised fault diagnosis model of generative countermeasure network, the discriminator mainly undertakes two tasks: one is to identify true and false data and the other is to classify the real data, which will undoubtedly increase the difficulty of convergence of the model. Therefore, the task of classifying the real data is extracted by the fault diagnosis model based on convolution neural network, and the discriminator only needs to identify the generated data and the real data [17, 18]. The disadvantage of convolution neural network discussed before is that it is a supervised learning method. It is not suitable for the scene with only a small amount of marked data, but now we can generate the data of each type of fault through the improved generation countermeasure network and then combine the generated data with the real data to train the fault diagnosis model based on convolution neural network to improve the accuracy of the diagnosis model [19, 20].

The fault diagnosis model proposed in this paper can be divided into two steps: data generation and fault diagnosis, as shown in Figure 6.

**3.1. GAN Generates Network Data.** Each node selects eight key network performance parameters, namely, RSRQ, DCR, HO, RSRP, ERAB, SNR\_UL, SNR\_DL, and LER, and obtains the data at time  $t$  as shown in

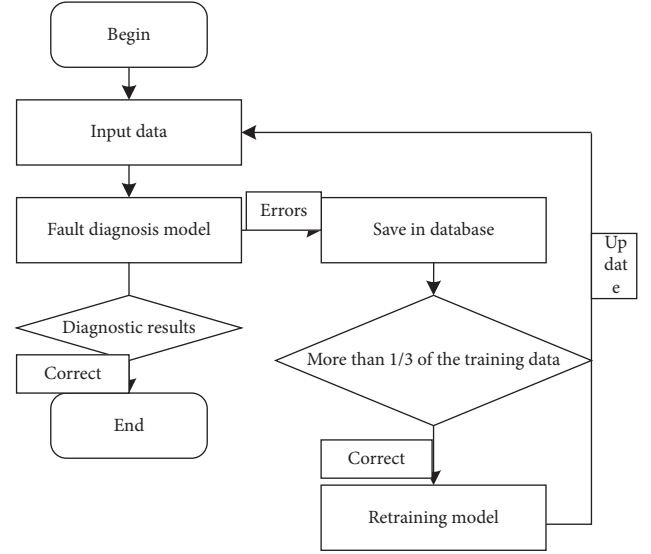


FIGURE 5: Flow chart of model correction.

$$\begin{aligned}
 X^t &= \begin{bmatrix} KPI_1^{t-T+1} & \cdots & KPI_1^t \\ \vdots & \ddots & \vdots \\ KPI_8^{t-T+1} & \cdots & KPI_8^t \end{bmatrix} \\
 &= \begin{bmatrix} \frac{1}{T} \sum_{i=t-T+1}^t KPI_1^i & \frac{1}{T} \sum_{i=t-T+1}^t KPI_2^i & \cdots & \frac{1}{T} \sum_{i=t-T+1}^t KPI_8^i \end{bmatrix} \quad (11) \\
 &= \begin{bmatrix} KPI_{avg}^{t-1} \\ KPI_{avg}^{t-2} \\ \vdots \\ KPI_{avg}^{t-t} \end{bmatrix}
 \end{aligned}$$

Considering that the network scenario in this paper is a dense heterogeneous wireless network, there is a certain correlation between base stations [21, 22], so we select the nearest 7 base stations as the neighbor base stations of the current base station. In order to ensure the same data format, when the number of neighbor base stations is less than 7, we use the average value of the neighbor base stations of the current base station to fill the insufficient data samples. Finally, the data of each base station at  $T$  time is shown in

$$X^t = \begin{bmatrix} X_{cur}^t \\ X_1^t \\ \vdots \\ X_7^t \end{bmatrix} = \begin{bmatrix} KPI_{cur_{avg1}}^t & \cdots & KPI_{cur_{avg8}}^t \\ \vdots & \ddots & \vdots \\ KPI_{7_{avg1}}^t & \cdots & KPI_{7_{avg8}}^t \end{bmatrix}, \quad (12)$$

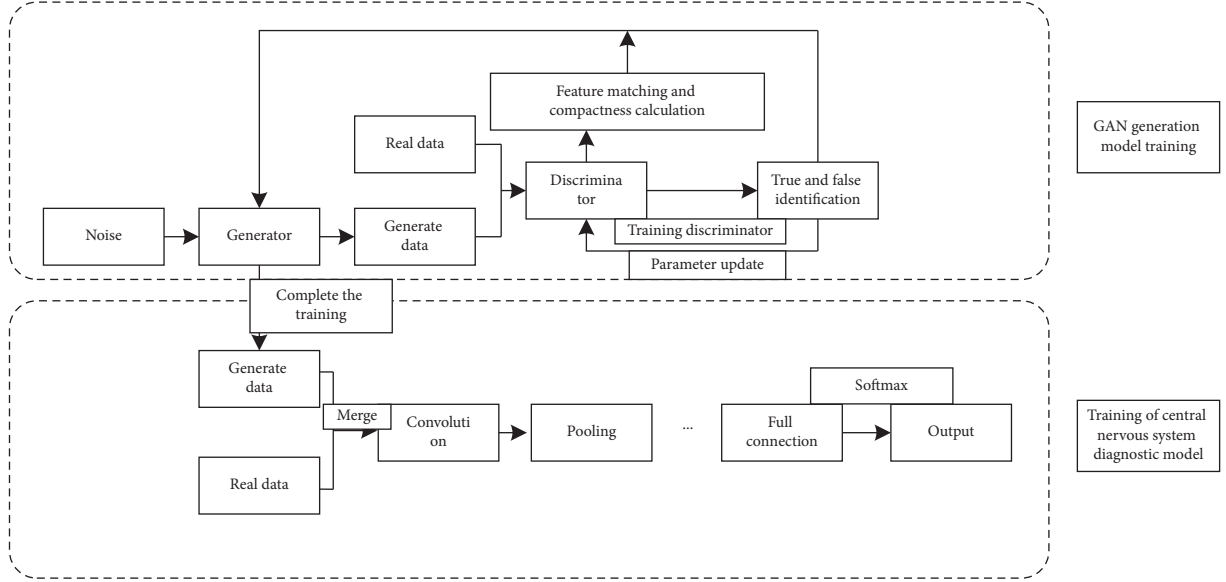


FIGURE 6: Generate a fault diagnosis model combining countermeasure network and convolution neural network.

where  $X_{cur}^t$  refers to the network key performance index parameter of the current base station at time  $t$  and  $X_i^t$  refers to the network key performance index parameter of the  $i$ -th neighbor base station at time  $t$ .

Assuming that there are  $K$  kinds of network faults, the labeled data samples are divided into  $K$  kinds according to the fault types, and then the classified data samples are input into the improved generation countermeasure network one by one for training, and the data of corresponding fault types are generated. The neural network structure for generating the countermeasure network still adopts the model parameters in the previous section, but the last two layers in the discriminator network are adjusted, the output format of the full connection layer is changed from  $[None, 7]$  to  $[None, 1]$ , and the Softmax layer is also changed to sigmoid activation layer to ensure that the output results are in the range of 0~1, and the loss function of the network is changed accordingly, as shown in

$$L_G = E_{\hat{z} \sim p(x)} [\log(1 - D(\hat{x}))] + \lambda * \left[ \frac{1}{l} \sum_{i=1}^l E_{x \sim p(x)} f_i(x) - E_{\hat{z} \sim p(x)} f_i(\hat{x})_2 \right], \quad (13)$$

$$L_D = - \left\{ E_{\hat{z} \sim p(x)} [\log(D(x))] + E_{\hat{z} \sim p(\hat{x})} [\log(1 - D(\hat{x}))] \right\}, \quad (14)$$

where input is the specific gravity coefficient, used to adjust the proportion between the cross-entropy loss function of the original generator network and the new target constraint function,  $X$  is the real data,  $\hat{x}$  is the generated data,  $x_r$  and  $x_f$  are the samples of the small batch real data set and the small batch generated data set respectively,  $n$  is the size of the small batch data set,  $l$  is the number of hidden layers in the discriminator,  $f_i(\cdot)$  is the output of the hidden layer of the  $i$  layer, and  $D(\cdot)$  is the output of the discriminator.

**3.2. Network Fault Diagnosis Model Based on CNN.** After all kinds of fault data are generated, we add corresponding fault labels manually and then merge them with real data as the training data set of convolution neural network.

The network structure of CNN diagnostic model in this section is shown in Table 2 where the convolution kernel size is  $3 \times 3$ , the convolution step is 1, the pool core size is  $2 \times 2$ , the pooling step size is 2, and the parameter of dropout operation in the full connection layer is 0.5; that is, half of the neurons in the full connection layer are temporarily discarded from the network during each training, so that the network structure of each training is different to avoid overfitting the model. The error function of the model still adopts the cross-entropy loss function, and the learning rate of the optimizer is set to 0.0001.

Specific fault diagnosis steps are as follows:

- (A) Building and generating a countermeasure network model according to the neural network parameters defined in (1) and dividing the marked real data into training data and test data according to a certain proportion.
- (B) Inputting the training data into the generated countermeasure network model according to the classification of fault categories, generating data of corresponding fault categories through the generator network after the model training converges, adding fault labels, and then combining the training data and the generated data as new training data of the convolution neural network diagnosis model.
- (C) Setting up a CNN model according to the neural network parameters defined in (2) and training the CNN model by using new training data.
- (D) Entering data from the test dataset to validate the performance of the diagnostic model.

TABLE 2: Network structure parameters of CNN fault diagnosis model.

Layer (operation)	Input format	Output format
Convolution layer 1	[None,8,8,1]	[None,8,8,32]
Batch normalization	[None,8,8,32]	[None,8,8,32]
Nonlinear activation	[None,8,8,32]	[None,8,8,32]
Pool layer	[None,8,8,32]	[None,4,4,32]
Convolution layer 2	[None,4,4,32]	[None,4,4,64]
Batch normalization	[None,4,4,64]	[None,4,4,64]
Nonlinear activation	[None,4,4,64]	[None,4,4,64]
Pool layer 2	[None,4,4,64]	[None,2,2,64]
Fully connected layer	[None,256]	[None,6]
Softmax	[None,6]	[None,6]

#### 4. Performance Evaluation and Results

In this paper, GAN model and CNN model are based on TensorFlow framework, software using Pycharm development tools, hardware using Intel (R) Core (TM) i7-6700 CPU @ 3.40 GHz, memory 8G, operating system Windows 10 desktop in Table 3.

Network operation data is generated by OPNET software simulation; the hardware of OPNET network simulation software is Intel (R) Xeon (R) CPU E7-4870 v2 @ 2.3 GHz (2 processors), with 3G memory and Windows 7 operating system; a cellular network composed of 3 macro base stations and 15 micro base stations is built by using this simulation software. The overall coverage area of the network is 5 km × 5 km, and the coverage radius of each macro base station is 1 km. There are 5 micro base stations distributed within each macro base station, and users are randomly distributed in their respective cells. The specific parameters are shown in Table 3.

In network simulation, this paper mainly sets up five different kinds of faults, which are uplink interference F1, downlink interference F2, coverage fault F3, base station fault F4 and link fault F5, and fault-free state F0. Before the start of the simulation, we will set the occurrence and recovery time of these faults in advance, so as to manually add fault labels to the data generated by the simulation. The simulation setting time is 24 hours, the total duration of each fault is 2 hours, and each fault lasts for 30 minutes and then recovers. Finally, the network simulation generated a total of 29,160 pieces of data, which were normalized and preprocessed by neighboring base stations to obtain 1,620 pieces of data as shown in formula (9), which were divided into training data and test data in a ratio of 7:3, and the ratio of various faults in each data set was ensured to be consistent. Then, the fault labels of about 1/10 of the training data are retained, and the rest of the training data are deleted. Finally, three data sets are formed, namely, 120 training data sets with fault labels, 1014 training data sets without fault labels, and 486 test data sets, and the proportion of various faults in each data set is consistent. Finally, these data are input into the improved generative countermeasure network diagnosis model proposed in this paper for training and testing, and the simulation results are introduced in detail.

*4.1. Improved GAN Diagnosis Model Influence of Different Batch Data Size on the Accuracy of Model Fault Diagnosis Firstly.* Some nouns in this simulation are explained. Here, fault diagnosis accuracy refers to the percentage of correct diagnosis information to the total amount of diagnosis information, iteration times refer to the times of inputting complete training data sets into the model, and batch data size refers to the number of samples for training and updating model parameters once. In the actual neural network training, when the data set is large, if all the data is entered into the model at one time, it will affect the efficiency and optimization degree of model training, so we batch the training data set according to the batch data size to improve the convergence speed and performance of the model. Moreover, the size of small batch data set is also related to the batch data size in the improved calculation of compactness in this paper.

Figure 7 is the change of fault diagnosis accuracy under different batch data sizes. It can be seen from the figure that when the batch data length is too small, the fluctuation of diagnostic accuracy of the model is relatively large, because the number of samples updated each time is small, and the model is difficult to converge. If the batch data length is too large, although the fluctuation of diagnostic accuracy of the model is stable, the rise of diagnostic accuracy is relatively slow, which requires more iterations. Therefore, the final batch data size set in this article is 100.

*4.2. The Influence of Specific Gravity Coefficient  $\lambda$  on the Fault Diagnosis Accuracy of the Model.* In this paper, two constraint functions are added to the loss function of the generator network that generates the countermeasure network, and the selection of the proportion between the constraint function and the original loss function also has certain influence on the performance of the model, as shown in Figure 8. As can be seen from the figure, when the specific gravity coefficient is 0.1, the constraint function has no constraint on the total loss function; therefore, the convergence of the generator network model is difficult, and the accuracy of fault diagnosis fluctuates greatly. With the increase of the proportion of constraint function, the accuracy of fault diagnosis gradually rises slowly. When the specific gravity coefficient is 1, the fluctuation of the model begins to increase again. This is mainly because the output of the hidden layer in the middle of neural network is too emphasized, so this paper sets the specific gravity coefficient  $\lambda$  to 0.5 according to the simulation results.

*4.3. Comparison of Fault Diagnosis Accuracy of Different Improved Generated Countermeasure Networks.* Figure 9 is a diagram showing the variation of fault diagnosis accuracy of the generated countermeasure network model based on different improved methods. SDGAN refers to the semi-supervised generation countermeasure network model which improves the generator network and discriminator network into convolution neural network. SDGAN-F means that the loss function of the generator is improved on the basis of SDGAN, and the constraint function  $D(x, \hat{x})$  based



TABLE 3: Simulation parameters of two-layer heterogeneous wireless network.

Simulation parameters	Macro base station	Micro base station
Number of base stations	1	3
Number of users	20/base station	10/base station
Transmission power	46 dBm	30 dBm
Standard deviation of shadow fading	8 dB	10 dB
Transmission loss model	SuburbanMacrocell (3GPP)/Free space	Indoor office environment/outdoor to indoor and pedestrian environment
Antenna gain	15 dBi	8 dBi
Operation mode	LTE 5 MHz FDD	LTE 10 MHz FDD
Receiving sensitivity	-110 dBm	-107 dBm
Base station selection strategy		Best suitable eNodeB
User distribution		Random distribution

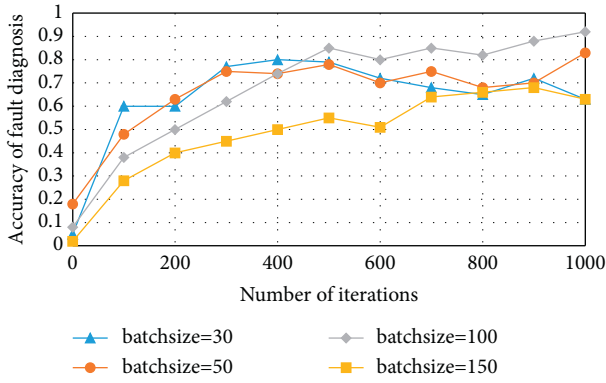


FIGURE 7: Variation of diagnostic accuracy under different batch data sizes.

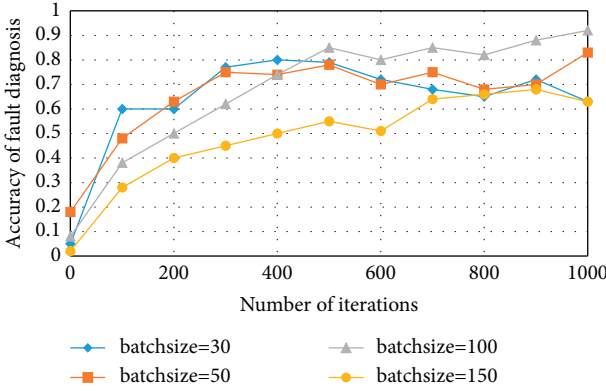


FIGURE 8: Variation of fault diagnosis accuracy under different specific gravity coefficients.

on feature matching is added. SDGAN-FM means that the loss function of the generator is modified on the basis of SDGAN, and a constraint function combining feature matching and batch sample compactness is added, such as formula (7). It can be seen from the figure that, compared with SDGAN, SDGAN-F does stabilize the convergence fluctuation of the generated countermeasure network in the training process because of adding the constraint function of feature matching, but compared with SDGAN-FM proposed in this paper, its fault diagnosis accuracy is still poor. The

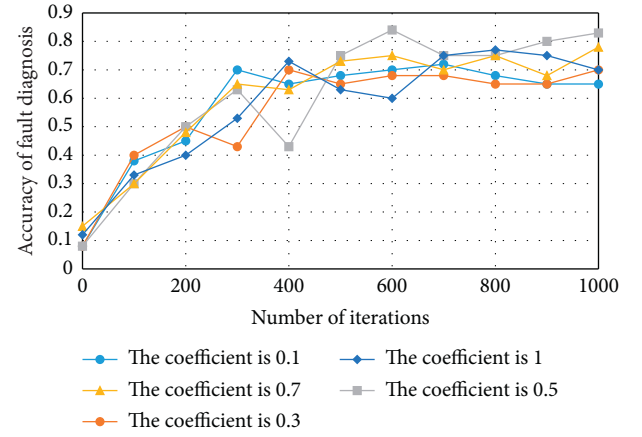


FIGURE 9: Variation of fault diagnosis accuracy based on different improved methods.

final fault diagnosis accuracy of SDGAN-FM algorithm can reach 91.2%, while that of SDGAN-F algorithm can only reach about 70%. This is because the increased batch sample compactness constraint function can avoid the generator only generating data of a single fault category and improve the performance of the generator, thus improving the fault diagnosis accuracy of the discriminator.

**4.4. The Influence of the Amount of Data Generated by the Generated Countermeasure Network on the Fault Diagnosis Accuracy of the Model.** In this paper, a fault diagnosis model combining generated countermeasure network with convolution neural network is proposed; its data sets are 120 training data sets with fault labels and 486 test data sets. After classifying the training data sets according to fault categories, they are input to generate data of corresponding categories in the generated countermeasure network. After 1000 iterations, the loss functions of the generator and discriminator tend to be stable and the model converges.

Then, the generated data and the original training data are combined and input into the convolution neural network to train the fault diagnosis model. Table 4 compares the fault diagnosis accuracy of the models under different generated data quantities. As can be seen from Table 4, with the increase of generated data, the fault diagnosis accuracy of the

TABLE 4: Fault diagnosis accuracy of the model under different generated data quantities.

Generated data amount/original data amount	1	2	3	4	5
Accuracy of fault diagnosis	0.827	0.919	0.933	0.986	0.988

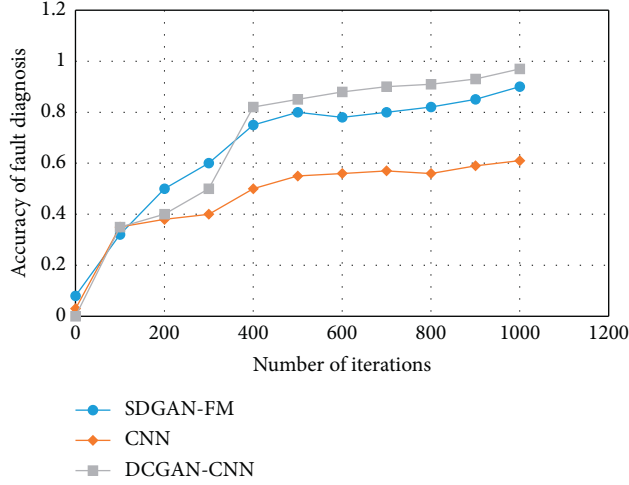


FIGURE 10: Comparison of fault diagnosis accuracy of different algorithms.

model is gradually improved. However, when the amount of generated data is 4 times the original training data, the improvement of fault diagnosis accuracy of the model will be relatively small if the amount of generated data is increased, and it takes more time to generate more data. Therefore, considering the overall performance of the model, this paper sets the amount of data generated by the generated countermeasure network to be 4 times the original training data.

**4.5. Comparison of Fault Diagnosis Accuracy of Different Algorithms.** Figure 10 is a comparison of the fault diagnosis accuracy of SDGAN-FM, CNN, and DCGAN-CNN algorithms. Among them, SDGAN-FM is a semisupervised fault diagnosis algorithm based on improved generation countermeasure network proposed in this paper, the training dataset includes a labeled dataset and an unlabeled dataset, CNN is a fault diagnosis algorithm based on convolution neural network, and the training data set only contains tagged data sets. DCGAN-CNN is a fault diagnosis algorithm based on the combination of generated countermeasure network and convolution neural network, and the training data set only contains tagged data sets. It can be seen from the figure that the final fault diagnosis accuracy of CNN algorithm is low due to the small amount of labeled data, while SDGAN-FM algorithm stabilizes the convergence fluctuation of the generated countermeasure network and makes full use of a large number of unlabeled data set, but the final diagnosis accuracy is only 91.2% due to the high complexity of the model. DCGAN-CNN algorithm makes full use of the characteristics of generated countermeasure network which is good at simulating data distribution and the good classification ability of convolution neural network,

makes up for the shortcoming of insufficient training data set of convolution neural network with generated countermeasure network, and finally obtains better fault diagnosis accuracy, which can reach 98.6%.

## 5. Conclusion

With the advent of the era of big data and the rapid development of technologies such as deep learning, computers with powerful computing power are needed to mine and extract key information from massive data by using complex neural network models. This paper presents a semi-supervised antinetwork fault diagnosis algorithm based on improved generation. The algorithm effectively guarantees the convergence of the generated network model, makes full use of a large number of trouble-free label data sets, and obtains better fault diagnosis accuracy. Then the diagnosis model is further optimized. The task of fault classification is completed by convolution neural network. In order to simplify the discriminant function of the network, the generated inverse network is only responsible for generating fault samples. The simulation results also show that the fault diagnosis algorithm based on generated inverse network combined with convolution neural network achieves better fault diagnosis accuracy and saves the overhead of manually marking a large number of data samples. In the next step, the performance comparison of this method under different network models is further studied. At present, the learning process of GAN can have a collapse problem, where the generator starts to degenerate and always produces the same sample points, unable to continue learning. When the generated model crashes, the discriminant model will also point to similar sample points in similar directions, and the training cannot continue, and this is also one of our research directions in the future.

## Data Availability

The experimental data used to support the findings of this study are available from the corresponding author upon request.

## Conflicts of Interest

The authors declare that they have no conflicts of interest regarding this work.

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## References

- [1] J. Gu, M. Li, L. Yu, S. Li, and K. Long, "Analysis on link travel time estimation considering time headway based on urban road RFID data," *Journal of Advanced Transportation*, vol. 2021, no. 3, 19 pages, Article ID 8876626, 2021.
- [2] J. Zhang and J. Chen, "An adaptive clustering algorithm for dynamic heterogeneous wireless sensor networks," *Wireless Networks*, vol. 25, no. 8, pp. 455–470, 2019.
- [3] L. Cheng, Y. Yang, K. Zhao, and Z. Gao, "Research and improvement of TF-IDF algorithm based on information theory," *Advances in Intelligent Systems and Computing*, vol. 905, pp. 608–616, 2020.
- [4] R. Yu, M. Lyu, J. Lu, Y. Yang, G. Shen, and F. Li, "Spatial coordinates correction based on multi-sensor low-altitude remote sensing image registration for monitoring forest dynamics," *IEEE Access*, vol. 8, p. 1, 2020.
- [5] X. Dai, X. Wu, B. Wang, and L. Zhang, "Semisupervised scene classification for remote sensing images: a method based on convolutional neural networks and ensemble learning," *IEEE Geoscience and Remote Sensing Letters*, vol. 16, no. 6, pp. 869–873, 2019.
- [6] M. Wang, Z. Zhang, K. Li, Z. Zhang, Y. Sheng, and S. Liu, "Research on key technologies of fault diagnosis and early warning for high-end equipment based on intelligent manufacturing and Internet of Things," *The International Journal of Advanced Manufacturing Technology*, vol. 107, no. 3, pp. 1039–1048, 2020.
- [7] L. Wang, H. Tian, and H. Zhang, "Soft fault diagnosis of analog circuits based on semi-supervised support vector machine[J]," *Analog Integrated Circuits and Signal Processing*, vol. 108, no. 3, pp. 1–11, 2021.
- [8] Y. Wu, R. Zhao, W. Jin, T. He, S. Ma, and M. Shi, "Intelligent fault diagnosis of rolling bearings using a semi-supervised convolutional neural network," *Applied Intelligence*, vol. 51, no. 4, pp. 2144–2160, 2021.
- [9] C. Fan, X. Liu, P. Xue, and J. Wang, "Statistical characterization of semi-supervised neural networks for fault detection and diagnosis of air handling units," *Energy and Buildings*, vol. 234, no. 12, Article ID 110733, 2021.
- [10] S. Shao, P. Wang, and R. Yan, "Generative adversarial networks for data augmentation in machine fault diagnosis," *Computers in Industry*, vol. 106, pp. 85–93, 2019.
- [11] Z. Q. Liu, T. Zhang, and Y. F. Wang, "Research on local dynamic path planning method for intelligent vehicle lane-changing," *Journal of Advanced Transportation*, vol. 2019, Article ID 4762658, 10 pages, 2019.
- [12] C. Jiang, J. Wan, and H. Abbas, "An edge computing node deployment method based on improved k-means clustering algorithm for smart manufacturing," *IEEE Systems Journal*, vol. 15, no. 2, pp. 2230–2240, 2021.
- [13] H. Zhao, B. Yang, L. Cao, and H. Li, "Data-driven enhancement of blurry retinal images via generative adversarial networks," in *Lecture Notes in Computer Science*, pp. 75–83, Springer, Cham, Switzerland, 2019.
- [14] B. Ssa, A. Hl, and C. Plb, "CEGAN: classification enhancement generative adversarial networks for unraveling data imbalance problems," *Neural Networks*, vol. 133, pp. 69–86, 2021.
- [15] D. Sun, J. Xu, H. Wen, and Y. Wang, "An optimized random forest model and its generalization ability in landslide susceptibility mapping: application in two areas of three gorges reservoir, China," *Journal of Earth Sciences*, vol. 31, no. 6, pp. 1068–1086, 2020.
- [16] Z. Liu, W. Zhan, J. Lai et al., "Balancing prediction accuracy and generalization ability: a hybrid framework for modelling the annual dynamics of satellite-derived land surface temperatures," *ISPRS Journal of Photogrammetry and Remote Sensing*, vol. 151, no. MAY, pp. 189–206, 2019.
- [17] T. Du, H. Zhang, and L. Wang, "Analogue circuit fault diagnosis based on convolution neural network," *Electronics Letters*, vol. 55, no. 24, pp. 1277–1279, 2019.
- [18] S. Chen, H. Ge, H. Li, Y. Sun, and X. Qian, "Hierarchical deep convolution neural networks based on transfer learning for transformer rectifier unit fault diagnosis," *Measurement*, vol. 167, Article ID 108257, 2021.
- [19] X. Zhang, G. Chen, T. Hao, and Z. He, "Rolling bearing fault convolutional neural network diagnosis method based on casing signal," *Journal of Mechanical Science and Technology*, vol. 34, no. 2, pp. pp2307–2316, 2020.
- [20] S. Gao, Z. Pei, Y. Zhang, and T. Li, "Bearing fault diagnosis based on adaptive convolutional neural network with Nesterov momentum," *IEEE Sensors Journal*, vol. 21, no. 7, pp. 9268–9276, 2021.
- [21] A. Oa, A. Gi, and A. Ma, "Energy efficiency techniques in ultra-dense wireless heterogeneous networks: an overview and outlook," *Engineering Science and Technology, an International Journal*, vol. 23, no. 6, pp. 1308–1326, 2020.
- [22] R. Ahmad, E. A. Sundararajan, and A. Khalifeh, "A survey on femtocell handover management in dense heterogeneous 5G networks," *Telecommunication Systems*, vol. 75, no. 4, pp. 481–507, 2020.

## Review Article

# Influencing User's Behavior Concerning Android Privacy Policy: An Overview

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The wide-ranging implementation of Android applications used in various devices, from smartphones to intelligent television, has made it thought-provoking for developers. The permission granting mechanism is one of the defects imposed by the developers. Such assessing of defects does not allow the user to comprehend the implication of privacy for granting permission. Mobile applications are speedily easily reachable to typical users of mobile. Despite possible applications for improving the affordability, availability, and effectiveness of delivering various services, it handles sensitive data and information. Such data and information carry considerable security and privacy risks. Users are usually unaware of how the data can be managed and used. Reusable resources are available in the form of third-party libraries, which are broadly active in android apps. It provides a diversity of functions that deliver privacy and security concerns. Host applications and third-party libraries are run in the same process and share similar permissions. The current study has presented an overview of the existing approaches, methods, and tools used for influencing user behavior concerning android privacy policy. Various prominent libraries were searched, and their search results were analyzed briefly. The search results were presented in diverse perspectives for showing the details of the work done in the area. This will help researchers to offer new solutions in the area of the research.

## 1. Introduction

The wide-ranging implementation of Android applications used in various devices from smartphones to intelligent television, has made it thought-provoking for developers. The permission granting mechanism is one of the defects imposed by the developers. Users of mobile are not aware of their proper use. Security and privacy are the primary concerns of mobile applications. Research work has focused on different aspects of mobile applications and devised solutions. In the context of Android applications, a novel process for evaluating privateer's protection approaches is proposed [1]. The device, which has recently been tested to include worrying examples of usage, dramatically simplifies the path toward comprehending the security repercussions of inserting in apps. The appliance is made to grow capability. As a result, inclines in the approach can be easily

integrated to improve the consistency of quality and sufficiency. To examine the relative usefulness of the two permissions interfaces was presented in the study [2]. People were recruited through Amazon Mechanical Turk for online research. Users do not read permissions for three reasons: they are unconcerned about or unaware of permits; instead, they rely on other measures to choose whether or not to download an app. They have faith in the programmer and system based on variables such as the number of downloads and user ratings, and they have confidence in the developer and platform to screen out highly unsafe programs. The Android 6 UI, according to participants, is more visually attractive than Android5. A proactive user-oriented approach is recommended to enhance user awareness of the privacy risks connected with Android applications to grant access [3]. An effectual privacy assessment approach is described, which evaluates users' privacy connected with a

set of permissions-required apps. Permissions' harshness and relative relevance, as well as their linkage, are the model's parameters. A standard severity evaluation method is used to determine severity. A data mining algorithm was used to identify association rules between permits.

The Android operating system is inspected to create Near-Field Communication (NFC) empowered applications [4]. The security of NFC is briefly discussed just as an outline of the three modes write/read, distributed, and card copying which Android's API exposes to developers. Some current Android NFC applications, like demonstrative apparatuses, contactless label control instruments, shared NFC applications, and some unusual use-cases, are also described. On mobile app privacy, thorough mapping research of Software Engineering literature is undertaken. The study aims to systematically expose the privacy practices of apps and make recommendations for how to preserve the privacy of mobile app users [5]. The objectives are to look into current software engineering application research patterns, categorize available affirmations, and make recommendations for future research. The goals further classify the state-of-the-art and list the issues that the Software Engineering research community must address. The study looked at privacy policies and the data security of depression-related mobile applications [6]. The transparency of data processing practices of the mobile applications acquired from the Google Play Store and iTunes was assessed and graded using the term "depression." A total of 116 eligible mobile phone applications have been discovered. The apps had only a 49% privacy policy, according to the study. Strategies ran enormously by stage, with iTunes applications being bound to incorporate one than applications from the Google Play shop.

Designers should dedicate additional time and effort to software development procedures to satisfy the expanded interest for excellent applications. With an emphasis on recent advancements, the research explores the main issues and genuine concerns in Android mobile application testing [7]. The study provides principles, rules, models, methodologies, and technology for Android application testing and outlines future perspectives. A new approach (CUPA) is offered that permits clients to oversee application admittance to Android framework assets, and private information dependent on client characterized techniques [8]. This method furnishes clients with alternatives not accessible in the Android consent framework in the establishment and the actual time of mobile application, allowing them to decrease the extent of the privacy breach. Users can regulate app behavior using the proposed approach, and application network connections lists can be included and inter-app communication. The suggested method comprises three main components that may be used to check program behavior during installation and runtime. First, a method was offered for analyzing an Android app to determine whether it is malicious or not [9]. Second, by examining permission patterns, a unique technique is suggested to discover malware-based programs. The proposed method obtains permission clusters by using the k-means algorithm to isolate malicious apps. The approach is validated by a 90 percent

efficiency rate for malicious behavior. This study backs up the use of application authenticity for applications in Android phishing detection.

## **2. User Privacy Approach for Android Mobile Application**

DroidNet uses the framework to put new apps through a trial period before granting their requests for approval. Based on peer expert user decisions, it provides suggestions about whether to approve or decline access requests to assist users in implementing limited resource access restrictions on unknown apps to protect their identity and improve resource consumption efficiency. Users can install programs in quest mode using the framework, which prompts them with resource access requests and allows them to choose whether or not to approve them [10]. A study [11] has demonstrated that giving mobile phone users more choices over their information disclosure and increasing their awareness of adverts substantially impacted privacy behaviors and views. Researchers created a privacy warning dialog that simulates actual pre-installation privacy controls screens for Android apps to carry out and manage advertisements recognition. The implications for creating privacy notification dialogs in mobile apps as well as distinct commercial methods are examined. PanGuard, an automated approach for detecting Third-party libraries (TPL) from a large number of Android APPs, is provided in this work [12]. To characterize TPLs, a novel combination of features is presented that includes packages in applications that can have both organizational and semantic data. In APPs, TPLs are isolated from the principal code, and invariants that remain unaltered during modification are identified, and the contained TPLs and versions are determined using these invariants. Extensive testing shows that PanGuard delivers significant TPL quality aspects and sustainability at the same time.

A semi-automated model is proposed to support smartphone app programmers in checking the security practices against their application code for reliability. It includes an API policy terminology map that links strategy phrases to API techniques to produce private data and dataflow analysis to diagnose disparity. According to the study, the implementation of the system relies on a series of mappings from API functionality to terms of policy and a cyber-security taxonomy [13]. Styx is a ground-breaking Android perceived communicating privacy system that provides users with information about privacy risks starting with the second security strategic viewpoint [14]. Styx's trial results are reviewed in terms of its impact on consumer perception of privacy problems and smartphone credibility, and its performance in managing risk. The study's findings imply that Styx's privacy risk information enhances the readability of security information disclosure and assists users in analyzing the privacy aspects of various applications. An AndroMalyZer framework is presented, which evaluates the application's expected privacy behavior to discover anomalous privacy behavior [15]. The framework derives semantics of desired privacy behavior from the application's description and privacy policy to identify probable privacy-

related abnormalities. The trials demonstrated AndroMaLyZer's feasibility and accuracy in inferring an application's predicted privacy behaviors and describing any anomalous privacy behaviors. This presentation provided a quick overview of Android permissions and their current security methods. A study [16] includes a complete assessment of the Android operating system drawbacks, their influence on end-user privacy and security, and an empirical model to resolve these concerns. Whenever it concerns program installation on Android smartphones, the results reported in the study reveal that people are unfamiliar with the most basic and essential aspects of Smartphone licensing.

User research with 26 participants was done, and it was discovered that while participants were satisfied with better privacy options, they struggled to adjust to complicated customized interfaces. In a study [17], a practical solution is proposed to assist users in sorting, suggestions, and profile management, and all require balancing absolute authority and the extra interactive complexity. The study's key conclusion is that privacy controls must allow users to control their devices and be informed about confidentiality. Research presented a privacy leak-based Android application analysis scheme with a combination attack. The linked apps are extracted after the risk components of the application are discovered. This scheme's implementation process and principles are discussed. Because it is supported by experimental evidence, the analytical strategy is viable. The difficulty and precision of application pretreatment are increased to some extent [18]. A new approach for effectively detecting and testing authority entrust flaws was constructed by integrating static code analysis, language processing, deep learning, and biological algorithm-based test creation strategies given in the study [19]. The approach finds and identifies insecure applications that reveal delighted to support other apps in an unusual way from legitimate permission entrust circumstances. To demonstrate the vulnerabilities, it also creates solid evidence intrusions and protection reports. The multi-criteria app evaluator of trust for android (MAETROID) framework is presented in this paper [20] as a way to assess the trustworthiness of Android apps in terms of secrecy and reliability. At the time of deployment, MAETROID does a multi-criteria evaluation of an app and provides a single, simple risk level rating, guiding the customer's choices as to whether or not to install a new application. A bundle of metadata acquired out from the global market that indicates the app's reliability and desirability and a collection of desired privileges are among the criteria.

A strategy was presented that uses privacy as a service level agreement rather than the transparency consciousness model. For evaluating an Ambient Assisted Living Application's proper privacy settings and managing real-time approval queries, the study [21] presented a participatory privacy protection algorithm. A case study is used to show how these algorithms function. The proposed method is also compared to the state-of-the-art Android privacy management methodology. The proposed algorithms can help users of Ambient Assisted Living Apps in digital cities safeguard their privacy and relieve them through cognitive offloading.

A survey [22] was presented to address the security and privacy concerns around Android application permissions. Because a real-world Android application investigation validates the findings, the protocol has serious security consequences. However, the Android permission protocol has several flaws. The attacker can altogether bypass the permission checks in each of these scenarios. Although application permission-based malware is discussed, as the Android market grows rapidly, a new sort of malware family is forming. A complete study on quick vulnerability assessment was described [23] and thorough reverse engineering using a variety of smartphones and digital operating systems. The data leakage of the use of messaging platforms on mobile phones is examined. Android-based smartphones with the help of a particular susceptibility evaluation system set were used for this project. Evaluation and vulnerability simulations are also covered in depth to make instant messaging systems more safe and free of vulnerabilities.

### 3. Privacy-Preserving Categorization of Mobile Applications

A study has proposed to adopt a proactive role to users' awareness concerning misuse of personal information connected with granting rights to mobile applications [24]. A general privacy risk assessment model was proposed, which assesses the vulnerability to clients' security associated with a collection of permissions-based applications. This proactive technique was validated through an experimental analysis. The work originality stems from the fact that the security risk for a particular node held by a user changes over time based on the device's various usage, applications, and related permissions. Research has presented mobile App Reviews Summarization (MARS), which uses Google-Play-Shop user evaluations as an appropriate source for extracting and quantifying private-related allegations linked with applications [25]. MARS uses machine learning to recognize privacy-relevant reviews and classify them into a pre-defined list of confidentiality in the mobile context application. The integration of such approaches enables developers with precise details regarding privacy issues and application behavior to provide self-reports that would be impossible to identify otherwise. The students' mobile privacy behavior and attitudes are investigated and compared in the case study. In Germany and the United States, participants were observed, and an experiment was used as part of the qualitative ethnographic studies. The findings of the study show that participants' mobile privacy behavior and attitudes are nearly identical across cultures. In reality, this research identifies and distinguishes various types of mobile privacy. These classifications, which range from "mobile privacy objection" to "mobile privacy learned helplessness," demonstrate how they have a massive effect on German and American pupils' privacy behavior and attitudes [26].

This discovery has led to developing a new confidentiality classification technique for mobile applications, which is intended to explain patterns from a vast amount of usage patterns. To make app feature vectors, shuffle usage data from a large number of users to make it anonymous, then



formalize data information as a dataset, identify and aggregate usage information for every application using Dynamic Time Warping, and then utilize the Dynamic Time Warping and Shape Features based on Symbolic Aggregate approXimation methods. On 3,086 apps, five machine learning techniques were employed to train and validate categorization models. SVM is the best performer, as per the results [27]. The Native Protector system, which regulates third-party in Android apps, local libraries are used is proposed [28]. The server app and the client app are the two halves of the standalone Android app. The client application holds the rest of the original app and the server application containing the libraries for offering services from the modules. Native Protector has been implemented as a prototype and successfully detects and blocks efforts by Android apps that use third-party native libraries to undertake harmful actions. In malicious assaults, Android phones can be used as a target and a tool. Individuals and corporations must be aware of the risks and take steps to avoid being exploited for nefarious ends. Mobile app developers must also pay greater attention to security issues and take responsibility for user data protection. Even if the basic security techniques recommended in this chapter do not provide total protection, they can act as a deterrent against most attempts [29]. The study has proposed a new hybrid methodology for ascertaining private information leaks that outperform existing static and dynamic approaches [30]. The notion tool implemented is Hybri-Droid, which extracts each app's models using both dynamic and static analysis methods, then refines the behavior model depending on the dynamic analysis results. According to the evaluation results, for both inter-app and intra-app interactions, Hybri-Droid is excellent at identifying security leaks. It can significantly increase data leakage detection performance when compared to previous techniques.

The research was presented with a large-scale and comprehensive examination of users' private information leakage over a nine month period which included surveillance of popular Chinese App Store apps [31]. The study's main findings are that mobile apps that access users' private information are widespread. However, the architecture of access to personal data differs slightly between various categories of applications, and applications downloading from big App stores do not always imply that the apps are safer more private. Another study was proposed which uses natural language processing techniques to translate abstract terminology in that the architecture of access to personal data differs slightly between various categories of applications. The violation detection system described by Hosseini [32] is planned to apply the automatically produced mapping. With the rising availability of private data and the widespread use of phone apps, the ability to trace relationships between app code and privacy policy requirements is becoming increasingly critical. NLP and program code analysis techniques can be used to establish automated traceability. Research has developed a model that relies on real appeals and investigates the factors that influence APP users of various experience levels' willingness to take steps to protect one's privacy and security [33]. Researchers observed

disparities in the contributing differences in factors across groups of users who have and do not have expertise in APP privacy protection after conducting a questionnaire survey and doing a route analysis. This research has some implications for third party cyber security providers such as application network operators. The study proposes two hypotheses [34]: (a) a lack of understanding of the relationship between authorization requests and privacy; and (b) the installation of sensitive data-accessing programs. The examination of the acquired data, which took into account both treatments, revealed the emergence of distinctive attributes that were shared by a certain user group. This research could be seen as a first step toward more secure smartphone usage, as such features could be used to draw users' attention to privacy concerns.

Two studies were done to test the hypothesis with the aim of this research [35]. App Tracer is being used to create a dynamic analytic tool to track user interactions and sensitive resource access, as well as to conduct an online survey to see how different UI interactions alter users' assumptions about whether an app accesses sensitive resources. The findings show that user button clicks, for example, can be considered authorization, it should be possible to reduce the requirement for separate queries that are not directly related to user activities, individually, possibly when apps are first launched. The mechanism by which various apps obtain when installed on Android smartphones, access to crucial device privileges is investigated [36]. It highlighted the user's difficulties in comprehending what impact differing device restrictions have on their security. Each permission's impact is influenced by its context and use-case, and when granted numerous permissions, estimating the possible impact on client privacy becomes challenging. The research quantifies the most important human rights have an impact and takes the first steps toward a privacy impact assessment of multiple device permissions. The functionality of the program was examined in a dynamic examination, while a static analysis was carried out by looking at the code. Backdoor configuration, capture of session parameters, insecure encrypting application data transported without authentication, the usage of harmful APIs, and privileges over disclosure are all issues that need to be addressed, and unlimited connection to the databases and modules of the program were detected after executing the vulnerability analysis. The methodology presented introduces an innovative design for running a privacy test on Android-based smartphone apps [37]. The privacy framework for mobile apps is examined for flaws and a survey of proposed tools and frameworks is conducted, with an emphasis on the consequences of confidential data leaks and the cyber security threats it poses [38]. The study also offers some insight into how rogue mobile applications can exploit users' personal data for their own gain. Users are classified based on how they handle their personal information. Then we spoke about some of the problems with the permissions model framework and how Google fixed them.

The research was presented that allows Android apps to be assessed for compliance recently with the issued Google Play security standards in real-time. A novel methodology for analyzing such compliance is discussed, which relies on a

successful mix of dynamic analysis and deep learning approaches. This methodology also examines if each program has private information that follows the Google Play security regulations and only accesses sensitive information once the user agrees on the policies [39]. Providing Android apps using permission control that is both versatile and perfect pleasing has been a challenging issue. A careful inspection of the Android application package file to solve such problem and the retrieved “AndroidManifest.xml” file, which lists all necessary permissions, is recommended, as well as a quick introduction to Android’s authorization administrator, which demonstrates that approvals can be canceled once the apps have been installed. Yet, it does not prevent applications from exploiting resources and information [40]. The study has introduced a risk assessment approach for Android smartphone app authorization that uses dynamic analysis to determine whether or not a specific application is likely to be over-privileged [41]. The technique establishes the necessity of asking authorization indicated in the obvious of the application. The approach differs from existing approaches in that it may be used to compute the attack surface of mobile applications as well as the danger posed by over privileges. By illustrating the importance of app value in the privacy trade-off, the research verifies earlier findings and adds to our understanding of the privacy calculus’ border limits [42]. The work provided is entirely experimental, and that may have implications for the internal and external validity of the conclusions. Every effort was made to make the experiments possibly realistic, and the research has strictly adhered to modification of perception criteria. According to surveys, whether downloading apps or accessing mobile websites, many people who use the Internet on their phones never check the privacy options.

#### 4. Privacy Protection in Mobile Apps

Research works were presented to discover the discriminate and persistent elements obtained from Android APK files that are used to detect malicious apps on a large scale [43]. To accomplish this, the research extract takes a lot of features from each application and divides them into two categories. These feature sets are then used to train classifiers to detect malicious programs. Based on classifier performance, the durability of application particular and framework features are evaluated with two data sets, and the Linear Regression classifier’s key characteristics are thoroughly studied. In Android, the tracking of security-related data was limited to taint tags. Taint-Droid has a simple design that allows for a maximum of thirty-two different data sources. The research introduces Kynoid, an Android-based system for monitoring and enforcing laws in real-time [44]. Kynoid deviates from the traditional taint tracking method by introducing finer granularity. It’s the first significant effort to show that adaptive vulnerability management tracking is possible at this level of detail. An overview of Android and its cutting-edge security features was presented [45]. Then, based on the literature, a thorough and analytic taxonomy of Android malware hardening techniques is offered. Application developers often use hardening measures to protect against

reverse engineering. The difficulties associated with them are highlighted and manifest future paths based on this in-depth survey. Then, to offer a complete picture, the trends in application hardening are shown, and a research gap summary for future studies. The knowledge of mobile app users about data gathering procedures is currently insufficient [46]. The study looks into the elements that support privacy and security in mobile applications. It adds to the knowledge about the subject. The findings demonstrate that greater degrees of consciousness and security concerns improve the motivation of smartphone applications users to participate in reducing malicious activity. According to the results, app users are inadvertently and desperately in the limelight, but this will change if they are increasingly concerned regarding their confidentiality in their ability to secure it.

Research work presented some of the security concerns addressed by the Android security architecture and reverse engineering of an Android banking app and static analysis of its code to identify flaws [47]. The work attempts to examine specific security threats in mobile networks. As a result, assaults such as malware infection and DDOS attacks are used. Finally, several recommendations are made to aid programmers in making their mobile apps more secure. A study was presented, and an X-Decaf privacy leakage detection tool and an Automatic Transparent File Encryption/Decryption (ATFed) auto-protection technique on the Android platform in mobile social networking applications (MSNAs) is recommended [48]. MSNAs from China’s domestic market was examined, and it was discovered that during the development process, MSNAs failed to address the security of the user’s privacy data. To keep the cache files created by MSNAs safe, an ATFed technique is provided, which allows the files to be saved in the ciphertext, and during the MSNA’s operation, secured cache files are produced. During the course of the literature review, researchers assembled different research papers and conducted a comprehensive literature evaluation, resulting in a substantial body of work. The goal of the research was to present a coherent picture of current modern work that statically analyzes Android applications, which may draw conclusions about static analysis trends [49]. The review is divided into five sections: challenges addressed by methodology, basic approaches used by the authors, dynamic testing sensitivity properly considered, android features factored, and the assessment scale used. The authors [50] presented a dynamic analysis approach that collects “second-step behavior cues” to aid application analysis in distinguishing between harmful and benign actions. The features of malicious operations are summarized, and they can be used to categorize them. SSdroid, an analytical prototype, was intended to derive the SSBFs structure of the network. Second step behavior features (SSBFs) have proven successful and valuable in over 9000 activities from benign and hostile programs. Research work has proposed a software library that enables older mobile crowdsourcing applications to boost client security without sacrificing crowdsourced datasets’ fundamental value [51]. The research presents Fougere, a decentralized method for transmitting raw data from consumer devices to

third-party databases. To examine this contribution, Fougere was deployed in a simulated Android platform by simulating a crowd of fifteen portable devices running multiple variations of MobiPerf and Fougere.

Research explains how to utilize application instrumentation to impose fine-grained usage control privacy limitations, allowing users to regulate how sensitive resources are accessed by applications [52]. The study aimed to give users more control over their mobile devices' privacy, confidentiality, and security, especially when it comes to invasive software behaviors. Rather than providing precise API methods that could allow a program to get private data, this approach provides unambiguous regulations that consider the resource being accessed. The study has examined whether a user's personality is a good predictor of the privacy access they had grant to apps downloaded on their smartphones [53]. The IUIPC questionnaire results and the app permission parameters that were chosen are presented. Deep learning meprivateere utilized to fgrantedst personalized privacy controls for users based on their characteristics and as a result, a unique way for providing permissions to apps is introduced. Research evaluated the privacy and security factor of an Android App in context of how vulnerable it is to leaking end-user personal data and disclosing vulnerabilities [54]. Android static the researchers were collected, and the static code metrics were utilized to estimate the applications' confidentiality risks. The Andrisk tool, which assesses the measure of privacy and security threat of an Android application as determined by an evaluation of Androidvileges and simulation models. The creation of a computational intelligence anti-malware framework (ClantiMF) is proposed [55]. It is built on powerful computational intelligence technologies and runs on the Android operating system. The Android OS was chosen due to its popularity and a large number of vital applications accessible for it. The ClantiMF can determine whether an android application's java classes are benign or malicious. It analyzes network data in order to find Tor-based Botnets. Abstract attack models are proposed to the semantics of various Android attacks are accurately identified [56]. The inter-component communication graph (ICCG) is a new diagram architecture for representing programs' internal management flows and internal component interactions. To discover attacks buried in ICCG, a static searching strategy is proposed and an effective algorithm to search for assaults in ICCG. Experiments have shown that the strategy is viable and effective.

Three new vulnerabilities connected to Web View are revealed in the study exposing new attack surfaces for the most well-known vulnerability related to JavaScript APIs [57]. A static analysis method based on a set of unique inference rules is designed to detect these new forms of vulnerabilities by creating a system that can detect the vulnerability stated in the state-of-the-art. In the study, Babel View was unable to detect three new types of vulnerabilities and was less precise and efficient in detecting previously known flaws. A method was explored, and it was discovered that using description and permission. As a result, a high number of false positives was shown [58]. It

was suggested that the app's privacy policy and byte code be used to improve the description and authorization for malware identification. Automatically analyzing privacy policies and performing cross-verification among various types of software artifacts is a difficult task. TAP Verifier is a revolutionary data flow model for assessing privacy policies and developing a novel system to investigate individual software artifacts and do cross verification. Researchers attempted to address the issue by presenting a behavior-based approach to detecting fraudulent Android programs [59]. An application's events and behavioral actions were utilized to create a signature compared to a signature database to detect it. The approach has shown to be effective in detecting malicious activities. It also describes the type of malicious behavior that an app can engage in. The method was shown to be effective since it provides a lot of information on virus interactions that lead to security and privacy issues. Research work was presented, graphs were used to model standard permissions requested by category, and a five-step technique was proposed [60]. It suggests a privacy score relating to risk caution criteria and the similarity of an application to a specified group structure. The threat caution was put to the test in terms of malware identification, and it outperformed similar modern efforts. The suggested study has addressed several current difficulties based on the best parameters and recommends a privacy rating and a threat alert level. The relation between terminal reviews on safety and confidentiality software updates is given [61]. Researchers looked at the influence of user ratings on the security and privacy features of Android applications that are categorized autonomously. Researchers showed that prior security and privacy relevant reviews are a vital component combining exploratory data regression and correlation analysis to estimate confidentiality application changes. The approach may inspire future research that uses user reviews to assess the impact of regulatory changes or modifications to Android's design.

The efficiency of machine learning detectable classifiers fraudulent applications in Android OS is thoroughly examined [62]. The study also has discussed different techniques to estimate the relevancy of the essential features. An Android OS provides a comprehensive assessment in machine learning-based malware detection. The study is based on a more extensive set of data that is open and free to use upon request. Even if only app intrinsic attributes are analyzed, the study confirms that machine learning may be a robust framework for detecting fraudulent apps. AutoPPG is a revolutionary approach that is proposed to make the development of privacy policies for Android applications easier. Based on its description, AutoPPG can recognize the personal data acquired by an API, do static code analysis to characterize its behaviors linked to the user's private information, and then use NLP techniques to generate readable words to describe these behaviors. The AutoPPG trial findings produce accurate privacy policy descriptions and reveal more user-related processes [63]. The study has proposed an essential distinction between harmful and benign actions associated with user intents [64]. Researchers provided an abstraction-based method for extracting and

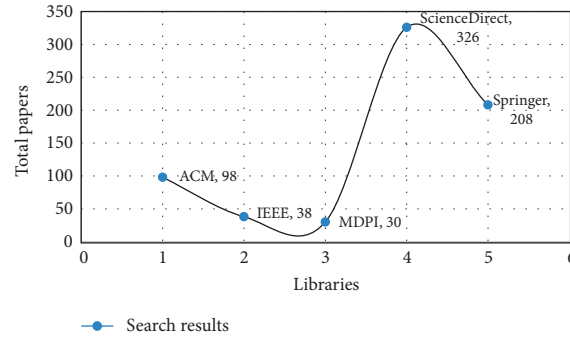


FIGURE 1: Overall search results in the given libraries.

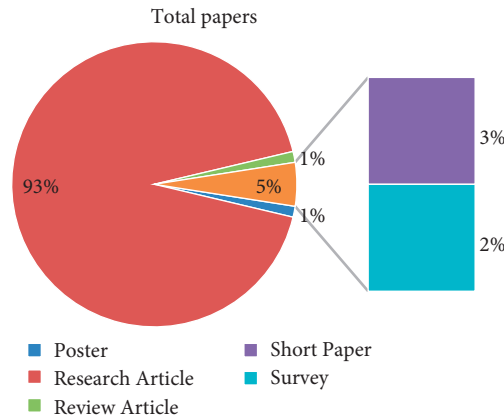


FIGURE 2: Total contents.

transforming user intention information into a set of essential features that can be utilized to tell the difference between good and bad behavior. IBdroid created and implemented an Android monitor system to carry out this strategy that can track the user interface, user actions, and surveillance behaviors with pinpoint accuracy. Precision and recall are accurately identified in this assessment. A unique method for detecting privacy policy violations caused by the leakage of user input data is provided [65]. Researchers updated the GATOR framework, and a layered object tracking violation detection system was constructed to handle the two technological constraints of infinite mapping and different GUI implementations. The suggested method was tested on three major domains, detecting both solid and weak violations in some of the domains' most popular apps. According to the trial, with the suitable similarity threshold established, this best technique variation may obtain 84 percent on general violation detection.

Research work established a new assessment approach based on analytical hierarchy theory and assessments and descriptions of recent design flaws or data security issues in Android apps [66]. The effort put forth in the project is estimated to make a substantial contribution to the security of Android application data. The study evaluation approach analyzed the data protection of Android apps on different stages and aspects but cannot account for all threats to Android application information security. A VULPIX tool

for the characteristics of dynamic analysis is combined to provide a comprehensive identification of privacy vulnerabilities in Android apps [67]. A detailed set of PI data items is also defined, which can be used to compare different PI detection methods. On a collection of Android apps, the consistency of detecting leaked confidential info is assessed using a comprehensive list of data pieces deemed private data. Another study was presented with MPDroid, a method for identifying a combination of simulation process and information retrieval that determines the minimal authorization for a mobile application based on its application description and API utilization [68]. Descriptive minimal permission set iteration method, and for each phone app, static analysis is utilized to determine the actual access. The methodology can also be used to assess the hazards associated with existing Android apps by analyzing their permissions.

## 5. Analyzing the Existing State-of-the-Art Research Work Based on Popular Libraries

Research works were presented with a new technique for actively defending against fiddling with the code, and reinstalling assault is provided [69]. Whenever downloading an application, the certificate authenticity is checked first, followed by the APP's integrity. If the certificate of authentication is accessed by the application but

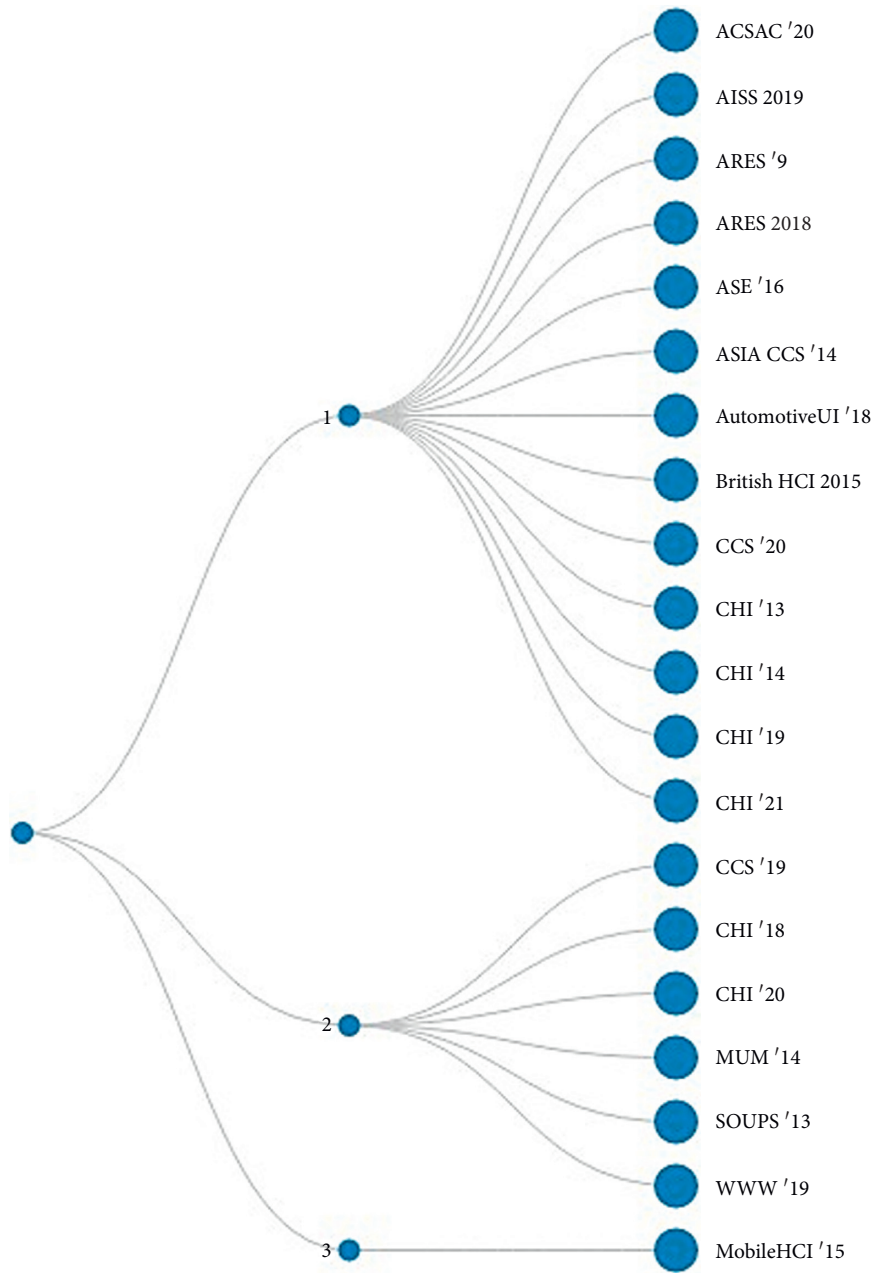


FIGURE 3: Events of conference.

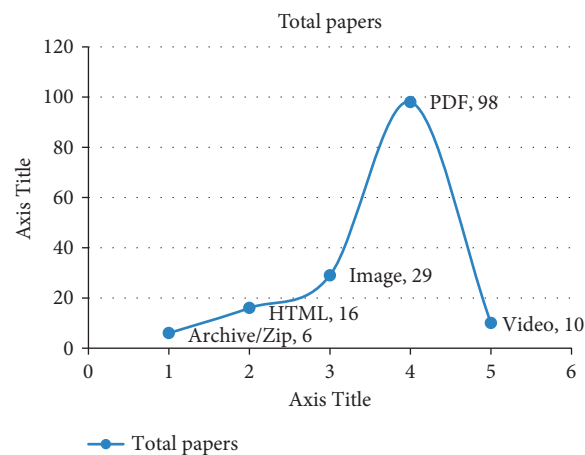


FIGURE 4: Format of media.

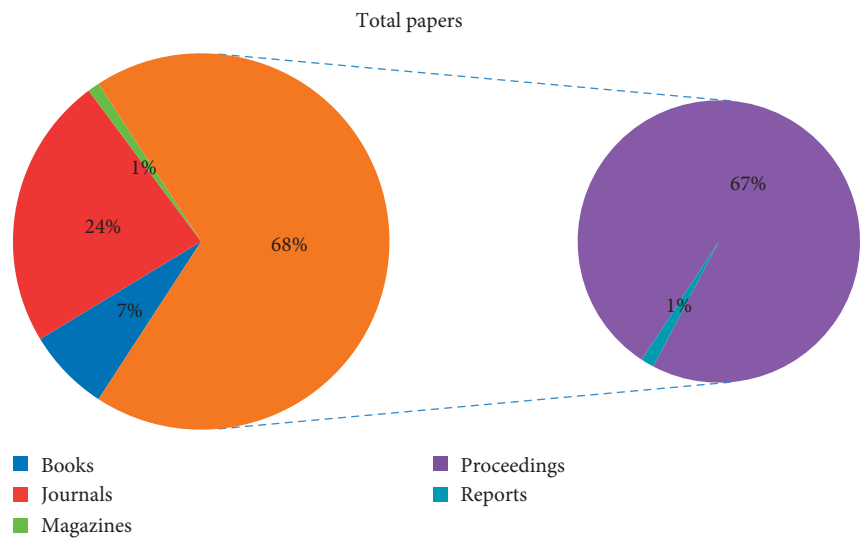


FIGURE 5: All publications.

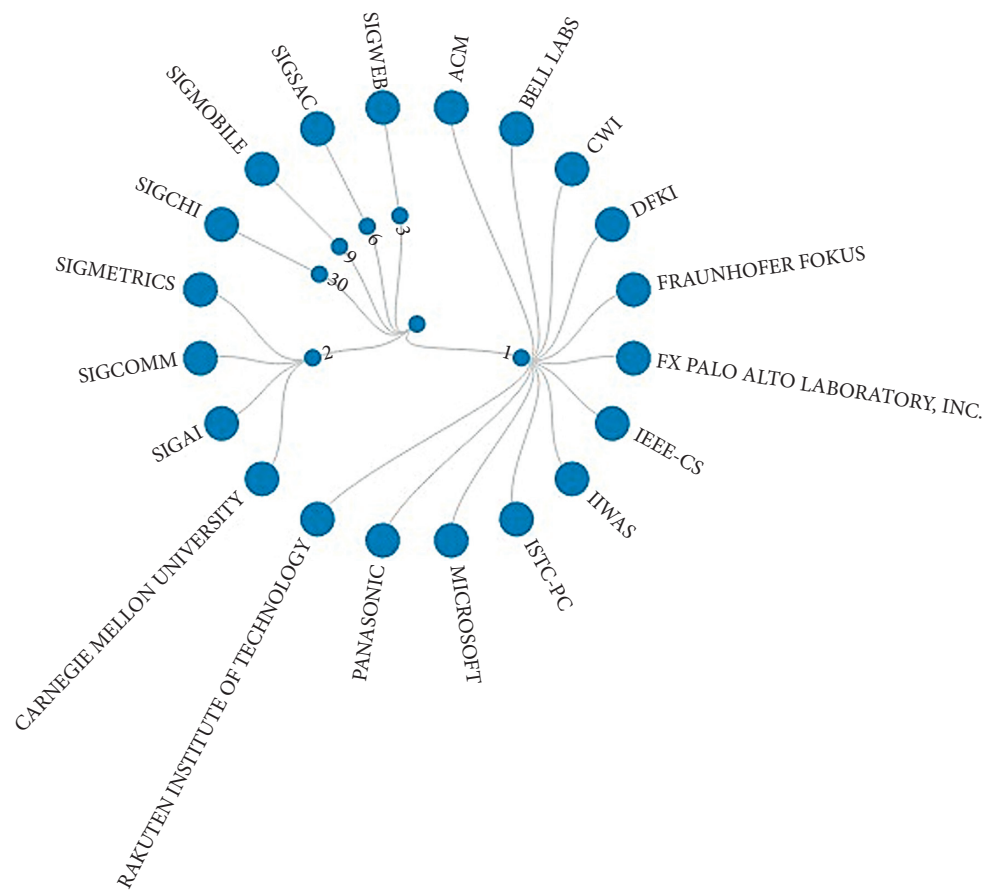


FIGURE 6: Sponsors of conferences.



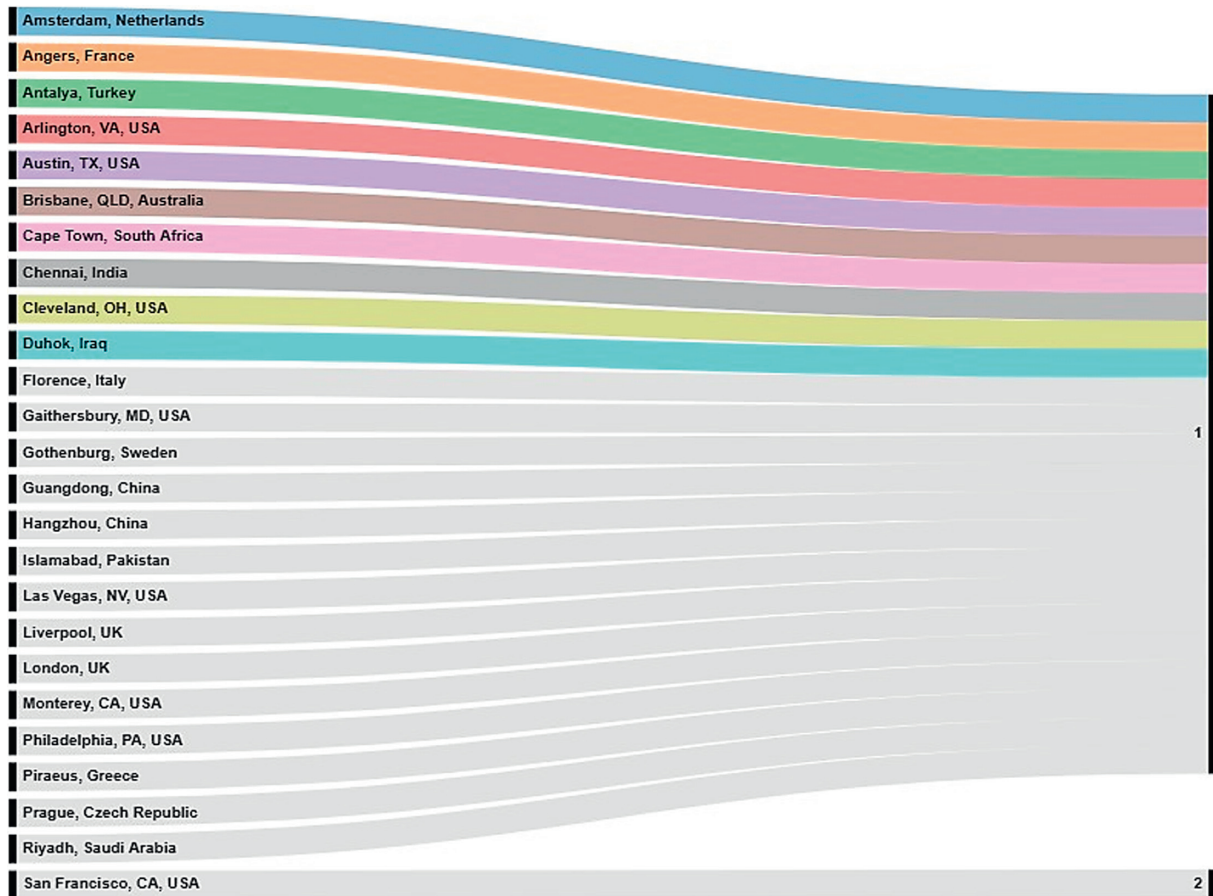


FIGURE 7: Locations of conferences held.

still has a flaw, the rogue developer can be easily identified. If the attacker updates the Application source and verifies it with unauthentic certificates, the certificate authentication will fail. The root source of code alteration and rebranding assaults is eliminated with this strategy. Another study is presented with documents the vocabulary used in Android app privacy policies to characterize the use of potentially harmful permissions [70]. The semi-automated approach uses NLP and IE approaches to link privacy policies' terminology to dangerous Android permissions. The study yielded over a hundred privacy policy terminology that corresponded to Android problematic permissions. The outcomes of this study serve as the foundation for future research in which the rationales for harmful permissions will be derived automatically from Android app privacy rules. Finally, researchers presented privacy guardian, a preventative policy enforcement system that can prevent malicious attacks in a short period [71]. Rather than being user-defined, the policy rules are based on the behavior model of privacy assaults. The user can choose whether to accept or refuse the procedure. The execution of privacy guardian is described as a finite state machine, and Linear Temporal Logic is used to show its security features. In this article, the effectiveness of privacy guardian was analyzed through the ROC gap, the average accuracy, and the positivity rate.

The first solution for automatically analyzing HTTP(s) predicted on APP protocol behavior for Android apps is presented [72]. Extractocol takes the application binal as input and employs dynamic program analysis and semantic analysis to reconstruct application-specific HTTP-based interactions, resulting in a complete characterization of application protocol behaviors. In-depth testing on both closed source and open source apps demonstrates the accuracy in identifying protocol messages and detailed characterization of app behavior that can be reverse-engineered. A study was presented to characterize and detect a method known as self-hiding behavior [73]. Research and a series of fundamental analyses focusing on SH in Android apps fill the need. According to the findings, the existence of self-concealment in an app is substantially linked to malice. Nonetheless, it has discovered a slew of benign, widely used apps that use masking strategies, implying end consumers and retailers would be benefited from utilizing a method like ours to expose potentially malicious improved user experience by modifying behavior in Android applications. The research aims to develop an excellent way to protect Android app users' private information [74]. A poll of smartphone users was done as part of the study to determine their comprehension of privacy protection. Simultaneously, certain existing approaches are compared to determine their flaws. When the project is completed, the new confidentiality functions provided by MIUI twelve were a

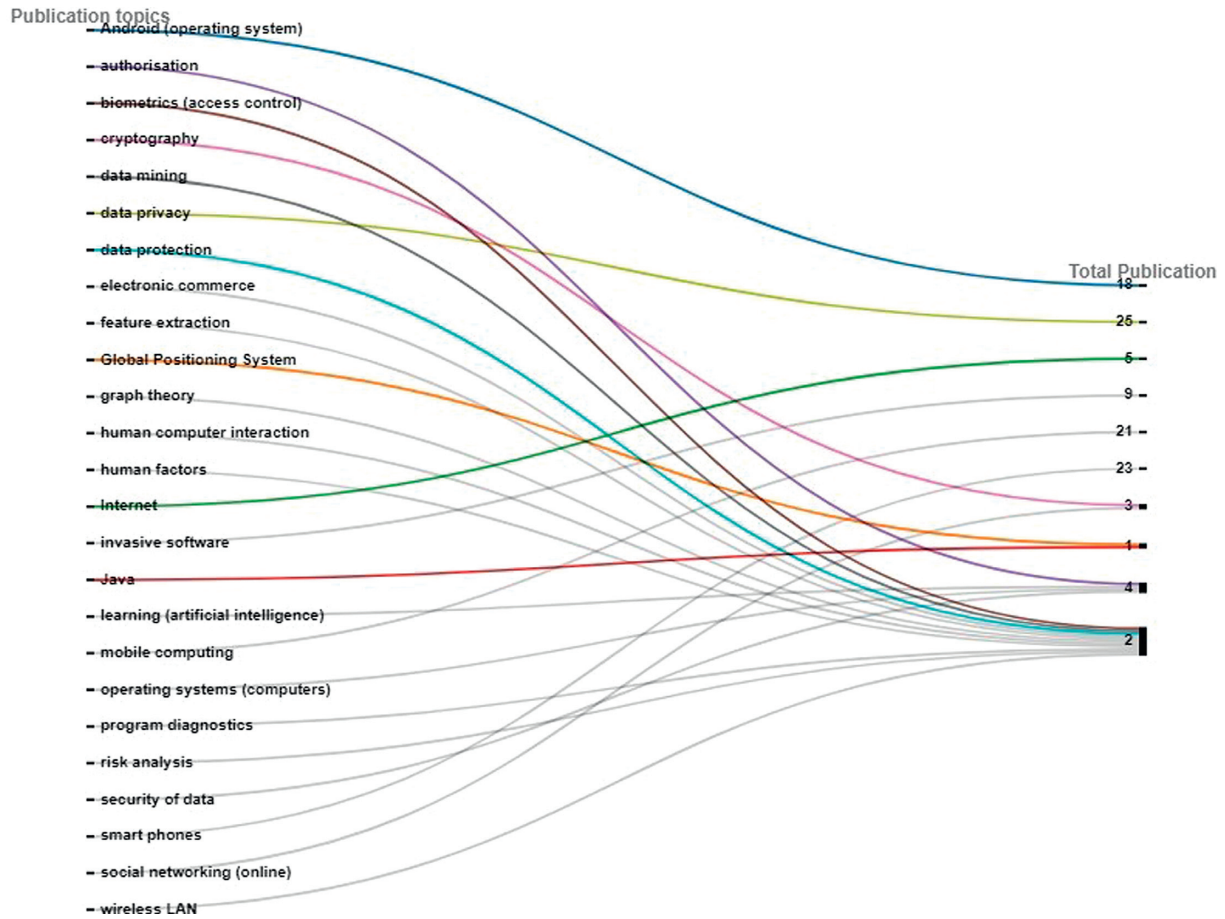


FIGURE 8: Topics of publications.

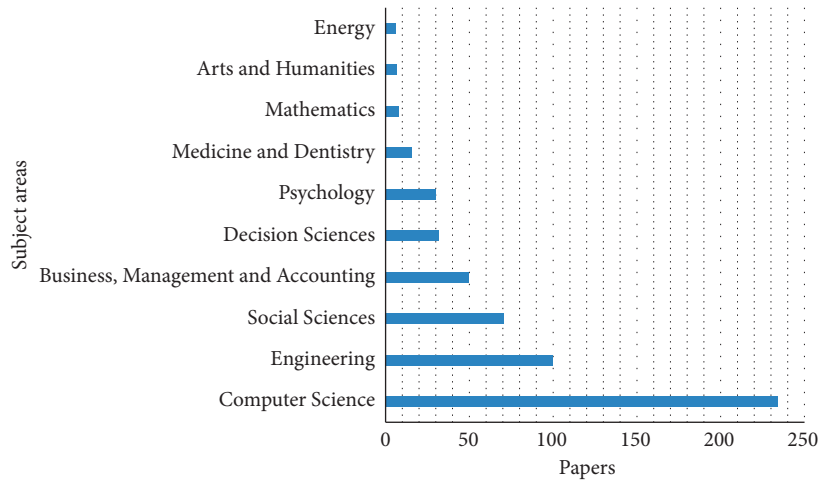


FIGURE 9: Subject areas.

good answer for preventing user secret and limiting app privileges. The terms of service and mobile application privacy rules raise many privacy concerns, which are discussed [75]. To assist designers in the development of applications, guidelines for establishing trust and privacy are offered. The applications' terms of use and privacy policies were examined in light of the guidelines. The Waze application was given

special attention because it exemplifies all of the concerns and also demonstrates viable solutions generated through a participatory design session and implementation of the principles developed.

The aim of the proposed study is to present an analysis of the existing literature to show associated materials published in the area. This will help researchers to offer the contents

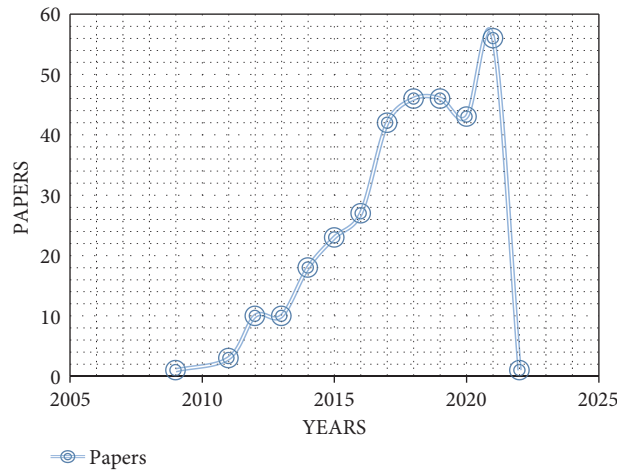


FIGURE 10: Years of publications.

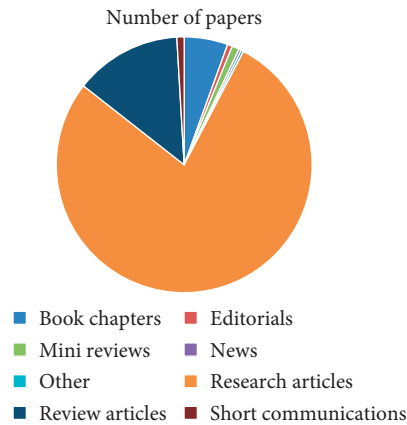


FIGURE 11: Articles types.

published in the area and then will devise new approaches to overcome challenges. The current study has considered the famous libraries with the search keywords “Influencing,” “User’s Behavior,” “Android,” and “Privacy.” Details of the libraries are given in the below subsections. Figure 1 describes the overall search results of all the libraries.

**5.1. Search Process in the ACM Library.** The ACM library was searched for the diverse format of the search process. The analysis derived from the search process is shown in different figures. The total contents in the ACM library are given in Figure 2.

The events of the conference are described in Figure 3.

The media format is shown in Figure 4.

All publications in the given library are shown in Figure 5.

The sponsors of conferences are given in Figure 6. The figure shows that more publications were done in the SIGCHI.

**5.2. Search Process in the IEEE Library.** The details of the IEEE library were presented in a different format, such as conference locations are shown in Figure 7.

The topics of publications are given in Figure 8.

**5.3. Search Process in the ScienceDirect Library.** Details of the ScienceDirect library are given with the details of subject areas are given in Figure 9.

The years of publications are shown in Figure 10. The figure shows that there is an increase in the number of publications year-wise.

Details of the article types are given in Figure 11. The figure describes that more publications were published as research articles.

The publications titles with papers are given in Figure 12.

**5.4. Search Process in the MDPI Library.** Details of the MDPI library are given with the details of subjects areas in Figure 13.

Details of the journals are depicted in Figure 14.

The county details are given in Figure 15.

Figure 16 shows the articles types. This figure shows that more papers were published as journal articles.

**5.5. Search Process in the Springer Library.** The Springer library details are given below. Figure 17 describes the details of article types in the given library.

Details of the disciplines are shown in Figure 18.

Figure 19 shows the sub-disciplines in the given library.

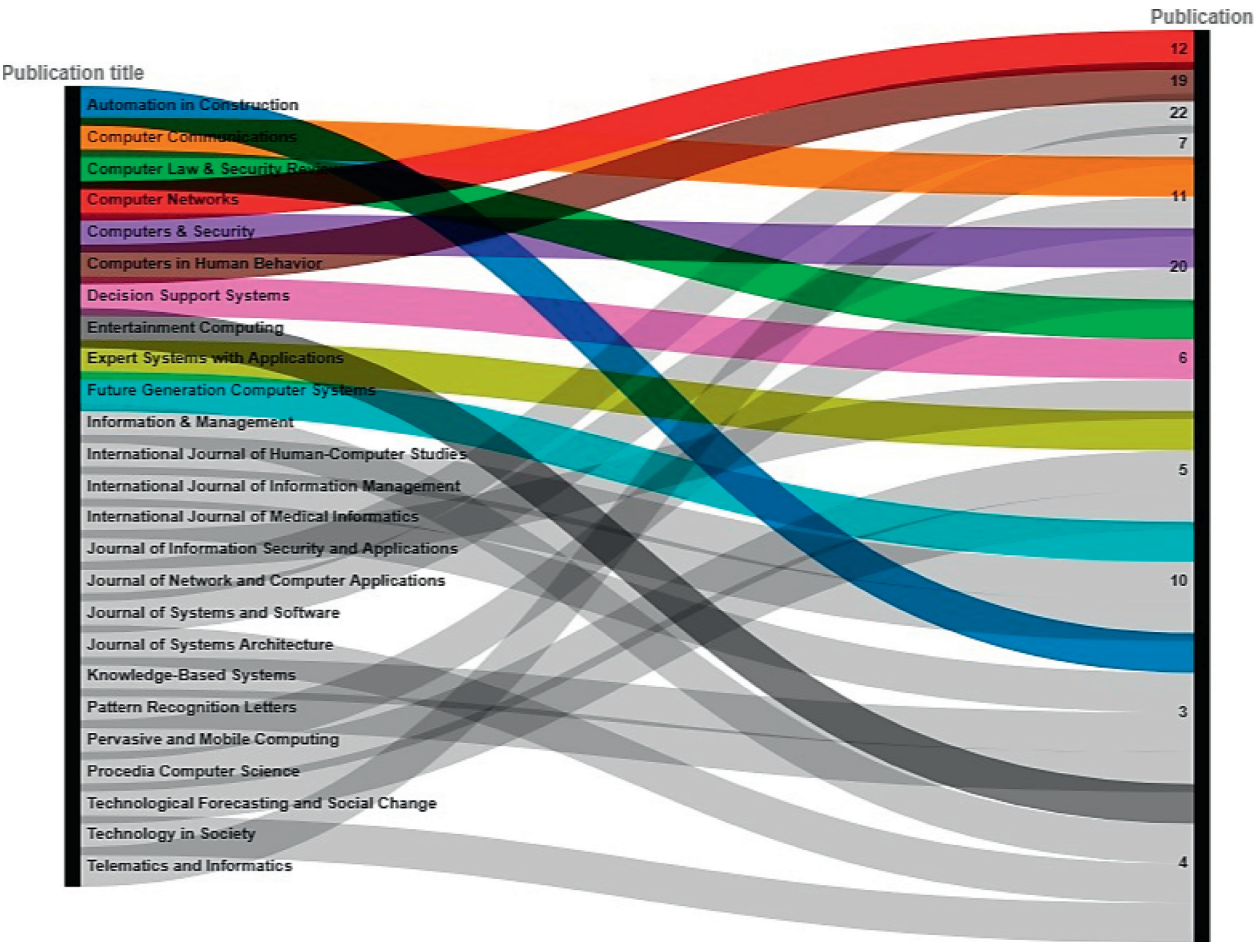


FIGURE 12: Publications titles.

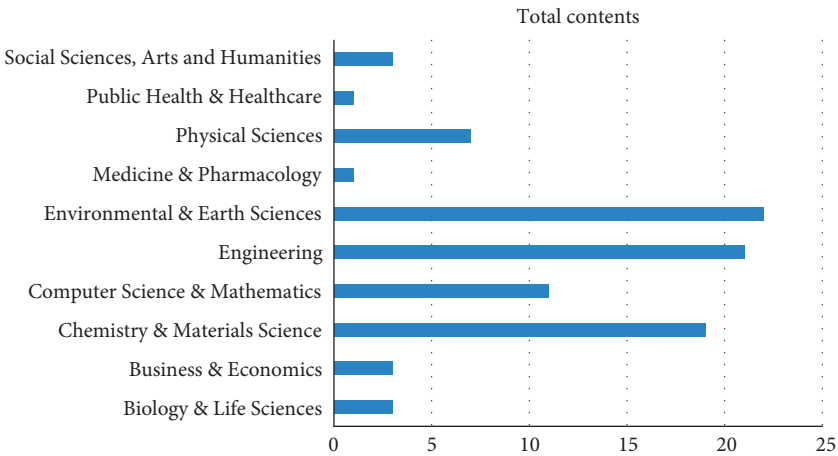


FIGURE 13: Subject areas.

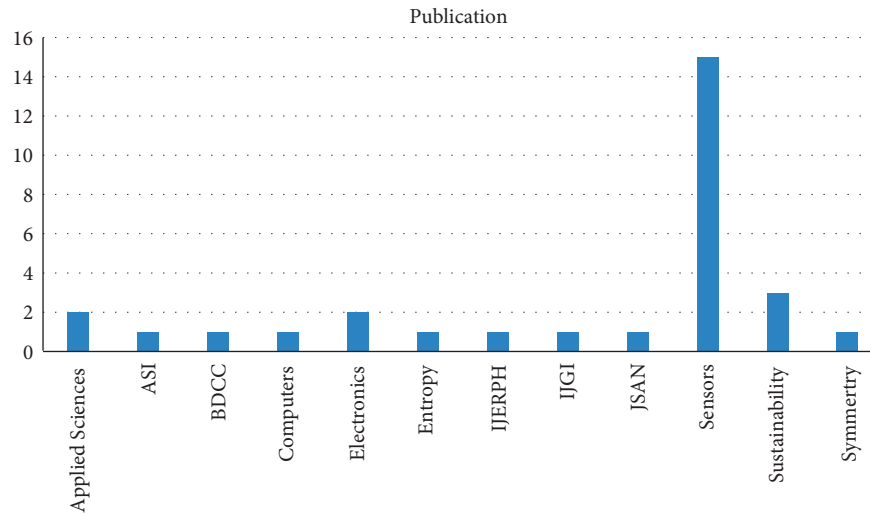


FIGURE 14: Journals with publications.

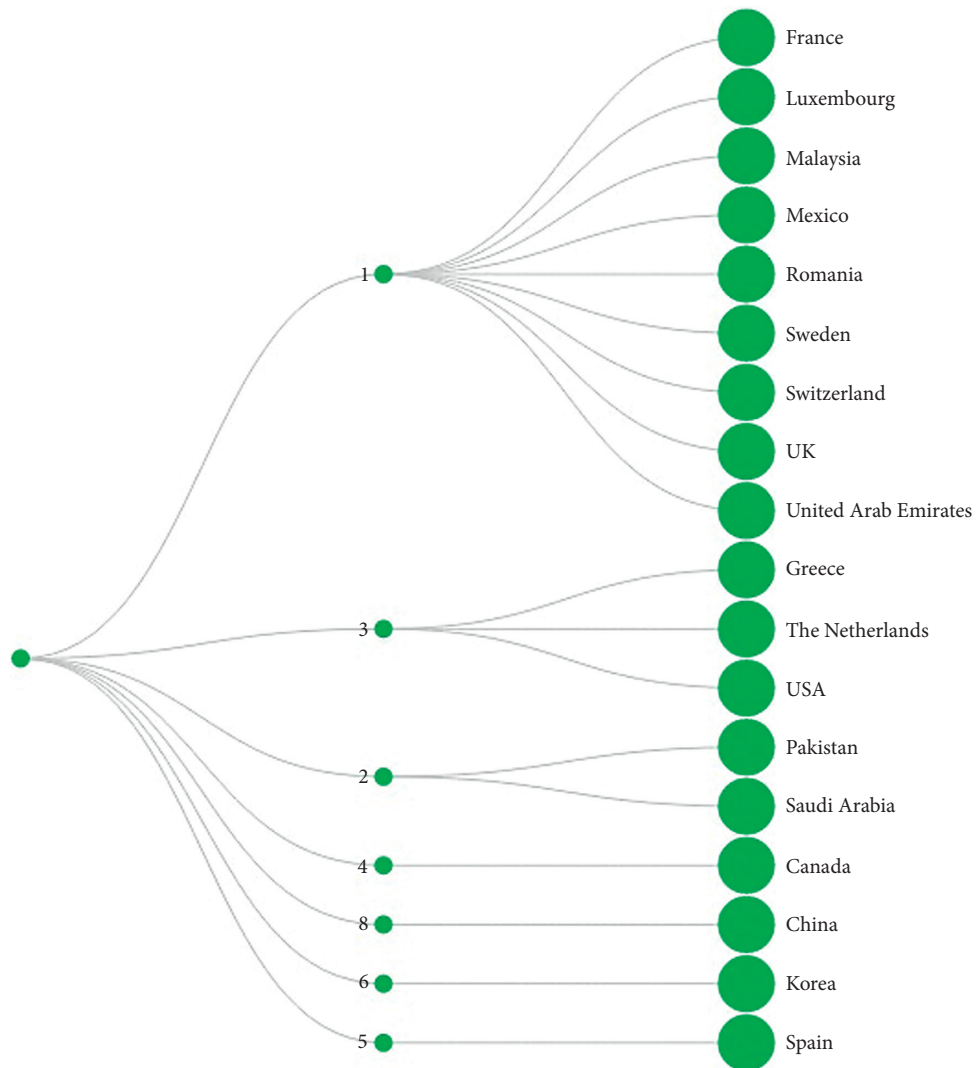


FIGURE 15: Countries details.

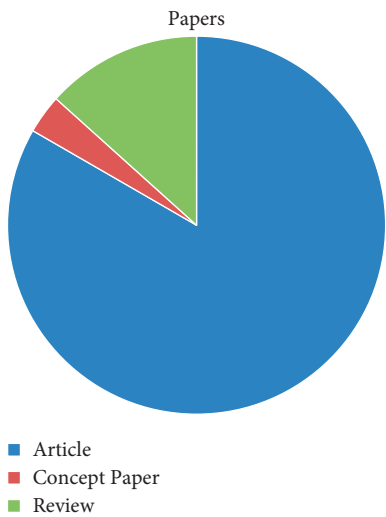


FIGURE 16: Article types.

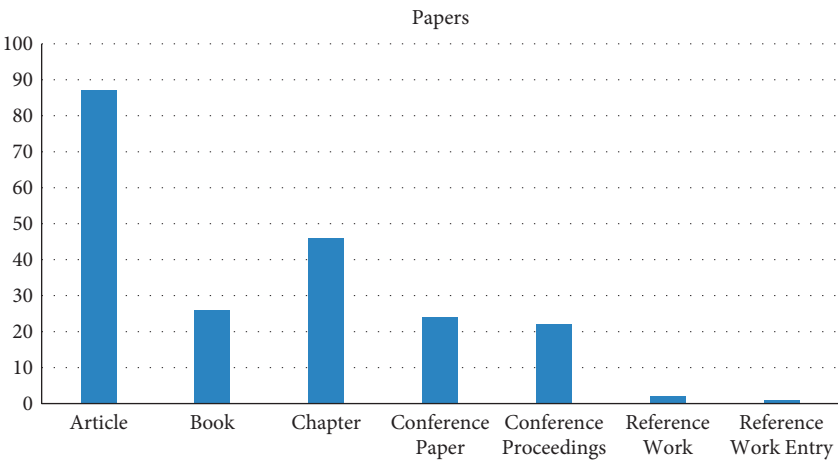


FIGURE 17: Article types description.

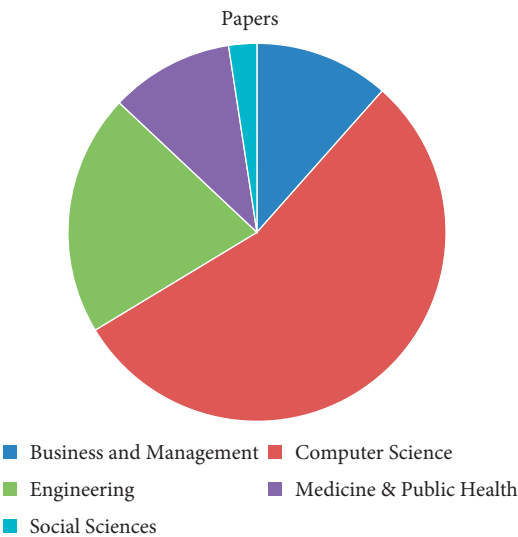


FIGURE 18: Details of the disciplines.



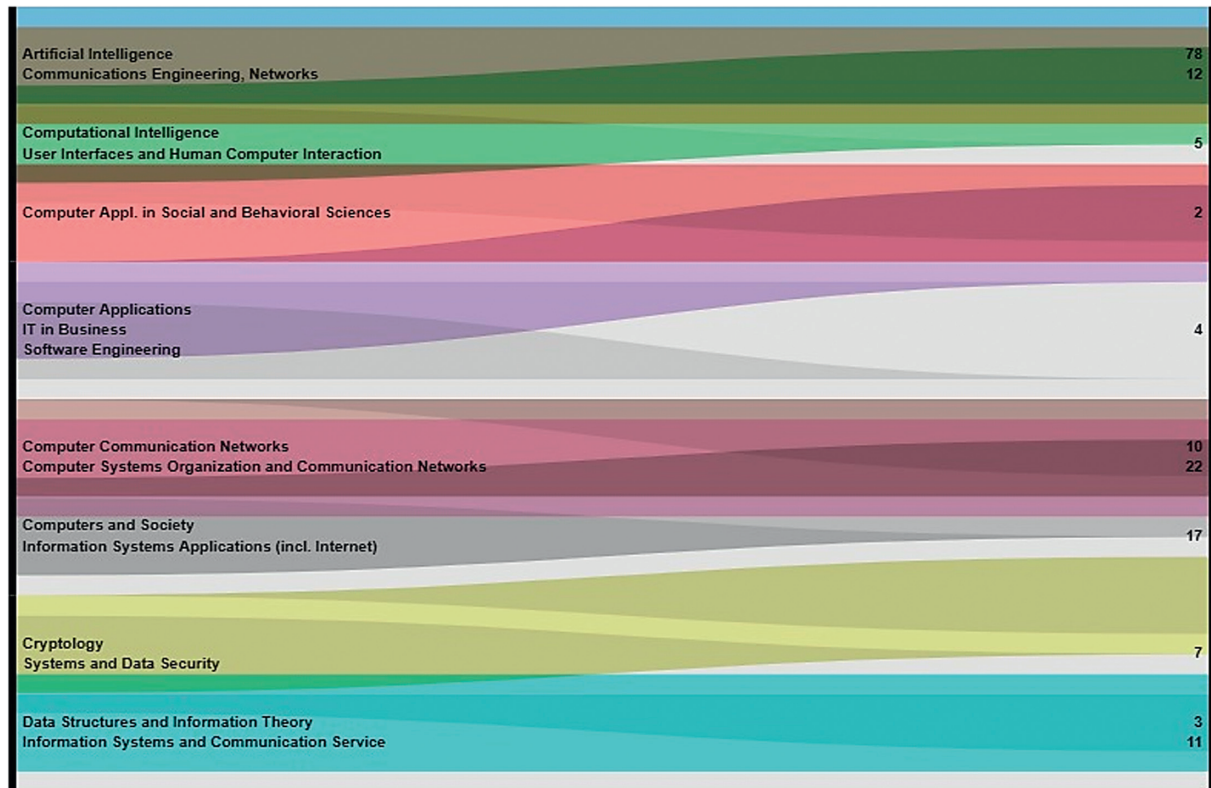


FIGURE 19: Sub-disciplines.

## 6. Conclusion

The widespread use and extensive applications of Android in various fields have given birth to new challenges and issues. Mobile applications are easily reachable to normal users of mobile. The mechanism of permission granting is one of the flaws imposed by the developers. Imposing such defects does not permit the user to simply understand the consequences of privacy for conceding permission. Despite conceivable applications for improving the affordability, availability, and effectiveness of delivering various services, it handles sensitive data and information. Risks of security and privacy leakages exist in such data and information. Users are usually unaware of how the data can be managed and used. The existing mobile applications have deficiencies of threats due to design ambiguities. A coherent and comprehensible framework is the dire need of modern industry to facilitate security and privacy solutions to overcome security breaches. This study has offered an overview of the current methodologies, approaches, and tools used for manipulating user behavior regarding the android privacy policy, keeping in view the security and privacy concerns. Numerous prominent libraries were searched, and their search results were analyzed briefly. The search results of these libraries were collected, analyzed, and then presented. This will help researchers in the field formulate novel solutions and overcome diverse challenges.

## Data Availability

No data are available.

## Conflicts of Interest

The authors declare no conflicts of interest.

## References

- [1] C. C. Sai, C. S. Prakash, J. Jose, S. C. Mana, and B. K. Samhitha, "Analysing android app privacy using classification algorithm," in *Proceedings of the 2020 4th International Conference on Trends in Electronics and Informatics (ICOEI)*, pp. 551–555, Tirunelveli, India, 2020.
- [2] S. R. Moore, H. Ge, N. Li, and R. W. Proctor, "Cybersecurity for android applications: permissions in android 5 and 6," *International Journal of Human-Computer Interaction*, vol. 35, no. 7, pp. 630–640, 2019.
- [3] A. Hamed and H. K. Ben Ayed, "Privacy risk assessment and users' awareness for mobile apps permissions," in *Proceedings of the 2016 IEEE/ACS 13th International Conference of Computer Systems and Applications (AICCSA)*, pp. 1–8, Agadir, Morocco, 2016.
- [4] J. Karmazin and P. Očenášek, "The state of near-field communication (NFC) on the android platform," in *Human Aspects of Information Security, Privacy, and Trust*, T. T. Cham, Ed., pp. 247–254, Springer International Publishing, Berlin, Germany, 2016.

- [5] F. Ebrahimi, M. Tushev, and A. Mahmoud, "Mobile app privacy in software engineering research: a systematic mapping study," *Information and Software Technology*, vol. 133, Article ID 106466, 2021.
- [6] K. O'Loughlin, M. Neary, E. C. Adkins, and S. M. Schueller, "Reviewing the data security and privacy policies of mobile apps for depression," *Internet Interventions*, vol. 15, pp. 110–115, 2019.
- [7] D. Amalfitano, A. R. Fasolino, P. Tramontana, and B. Robbins, "Testing android mobile applications: challenges, strategies, and approaches," in *Advances in Computers*, A. Memon, Ed., vol. 89, pp. 1–52, Elsevier, Amsterdam, Netherlands, 2013.
- [8] Z. Alkindi, M. Sarrah, and N. Alzidi, "CUPA: a configurable user privacy approach for android mobile application," in *Proceedings of the 2020 7th IEEE International Conference on Cyber Security and Cloud Computing (CSCloud)/2020 6th IEEE International Conference on Edge Computing and Scalable Cloud (EdgeCom)*, pp. 216–221, New York, NY, USA, 2020.
- [9] G. Shrivastava and P. Kumar, "Android application behavioural analysis for data leakage," *Expert Systems*, vol. 38, no. 1, Article ID e12468, 2021.
- [10] B. Rashidi, C. Fung, A. Nguyen, and T. Vu, "Android permission recommendation using transitive bayesian inference model," in *Computer Security—ESORICS 2016*, pp. 477–497, Springer International Publishing, Cham, Switzerland, 2016.
- [11] N. Wang, B. Zhang, B. Liu, and H. Jin, "Investigating effects of control and ads awareness on android users' privacy behaviors and perceptions," in *Proceedings of the 17th International Conference on Human-Computer Interaction with Mobile Devices and Services*, Copenhagen, Denmark, 2015.
- [12] Z. Tang, M. Xue, G. Meng et al., "Securing android applications via edge assistant third-party library detection," *Computers & Security*, vol. 80, pp. 257–272, 2019.
- [13] R. Slavin, X. Wang, M. B. Hosseini et al., "Toward a framework for detecting privacy policy violations in android application code," in *Proceedings of the 2016 IEEE/ACM 38th International Conference on Software Engineering (ICSE)*, pp. 25–36, Austin, TX, USA, 2016.
- [14] G. Bal, K. Rannenbergh, and J. I. Hong, "Styx: privacy risk communication for the android smartphone platform based on apps' data-access behavior patterns," *Computers & Security*, vol. 53, pp. 187–202, 2015.
- [15] M. M. Al Sobeihy, "Towards an application-based notion of anomalous privacy behavior in android applications," in *Proceedings of the 1st International Conference on Computer Applications & Information Security (ICCAIS)*, pp. 1–6, Riyadh, Saudi Arabia, 2018.
- [16] A. Ngoben and S. Mhlango, "Towards enhancing security in android operating systems - android permissions & user unawareness," in *Proceedings of the 2019 2nd International Conference on Computer Applications & Information Security (ICCAIS)*, pp. 1–6, Riyadh, Saudi Arabia, 2019.
- [17] Y. Zhou, L. Qi, A. Raake, T. Xu, M. Piekarska, and X. Zhang, "User attitudes and behaviors toward personalized control of privacy settings on smartphones," *Concurrency and Computation: Practice and Experience*, vol. 31, no. 22, Article ID e4884, 2019.
- [18] J. Gu, C. Li, D. Lei, and Q. Li, "Combination attack of android applications analysis scheme based on privacy leak," in *Proceedings of the 2016 4th International Conference on Cloud Computing and Intelligence Systems (CCIS)*, pp. 62–66, Beijing, China, 2016.
- [19] B. F. Demissie, M. Ceccato, and L. K. Shar, "Security analysis of permission re-delegation vulnerabilities in android apps," *Empirical Software Engineering*, vol. 25, no. 6, pp. 5084–5136, 2020.
- [20] G. Dini, F. Martinelli, I. Matteucci, M. Petrocchi, A. Saracino, and D. Sgandurra, "Risk analysis of android applications: a user-centric solution," *Future Generation Computer Systems*, vol. 80, pp. 505–518, 2018.
- [21] H. Elahi, A. Castiglione, G. Wang, and O. Geman, "A human-centered artificial intelligence approach for privacy protection of elderly app users in smart cities," *Neurocomputing*, vol. 444, pp. 189–202, 2021.
- [22] G. Shrivastava, P. Kumar, D. Gupta, and J. J. P. C. Rodrigues, "Privacy issues of android application permissions: a literature review," *Transactions on Emerging Telecommunications Technologies*, vol. 31, no. 12, Article ID e3773, 2020.
- [23] R. S. Gaharwar and R. Gupta, "Vulnerability assessment of android instant messaging application and network intrusion detection prevention systems," *Journal of Statistics and Management Systems*, vol. 23, no. 2, pp. 399–406, 2020.
- [24] A. Hamed, H. Kaffel-Ben Ayed, and D. Machfar, "Assessment for android apps permissions a proactive approach toward privacy risk," in *Proceedings of the 2017 13th International Wireless Communications and Mobile Computing Conference (IWCMC)*, pp. 1465–1470, Valencia, Spain, 2017.
- [25] M. Hatamian, J. Serna, and K. Rannenbergh, "Revealing the unrevealed: mining smartphone users privacy perception on app markets," *Computers & Security*, vol. 83, pp. 332–353, 2019.
- [26] S. Havelka, "Typologies of mobile privacy behavior and attitude: a case study comparing German and American library and information science students," *The Serials Librarian*, 2021.
- [27] Y. He, C. Wang, G. Xu, W. Lian, H. Xian, and W. Wang, "Privacy-preserving categorization of mobile applications based on large-scale usage data," *Information Sciences*, vol. 514, pp. 557–570, 2020.
- [28] Y.-Y. Hong, Y.-P. Wang, and J. Yin, "NativeProtector: protecting android applications by isolating and intercepting third-party native libraries," in *ICT Systems Security and Privacy Protection*, J.-H. Hoepman and S. Katzenbeisser, Eds., Springer International Publishing, Cham, Switzerland, pp. 337–351, 2016.
- [29] A. Hoog, "Android device, data, and app security," *Android Forensics*, Elsevier, Amsterdam, Netherlands, pp. 159–194, 2011.
- [30] H. Chen, H.-f. Leung, B. Han, and J. Su, "Automatic privacy leakage detection for massive android apps via a novel hybrid approach," in *Proceedings of the 2017 IEEE International Conference on Communications (ICC)*, pp. 1–7, Paris, France, 2017.
- [31] Y. Ge, B. Deng, Y. Sun et al., "A comprehensive investigation of user privacy leakage to android applications," in *Proceedings of the 2016 25th International Conference on Computer Communication and Networks (ICCCN)*, pp. 1–6, Waikoloa, HI, USA, 2016.
- [32] M. B. Hosseini, "Semantic inference from natural language privacy policies and android code," in *Proceedings of the 2018 26th ACM Joint Meeting on European Software Engineering Conference and Symposium on the Foundations of Software Engineering*, Lake Buena Vista, FL, USA, 2018.
- [33] X. Zhu, P. Zhu, and Y. Qiu, "Research on the influence of fear appeals on app users' privacy protection behavior," in

- Proceedings of the 2018 International Conference on Information Management & Management Science*, Chengdu, China, 2018.
- [34] M. Furini, S. Mirri, M. Montangero, and C. Prandi, "Privacy perception and user behavior in the mobile ecosystem," in *Proceedings of the 5th EAI International Conference on Smart Objects and Technologies for Social Good*, Valencia, Spain, 2019.
  - [35] K. Micinski, D. Votipka, R. Stevens, N. Kofinas, M. L. Mazurek, and J. S. Foster, "User interactions and permission use on android," in *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, Denver, CO, USA, 2017.
  - [36] A. Khatoon and P. Corcoran, "Android permission system and user privacy—a review of concept and approaches," in *Proceedings of the 2017 IEEE 7th International Conference on Consumer Electronics—Berlin (ICCE-Berlin)*, pp. 153–158, Berlin, Germany, 2017.
  - [37] A. Argudo, G. López, and F. Sánchez, "Privacy vulnerability analysis for android applications: a practical approach," in *Proceedings of the 2017 4th International Conference on eDemocracy & eGovernment (ICEDEG)*, pp. 256–260, Quito, Ecuador, 2017.
  - [38] S. Kumar and R. Shanker, "Your privacy is not so private: unveiling android apps privacy framework from the dark," in *Proceedings of the 2017 International Conference on Next Generation Computing and Information Systems (ICNGCIS)*, pp. 48–53, Jammu, India, 2017.
  - [39] L. Verderame, D. Caputo, A. Romdhana, and A. Merlo, "On the (un)reliability of privacy policies in android apps," in *Proceedings of the 2020 International Joint Conference on Neural Networks (IJCNN)*, pp. 1–9, Glasgow, UK, 2020.
  - [40] P. Singh, S. Singh, and P. Tiwari, "Discovering persuaded risk of permission in android applications for malicious application detection," in *Proceedings of the 2016 International Conference on Inventive Computation Technologies (ICICT)*, vol. 3, pp. 1–5, Coimbatore, India, 2016.
  - [41] D. Geneiatakis, I. N. Fovino, I. Kounelis, and P. Stirparo, "A permission verification approach for android mobile applications," *Computers & Security*, vol. 49, pp. 192–205, 2015.
  - [42] V. M. Wottrich, E. A. van Reijmersdal, and E. G. Smit, "The privacy trade-off for mobile app downloads: the roles of app value, intrusiveness, and privacy concerns," *Decision Support Systems*, vol. 106, pp. 44–52, 2018.
  - [43] X. Wang, W. Wang, Y. He, J. Liu, Z. Han, and X. Zhang, "Characterizing android apps' behavior for effective detection of malapps at large scale," *Future Generation Computer Systems*, vol. 75, pp. 30–45, 2017.
  - [44] D. Schreckling, J. Köstler, and M. Schaff, "Kynoid: real-time enforcement of fine-grained, user-defined, and data-centric security policies for android," *Information Security Technical Report*, vol. 17, no. 3, pp. 71–80, 2013.
  - [45] V. Sihag, M. Vardhan, and P. Singh, "A survey of android application and malware hardening," *Computer Science Review*, vol. 39, Article ID 100365, 2021.
  - [46] V. M. Wottrich, E. A. Reijmersdal, and E. G. Smit, "App users unwittingly in the spotlight: a model of privacy protection in mobile apps," *Journal of Consumer Affairs*, vol. 53, no. 3, pp. 1056–1083, 2019.
  - [47] Y. Kouraogo, K. Zkik, E. J. El Idrissi Noredidine, and G. Orhanou, "Attacks on android banking applications," in *Proceedings of the 2016 International Conference on Engineering & MIS (ICEMIS)*, pp. 1–6, Agadir, Morocco, 2016.
  - [48] H. Li, W. Liu, B. Wang, and W. Zhang, "Detection and auto-protection of cache file privacy leakage for mobile social networking applications in android," in *Human Aspects of Information Security, Privacy and Trust*, T. Tryfonas, Ed., Springer International Publishing, Cham, Switzerland, pp. 703–721, 2017.
  - [49] L. Li, T. F. Bissyandé, M. Papadakis et al., "Static analysis of android apps: a systematic literature review," *Information and Software Technology*, vol. 88, pp. 67–95, 2017.
  - [50] P. Li, J. Fu, C. Xu, B. Cheng, and H. Zhang, "Differentiating malicious and benign android app operations using second-step behavior features," *Chinese Journal of Electronics*, vol. 28, no. 5, pp. 944–952, 2019.
  - [51] L. Meftah, R. Rouvoy, and I. Chrisment, "Empowering mobile crowdsourcing apps with user privacy control," *Journal of Parallel and Distributed Computing*, vol. 147, pp. 1–15, 2021.
  - [52] R. Neisse, G. Steri, D. Geneiatakis, and I. Nai Fovino, "A privacy enforcing framework for android applications," *Computers & Security*, vol. 62, pp. 257–277, 2016.
  - [53] F. Raber and A. Krueger, "Towards understanding the influence of personality on mobile app permission settings," in *Human-Computer Interaction—INTERACT 2017*, pp. 62–82, Springer International Publishing, Cham, Switzerland, 2017.
  - [54] A. Rahman, P. Pradhan, A. Partho, and L. Williams, "Predicting android application security and privacy risk with static code metrics," in *Proceedings of the 2017 IEEE/ACM 4th International Conference on Mobile Software Engineering and Systems (MOBILESoft)*, Buenos Aires, Argentina, 2017.
  - [55] K. Demertzis and L. Iliadis, "Computational intelligence anti-malware framework for android OS," *Vietnam Journal of Computer Science*, vol. 4, no. 4, pp. 245–259, 2017.
  - [56] G. Meng, R. Feng, G. Bai, K. Chen, and Y. Liu, "DroidEcho: an in-depth dissection of malicious behaviors in android applications," *Cybersecurity*, vol. 1, no. 1, p. 4, 2018.
  - [57] M. A. El-Zawawy, E. Losiouk, and M. Conti, "Vulnerabilities in android webview objects: still not the end!" *Computers & Security*, vol. 109, Article ID 102395, 2021.
  - [58] L. Yu, X. Luo, C. Qian, and S. Wang, "Revisiting the description-to-behavior fidelity in android applications," in *Proceedings of the 2016 IEEE 23rd International Conference on Software Analysis, Evolution, and Reengineering (SANER)*, vol. 1, Osaka, Japan, 2016.
  - [59] V. Sihag, A. Swami, M. Vardhan, and P. Singh, "Signature based malicious behavior detection in android," in *Computing Science, Communication and Security*, N. Chaubey, S. Parikh, and K. Amin, Eds., Springer, Singapore, pp. 251–262, 2020.
  - [60] K. Sokolova, C. Perez, and M. Lemerrier, "Android application classification and anomaly detection with graph-based permission patterns," *Decision Support Systems*, vol. 93, pp. 62–76, 2017.
  - [61] D. C. Nguyen, E. Derr, M. Backes, and S. Bugiel, "Short text, large effect: measuring the impact of user reviews on android app security & privacy," in *Proceedings of the 2019 IEEE Symposium on Security and Privacy (SP)*, San Francisco, CA, USA, 2019.
  - [62] V. Syrris and D. Geneiatakis, "On machine learning effectiveness for malware detection in android OS using static analysis data," *Journal of Information Security and Applications*, vol. 59, Article ID 102794, 2021.
  - [63] L. Yu, T. Zhang, X. Luo, L. Xue, and H. Chang, "Toward automatically generating privacy policy for android apps," *IEEE Transactions on Information Forensics and Security*, vol. 12, no. 4, pp. 865–880, 2017.

- [64] J. Fu, P. Li, Y. Lin, and S. Ding, "Android app malicious behavior detection based on user intention," in *Proceedings of the 2016 IEEE Trustcom/BigDataSE/ISPA*, Tianjin, China, 2016.
- [65] X. Wang, X. Qin, M. B. Hosseini, R. Slavin, T. D. Breaux, and J. Niu, "GUILeak: tracing privacy policy claims on user input data for android applications," in *Proceedings of the 2018 IEEE/ACM 40th International Conference on Software Engineering (ICSE)*, Gothenburg, Sweden, 2018.
- [66] Y. Wan, G. Wang, and X. Feng, "An evaluation model for information security of android application based on analytic hierarchy process," in *Proceedings of the 2016 World Automation Congress (WAC)*, Rio Grande, PR, USA, 2016.
- [67] N. Wongwiwatchai, P. Pongkham, and K. Sripanidkulchai, "Comprehensive detection of vulnerable personal information leaks in android applications," in *Proceedings of the IEEE INFOCOM 2020—IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS)*, Toronto, Canada, 2020.
- [68] J. Xiao, S. Chen, Q. He, Z. Feng, and X. Xue, "An android application risk evaluation framework based on minimum permission set identification," *Journal of Systems and Software*, vol. 163, Article ID 110533, 2020.
- [69] X. Zhang and R. Zhang, "A solution of code authentication on android," in *Information and Communications Security*, pp. 356–362, Springer International Publishing, Cham, Switzerland, 2016.
- [70] R. Baalous and R. Poet, "How dangerous permissions are described in android apps' privacy policies?" in *Proceedings of the 11th International Conference on Security of Information and Networks*, Cardiff, UK, 2018.
- [71] D. Zhu, H. Jin, Y. Yang, and W. Chen, "Privacy guardian: preventive policy enforcement against privacy malware on android," in *Proceedings of the 6th International Conference on Information Engineering*, Dalian, China, 2017.
- [72] J. Kim, H. Choi, H. Namkung et al., "Enabling automatic protocol behavior analysis for android applications," in *Proceedings of the 12th International Conference on emerging Networking Experiments and Technologies*, Irvine, CA, USA, 2016.
- [73] Z. Shan, I. Neamtiiu, and R. Samuel, "Self-hiding behavior in android apps: detection and characterization," in *Proceedings of the 40th International Conference on Software Engineering*, Gothenburg, Sweden, 2018.
- [74] J. Wang and R. Poet, "Permission management and user privacy based on android: permission management on android," in *Proceedings of the 13th International Conference on Security of Information and Networks*, Merkez, Turkey, 2020.
- [75] E. A. Yamauchi, P. C. d. Souza, and D. P. S. Junior, "Prominent issues for privacy establishment in privacy policies of mobile apps," in *Proceedings of the 15th Brazilian Symposium on Human Factors in Computing Systems*, São Paulo, Brazil, 2016.

## Research Article

# Intelligent Method of Supply Chain Circulation Industry Structure Based on Machine Learning

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In the deepening of supply chain competition, whether the structure of supply chain industry is reasonable and scientific has been severely tested. For warehousing, purchase and distribution channels, and customers, it largely determines whether the structure of supply chain is stable and efficient. The rationality of structure can determine the value of supply chain. By analyzing these four levels, this paper judges whether the supply chain structure is reasonable; the judgment standard is based on the three popular machine learning models, Stochastic Forest, XGBoost, and Support Vector Machine. The three models are based on a large number of real data environments. Through data simulation and parameter optimization, four supply chain characteristics are put into the model for simulation training for many times, and the three error numbers of MAE, RMSE, and MAPE of the model are analyzed to judge the reliability of the model. On this basis, through the combination of models, it is determined that the average percentage error of the combination of the three models is higher than that of the other pairwise combinations, reaching 0.937, which completes the expectation of intelligent prediction of supply chain structure.

## 1. Introduction

Thanks to the development of market economy, the supply chain system has gradually become more mature, but it brings new problems. The intelligent structure of supply chain is often more severe when facing the development impact of the new era, and the intelligent structure of supply chain network has become an important challenge for enterprises to develop at a higher speed. In the intelligent of supply chain structure, more and more people are beginning to pay attention to its commercial and environmental factors. People are also looking for suitable models in order to solve the uncertainty and reduce the uncertain parameters caused by risks. Most scholars put forward models based on mathematical programming for intelligent supply chain structure; for example, a biobjective possibility mixed integer programming model is proposed to solve the cost problem [1]. Corresponding to the whole supply chain structure, there are some limitations in the planning of mathematical models; according to the complexity of the problem, the traditional precise method [2], optimization

software, or heuristic algorithm can be used. The two-stage stochastic programming model is proposed [3]; it also has reference value when dealing with the supplier production capacity problem based on the actual situation. The model makes a sufficient trade-off between cost and risk. For the same model can also solve different practical problems, such as the same two-stage stochastic programming model, researchers also considered using value-at-risk (CVaR) as a risk evaluator to optimize the risk caused by location-allocation by changing the expected value of parameters [4]. In the CLSC network in the secondary supply market mentioned in some studies [5], fuzzy algorithm can be used to stimulate the customer's demand positively to improve the activity of the supply chain network. To improve the reliability of the system, a heuristic algorithm-comparative particle swarm optimization algorithm is proposed [6]. In the face of environmental uncertainty and instability of supply chain network, the stability of the whole system can be greatly enhanced by optimizing the robustness. A fuzzy value-at-risk (VAR) optimization model is proposed [7], to simulate and optimize the uncertain demand and cost of



supply chain. In recent years, machine learning has become increasingly popular. Because of its strong predictability and trainability, it has brought about the evolution and progress of traditional mathematical models. As mentioned in recent research [8], the field of machine learning has been gradually established, and it has great relevance to other fields. Some studies also prove that machine learning has made great progress in various aspects [9]. Hinton [10] puts forward that better assignment of initial weights can better solve the gradient descent problem caused by machine learning model. Cavalcante I M [11] discusses the correlation of supply chain performance using simulation and machine learning. The problem of building energy consumption can also be solved by machine learning and data, just like the results completed by Bourdeau M et al. [12]. In machine learning, there are three suitable models for simulating supply chain structure, among which XGBoost model has attracted great attention since it was launched. Because of its excellent performance, it is also the best recommended model in mathematics competition. Stochastic forest model transforms predicted things into tree structure, which is connected by vectors one by one to minimize the error rate [13].

In addition, there is a support vector machine model (SVM), which projects data in high-dimensional space through nonlinear mapping and then constructs an optimal regression plane in feature space to complete classification or regression tasks [14].

As a famous machine learning algorithm, SVM can get much better results than other algorithms on small sample training sets. Support vector machine has excellent generalization ability, but for relatively large training set, SVM training time will be relatively long. Random forests can process very high dimensional data (that is, data with many features) without feature selection. In addition, after the training, random forest can give which features are more important and have good performance, which has great advantages compared with other algorithms. XGBoost takes a page from the random forest playbook and supports column sampling, which not only reduces overfitting, but also reduces computation. XGBoost has fast training speed and can support parallel computing with high computational efficiency. To sum up, for the intelligence of supply chain structure, the performance of three machine learning models is tested [15], and then these three machine learning models are combined, and the combined results are analyzed to find the most suitable model combination for the intelligent of supply chain structure and explain the feasibility and effectiveness of the models.

This paper mainly has the following highlights and contributions: (1) three classic ML algorithms (XGBoost, SVM, and RF) are applied in the field of supply chain structure prediction, and the method is evaluated by different values such as MAPE. (2) Gray wolf optimization algorithm is applied for parameters optimization to improve the accuracy of the proposed model. (3) We proposed a hybrid assemble model through mixing the three models in different ways, and the experiment result indicates that it outperforms other classical benchmark methods.

## 2. Basic Theory of Supply Chain Structure

**2.1. Supply Chain Structure.** Supply chain refers to the turnover of products or services from the factory to the enterprise, and through a certain route to deliver them to consumers. Supply chain is a chain channel that connects suppliers, warehouses, distributors, and retailers in series. The structural intelligence of supply chain is mainly to solve the problems between structures. If enterprises connected with supply are represented by nodes, and links between enterprises are represented by line segments, then supply chain can be regarded as a network chain structure composed of multiple points and lines [16], as shown in Figure 1.

**2.2. Machine Learning Algorithm in Supply Chain Forecasting.** The powerful predictive ability of machine learning model in regression and classification has been applied in various fields [17]. Machine learning algorithm can analyze and predict big data and improve supply chain efficiency. Resource, time, or cost constraints are the most important problems faced by supply chain managers, and the most ideal solution to these problems is to optimize analysis and design with the help of machine learning. This is the theoretical basis for machine learning to solve the problem of supply chain optimization. At present, Amazon Kiva, which is relatively mature, relies on artificial intelligence and machine learning technology to forecast the network demand for DHL, a world-famous logistics group [18]. The analysis system sets 58 different parameters based on machine learning algorithm to analyze and interpret the main factors leading to delivery delay. The use of machine learning improves the fitting accuracy and response speed of prediction network and enables enterprise managers to devote more energy to improving customer service quality. It can be said that artificial intelligence is changing this era, and the extensive use of machine learning will redefine the management mode of supply chain. According to the report of Gartner, the world's top information technology research company, it is predicted that the future supply chain will rely on supervised or unsupervised machine learning analysis results to assist the formulation of unexpected problem solutions. Gartner also predicts that artificial intelligence technology will be deployed in all key nodes of the supply chain in an embedded or nonembedded way, which will improve the information transmission efficiency of supply chain nodes and realize the information sharing of the whole supply chain.

**2.2.1. XGBoost.** In 2016, Chen and Guestrin first proposed XGBoost model [19]. Since the model came out, it has been noted by data enthusiasts from all over the world. Because the XGBoost model has a direct or continuous system, the best performance solution of the XGBoost model in the running process is to complement the XGBoost model, so XGBoost is the best recommended model in the competition. XGBoost's high performance and low data features can be applied in many ways. XGBoost integrates multiple decision models by using the idea of integration and obtains



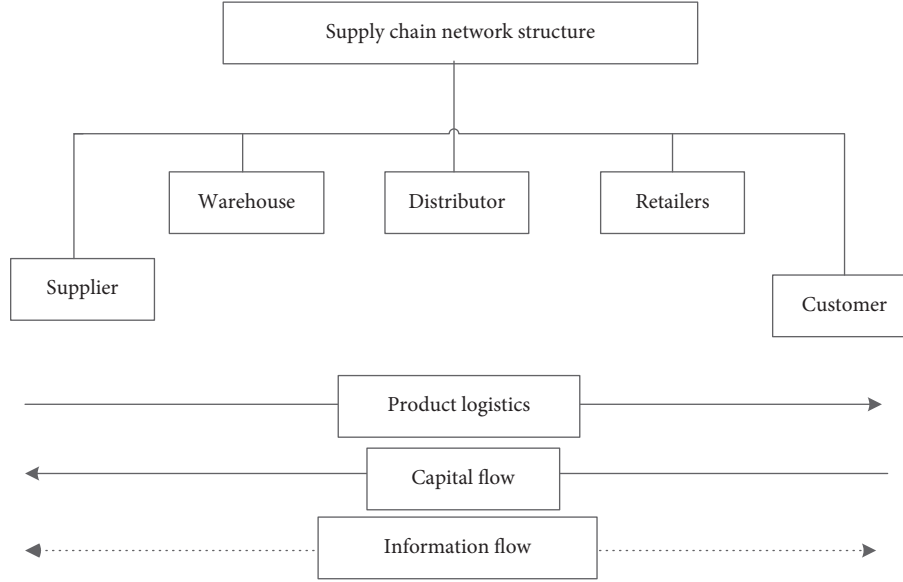


FIGURE 1: Supply chain structure diagram.

greater integration ability than the original model. XGBoost has the following three points:

First, it supports parallel computing, and the algorithm is fast; second, based on the extraction algorithm, sparse data can be automatically sorted; third, the data can be in batches, and the calculation speed is high. In the XGBoost model, decision trees interact with each other through the principle of addition, as shown in the following formula:

$$\bar{y} = \sum_{k=1}^K f_k(X_i), \quad f_k \in F. \quad (1)$$

The objective function in the algorithm is shown in the following formula:

$$L(\varphi) = \sum_i l(\bar{y}, y_i) + \sum_k \Omega(f_k). \quad (2)$$

For each regression tree, it can be expressed as

$$f_k = w_{q(x)}, \quad w \in \mathbb{R}^T, \quad q: \mathbb{R}^d. \quad (3)$$

The complexity for each tree can be written as

$$\Omega(f_k) = \gamma T + \frac{1}{2} \lambda \sum_{j=1}^T w_j^2. \quad (4)$$

**2.2.2. Random Forests.** Stochastic forest, proposed by Breiman in 2001, is a machine learning method that uses ensemble learning idea to establish multiple decision tree sets that do not affect each other to solve regression or classification [20]. The weak learner clusters are combined to build a decision tree group. In the sampling mode, we choose the random way to extract the data from the target data set and use the extracted samples to build the basic learner. Generally, we choose CART decision tree as the use scheme of weak learner. The random processing mode of random

forest is the random grasping analysis of data. For 1/3 of the data that does not participate in random calculation, it is called out of bag (OOB). Based on these advantages, the whole simulation process in random forest is very close to reality and has high computational efficiency. Spam data can be properly filtered. The modeling steps of stochastic forest model are as follows:

Step1:  $m$  sample points are randomly selected from the training sample set  $S$  to obtain a new  $S_1 \dots S_n$  sub-training set.

Step2: Train a CART regression tree (decision tree) with subtraining set. In the process of training, the segmentation rule for each node is to randomly select  $K$  features from all features and then select the optimal segmentation point from these  $K$  features to divide left and right subtrees (the resulting decision trees are binary trees).

Step3: Through the second step, many CART regression tree models can be generated.

Step4: The final prediction result of each CART regression tree is the mean value of the leaf nodes reached by this sample point.

Step5: The final prediction result of the random forest is the mean of the predicted results of all CART regression trees.

**2.2.3. Support Vector Machines (SVM).** Support Vector Machines are a supervised learning model, which is used for data analysis and pattern recognition and is widely used in classification and regression fields [21]. The mathematical expression of the model construction is as formula (10), where  $w$  represents the weight, and  $c$  represents the penalty coefficient, where  $\xi$  is a relaxation variable. The basic rule of support vector machine is to construct data resources in space vector to form high-dimensional map. Then, the

classification or regression task is completed by regression plane. Regression model optimization equation is

$$\min \frac{1}{2} \|w\|^2 + c \sum_{i=1}^m (\xi_i + \xi_i^*). \quad (5)$$

The general regression expression is shown in the following formula:

$$f(x) = (w, \phi(x)) + b. \quad (6)$$

There are four basic kernel functions in support vector machine [22], which are linear kernel function, Gaussian kernel function, polynomial kernel function, and radial basis function kernel function. The Gaussian kernel function is

$$K(x_i, x_j) = e^{-(1/2\sigma^2) \|x_i - x_j\|^2}. \quad (7)$$

The expression of polynomial kernel function is

$$K(x_i, x_j) = ((x_i, x_j) + r)^d. \quad (8)$$

The expression of radial basis kernel function is

$$K(x_i, x_j) = e^{-\gamma \|x_i - x_j\|^2}. \quad (9)$$

The expression of linear kernel function is

$$K(x, z) = x \bullet z. \quad (10)$$

### 3. Optimization of Model Parameters and Analysis of Influencing Factors

**3.1. Parameter Optimization Method.** The effective prediction of data by machine learning has seized the stage in the field of artificial intelligence aided decision-making. It has the inherent advantages of self-learning and dealing with complex nonlinear problems. Manual or automatic input can effectively make the model better train and simulate the fitting ability. The specific form of parameters determines what kind of optimization methods scientists use to optimize their design. Parameter optimization methods often used in data analysis competition and scientific practice include grid search method and gray wolf optimization algorithm. In recent years, gray wolf optimization algorithm stands out among swarm intelligence algorithms for its excellent performance and is widely used in various fields of model parameter adjustment.

**3.1.1. Grid Search Method.** Using enumeration search method, the searched parameter values are mapped to a multidimensional grid, and a node in the grid represents a fixed combination of parameter values. Using this combination, the performance of the model under this group of parameters is returned. The training process is similar to the exhaustive process, and all nodes of the grid need to be traversed to find the optimal parameters. Based on single training, the parameters are adjusted, and the training time and adjustment accuracy are higher than those of other complex optimization algorithms in the state of few parameters. The grid search method is easy to use, and the evaluation standard is obtained through two-way inspection.

**3.1.2. Grey Wolf Optimization.** Gray wolf algorithm, proposed by Emary in 2016, is a new intelligent optimization algorithm for simulating the hierarchy and predation behavior of wolf pack system in nature. Wolf population has strict social hierarchy. There are four classes of gray wolves:  $\alpha, \beta, \delta, \omega$ . High-level  $\alpha$  wolves lead other low-level wolves to hunt [23]. The hunting behavior of gray wolves can be defined as

$$D = |C \cdot X_p(t) - X(t)|. \quad (11)$$

$$X(t+1) = X_p(t) - A \cdot D. \quad (12)$$

Formula (11) represents the distance between individuals and prey, and formula (12) is the position update formula of gray wolves, where  $t$  is the current iterative algebra,  $X$  and  $X_p$  are coefficient vectors, and  $A$  and  $C$  are the position vectors of prey and gray wolf, respectively. Formulae (13) and (14) for  $A$  and  $C$  are as follows:

$$A = 2a \cdot r_1 - a, \quad (13)$$

$$C = 2 \cdot r_2. \quad (14)$$

### 3.2. Characteristic Analysis

**3.2.1. Warehouse Analysis.** Warehouse management is one of the important links in the supply chain structure. Unreasonable warehouse management will increase the storage cost in large quantities. Calculate the statistical sum of commodity attributes passing through the warehouse and divide the number of orders returned by the warehouse every week with the total number of orders handled by the warehouse every week, so as to get the index of warehouse return rate. The formula can be expressed as

$$S(t) = \sum_{i=1}^t X_i + \log^d. \quad (15)$$

**3.2.2. Analysis of Purchase Channels.** Calculate the weekly sales units, weekly sales, the number of returned pieces in the next week, the number of returned pieces in the next week, and the demand data after each channel, and calculate the return rate based on this. Calculate the number of orders flowing through each incoming channel. The formula can be expressed as

$$C(t) = W_d + \sum_{i=1}^t X_i. \quad (16)$$

**3.2.3. Analysis of Distribution Channels.** The relationship between distribution channels and warehousing is a many-to-many connection. In the distribution channel link, there may be great differences in the sales volume of a single node, and the sales volume of nodes fluctuates greatly, so it is easy to have unsalable goods, so the return rate of nodes is higher

than that of other links analyzed above. Its formula can be expressed as

$$p(\theta) = \log^2 \frac{W_d}{(c_d + w_d)}. \quad (17)$$

**3.2.4. Customer Analysis.** The number of channels corresponding to each customer is counted to form a one-way channel between customers and channels. The number of channels in its supply chain is far less than the number of customers, and different suppliers can use the same channel to supply goods to one customer. The formula can be expressed as

$$C(\theta) = \sum_{d=1}^d (\log^2 - \bar{X})^2. \quad (18)$$

## 4. Experimental Simulation Analysis

**4.1. Data Preparation.** Data is the core content of the development of the information age. In order to protect their own interests, companies refuse to share relevant supply chain or inventory production data, which makes it difficult to obtain the data of this study. This paper selects a part of the data about G Company's food supply chain on Kaggle, a big data competition platform, as the experimental data of this paper.

**4.2. Modeling.** XGBoost modeling and analysis should first screen the input variables, fully mine the demand fluctuation information contained in the known variables, use the known variables for feature engineering design, and complete the construction of new input variables. The characteristic variable  $n$  is the statistics of the behavior times of the customer purchasing this kind of product in the previous week,  $j$  represents the  $j$ -th purchase of this kind of product in the previous week, and  $v(t)$  represents the second manual input variable created as

$$v(t) = \frac{\sum_{j=1}^n m_i - 1}{n}. \quad (19)$$

$w(t)$  denotes the frequency of user usage in week  $t$  as

$$w(t) = \frac{\sum_{o=1}^p i}{n}. \quad (20)$$

For logarithmic variations, transform the logarithmically transformed requirements as shown in (21). The final results of the model are shown exponentially as

$$y(t) = e^{y^{(t)}}. \quad (21)$$

Modeling and analysis of stochastic forest stochastic forest have high tolerance to redundant variables and can complete the modeling of samples with missing or abnormal values. At the same time, because of its integration idea in modeling, the model shows strong stability in classification and regression tasks. The initial model of random forest is

constructed by using the input variables constructed above, where  $m$  represents the maximum feature number index, and  $N$  represents the total number of features of the input variables as

$$m = \log_2 N. \quad (22)$$

Support vector machine modeling and analysis researchers regard support vector machine as a technical black box and can quickly model and analyze the target data set after preliminary cleaning and processing. Integrate data to avoid the influence of dimension difference. The integrated usage method is shown in

$$p_i = \frac{p_i - p_{\min}}{p_{\max} - p_{\min}}. \quad (23)$$

Through reading the literature, it is found that the evaluation indexes of demand forecasting model mainly adopt Mean Absolute Error (MEA), Root Mean Square Error (RMSE), Mean Absolute Percentage Error (MAPE), and Spielman correlation coefficient [24]. However, due to the occurrence of zero node demand, this paper uses indexes other than Spielman coefficient to evaluate the prediction performance of the model.

The average absolute errors of the three models with training times are shown in Figure 2:

Overall, XGBoost and stochastic forest model outperform support vector machine model in this supply chain data set. In terms of average absolute error, the value of XGBoost is slightly lower than that of random forest, indicating that the approximate simulation degree is close, but the value of SVM is much higher than them, indicating that the accuracy of prediction analysis is slightly poor.

The RMSE training times of the three models are shown in Figure 3:

The difference between the three models is very large in the Root Mean Square Error. XGBoost model also appears in the statistic list in the form of minimum value, which represents that the predicted value of this model in the discrete degree in the test sample data is approximately equivalent to the actual value, which confirms the reliability of XGBoost prediction. The performance of stochastic forest model in this index is slightly inferior to XGBoost model, but the processing ability of discrete points is obviously better than that of support vector machine.

The average absolute percentage error of the three models with training times is shown in Figure 4:

MAPE is used to describe the correlation degree between predicted value and real value. The closer it is to 1, the greater the correlation between the two sequences is, and the more accurate the prediction result of the model is. As can be seen from Figure 4, XGBoost and stochastic forest model have similar fitting ability to supply chain demand sequence. Compared with the other two models, the value of SVM is relatively low, which may be due to the wrong way of processing redundant data in SVM. A large amount of redundant data makes SVM mistakenly select redundant data as support vector data in the training process.

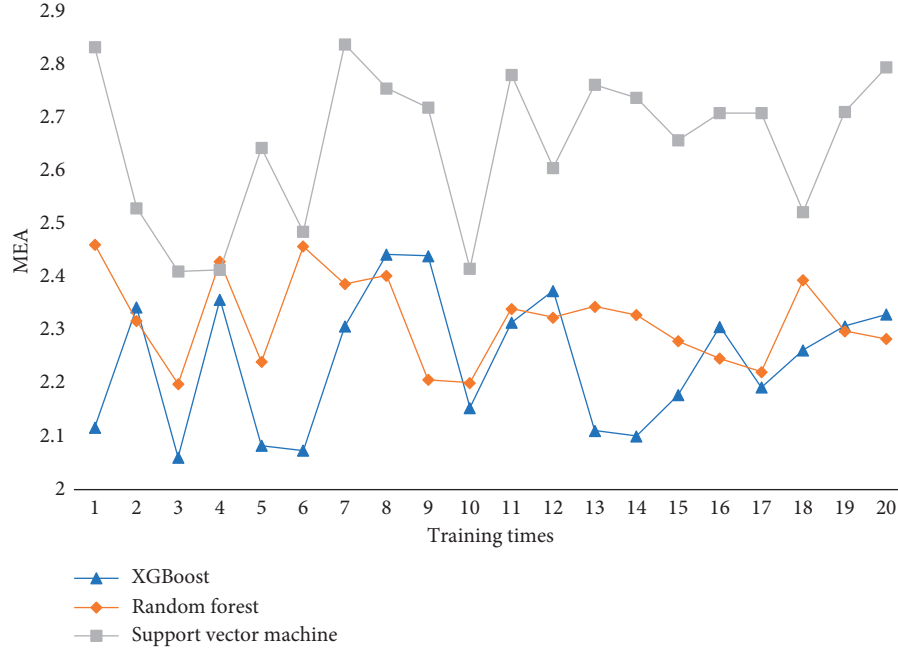


FIGURE 2: Average absolute error diagram.

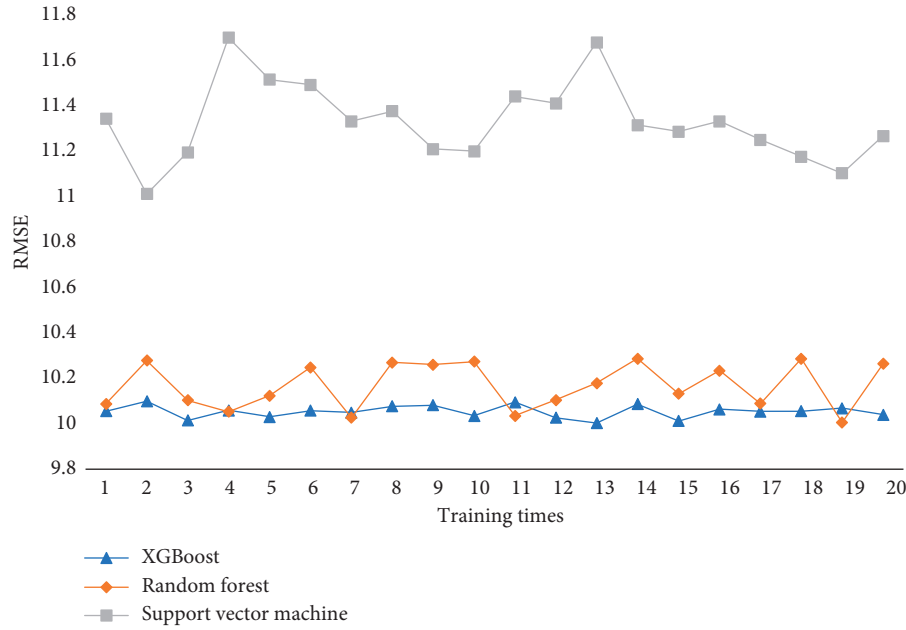


FIGURE 3: Root Mean Square Error diagram.

**4.3. Combination Forecasting.** In the existing literature, it is mentioned that the combination analysis of different attribute models can improve the overall performance of the models. In this paper, the prediction performance of the model in the validation data set is used as the basis for judging the weight of combination forecasting. The judgment method is shown in

$$w_k = \frac{1/e_k}{\sum_1^n 1/e_i}. \quad (24)$$

Performing and combining the three models, four combination models are obtained. Combination model 1 is completed under the combined effect of the prediction performance of the three models. Combination model 2 is completed by integrating the prediction results of XGBoost and stochastic forest model. Combination model 3 is the combination of XGBoost support vector machine model, and combination model 4 is the combination of stochastic forest and support vector machine model. The prediction effect of the combined model in the test set is drawn as a

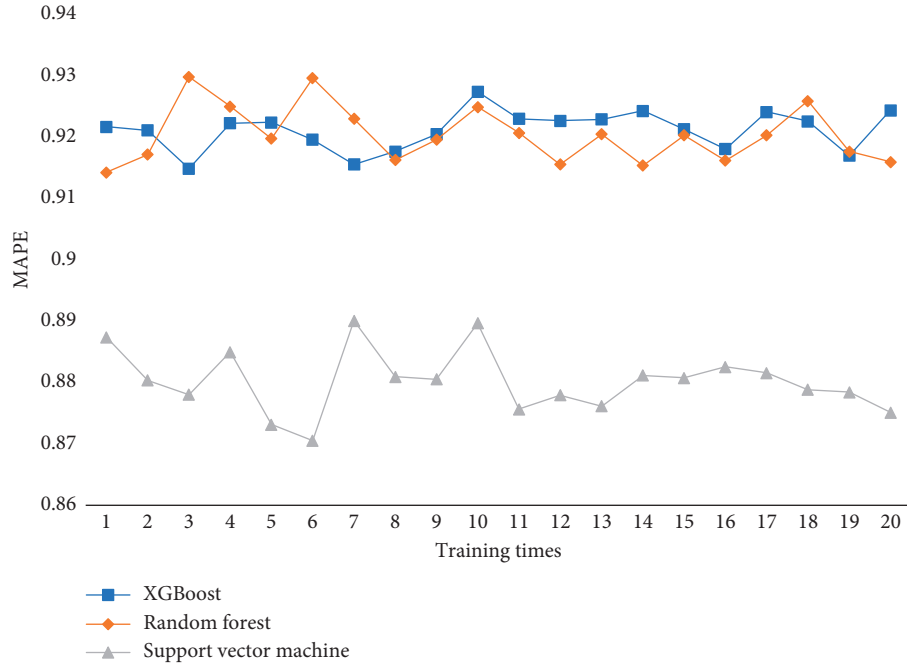


FIGURE 4: Average absolute percentage error chart.

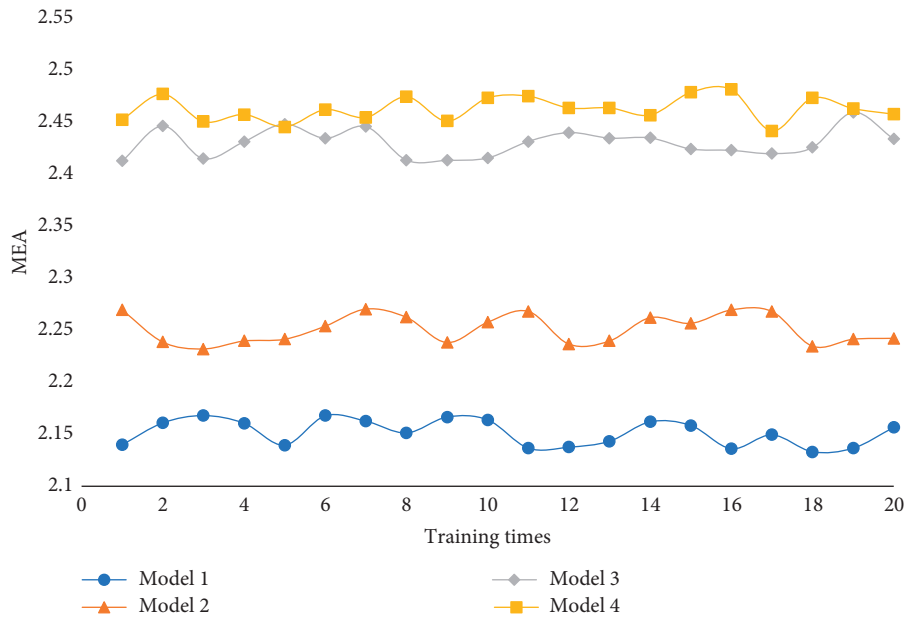


FIGURE 5: Average absolute error diagram of four combinations.

scatter line chart. The MEA, RMSE, and MAPE of the four combinations with training times are shown in Figures 5–7, respectively.

From Figures 5–7, it can be found that the prediction results of MEA, RMSE, and MAPE are integrated. Combination model 1 obtains better prediction effect than the previous optimal XGBoost model. However, combination model 2, which combines XGBoost and random forest, has higher average prediction accuracy than the previous optimal single model on the test data set.

However, from the degree of dealing with discrete values, it can be found that the combination model does not inherit the good fitting performance from XGBoost model in this respect. MAPE shows that combination model 2 has better prediction ability in overall prediction. As for combination model 3 and combination model 4, when the two models are simply combined, the weight of the model with large error cannot be reduced to a very low level, which is the main reason for the poor performance of the combination model.

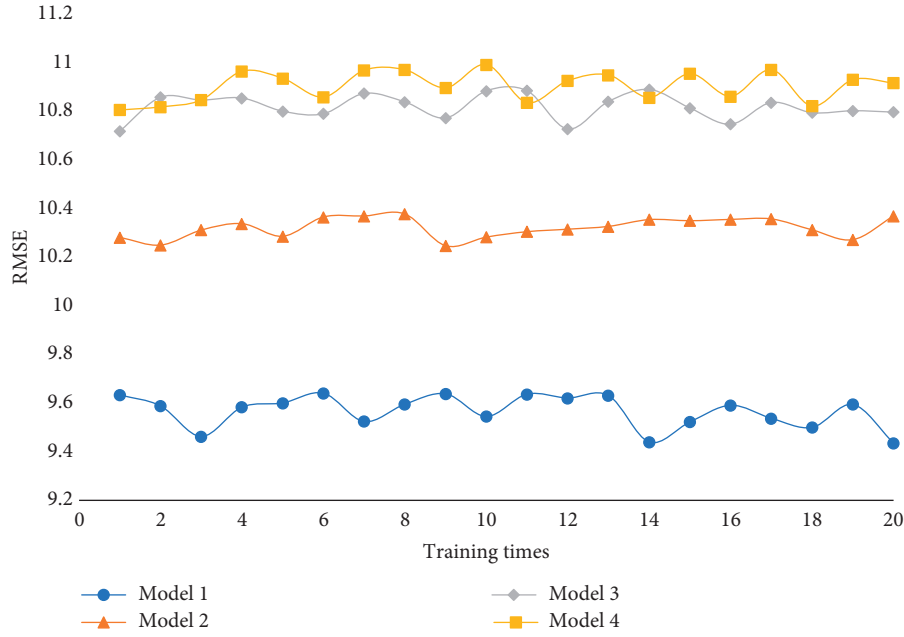


FIGURE 6: Root Mean Square Error diagram of four combinations.

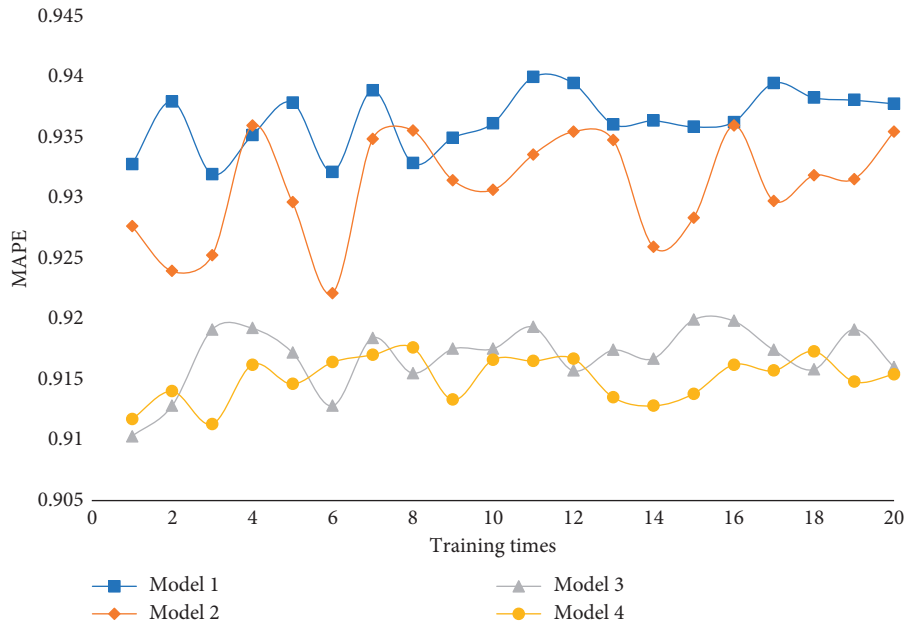


FIGURE 7: Average absolute percentage error diagram of four combinations.

## 5. Conclusion

By modeling and analyzing the data of G Company's food supply chain, the machine learning model is used to intelligently predict the supply chain structure, and the main achievements are as follows: (1) we carry out correlation analysis and variable screening on data sets, and screen for correlation relations, determine variables, and select them. Using characteristic analysis, we find that there are a lot of jumbled data in the demand data of supply chain nodes, and there are key nodes in the supply chain. Accurate analysis of them can help decision makers understand the real overall

demand in the supply chain. (2) Model introduction and parameter automatic optimization: three mature machine learning prediction models are introduced to train and predict the demand data of supply chain nodes, and the appropriate optimization methods are selected according to the characteristics of their models to complete the automatic adjustment of parameters. (3) Model combination and weight determination: there are some differences in forecasting performance of a single model on different data sets. Introducing model combination can minimize the forecasting error caused by the characteristics of the model itself and ensure the accuracy of final demand forecasting.



(4) Model evaluation and statistical indicators: the model evaluation system is introduced, which is convenient to predict the model quickly and intuitively. It is convenient for scholars to introduce and evaluate new models in the future, so that the field of supply chain forecasting can develop rapidly and shorten the gap between this discipline and other advanced forecasting fields. Only by establishing a scientific and systematic demand forecasting framework can we fundamentally improve the quality of demand forecasting, reduce the backlog of inventory, and improve the overall benefit and efficiency of supply chain. In addition, through data simulation and parameter optimization, four supply chain characteristics are put into the model for simulation training for many times, and the three error numbers of MAE, RMSE, and MAPE of the model are analyzed to judge the reliability of the model. On this basis, through the combination of models, it is determined that the average percentage error of the combination of the three models is higher than that of the other pairwise combinations, reaching 0.937, which completes the expectation of intelligent prediction of supply chain structure. Furthermore, this paper uses Kaggle's existing data set to analyze the supply chain demand. The sampling standard and frequency of this data set are different from those collected in other environments. In the next stage, supply chain demand data sets with other attributes can be used to further verify the effectiveness of the model.

## Data Availability

The experimental data used to support the findings of this study are available from the corresponding author upon request.

## Conflicts of Interest

The authors declare that they have no conflicts of interest regarding this work.

## References

- [1] C. Y. Wang, J. Z. Chen, and W. Li, "Review on superpixel segmentation algorithms," *Application Computer Research*, vol. 31, no. 1, pp. 6–12, 2014.
- [2] L. Li, J. Pan, and W. Lai, "Learning a critical prior for blind image Deblurring," in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, pp. 6616–6625, IEEE Press, New York, NY, USA, June 2018.
- [3] J. Pan, D. Sun, and H. Pfister, "Blind image deblurring using dark channel Prior," in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, pp. 1628–1636, IEEE Press, New York, NY, USA, June 2016.
- [4] W. Han, S. Chang, and L. Ding, "Image super-resolution via dual-state recurrent IEEE conference on network," in *Proceedings of the Computer Vision and Pattern Recognition*, pp. 1654–1663, Salt Lake City, NV, USA, June 2018.
- [5] M. Wani and M. Ahmad, "Information diffusion modelling and social network parameters (A survey)," in *Proceedings of the High-level Negotiations at International Conferences Computer, Communication and Electronic Engineering Company*, pp. 16–18, India: Kashmir, October 2015.
- [6] Y. Bae and H. Lee, "Sentiment analysis of twitter audiences: measuring the positive or negative influence of popular twitterers," *Journal of the American Society for Information Science and Technology*, vol. 63, no. 12, pp. 2521–2535, 2012.
- [7] X. Xiong, Y. Li, S. Qiao et al., "An emotional contagion model for heterogeneous social media with multiple behaviors," *Physica A: Statistical Mechanics and Its Applications*, vol. 490, pp. 185–202, 2018.
- [8] L. Mei, X. Wang, and K. Gao, "A survey on information diffusion in online social networks: patterns and methods," *Info*, vol. 8, no. 4, p. 118, 2017.
- [9] Y. Yi, Z. Zhang, and C. Gan, "The effect of social tie on information diffusion in complex networks," *Physica A: Statistical Mechanics and Its Applications*, vol. 509, pp. 783–794, 2018.
- [10] S. Shan and X. Lin, "Research on emergency dissemination models for social media based on information entropy," *Enterprise Information Systems*, vol. 12, no. 6-10, pp. 888–909, 2018.
- [11] D. Zinoviev, V. Duong, and H. Zhang, "A game theoretical approach to modeling information dissemination in social networks," vol. 1, pp. 407–412, 2010, Eprint Arxiv.
- [12] X. Liu, D. He, L. Yang, and C. Liu, "A novel negative feedback information dissemination model based on online social network," *Physica A: Statistical Mechanics and Its Applications*, vol. 513, pp. 371–389, 2019.
- [13] L. Zhao, J. Wang, Y. Chen, Q. Wang, J. Cheng, and H. Cui, "SIHR rumor spreading model in social networks," *Physica A: Statistical Mechanics and Its Applications*, vol. 391, no. 7, pp. 2444–2453, 2012.
- [14] M. M. Tulu, R. Hou, and T. Younas, "Identifying influential nodes based on community structure to speed up the dissemination of information in complex network," *IEEE Access*, vol. 6, pp. 7390–7401, 2018.
- [15] C. Granell, S. Gmez, and A. Arenas, "Dynamical interplay between awareness and epidemic spreading in multiplex networks," *Physical Review Letters*, vol. 111, pp. 1–5, 2013.
- [16] D. Y. Melesse and A. B. Gumel, "Global asymptotic properties of an SEIRS model with multiple infectious stages," *Journal of Mathematical Analysis and Applications*, vol. 366, no. 1, pp. 202–217, 2010.
- [17] L. Zhao, X. Qiu, X. Wang, and J. Wang, "Rumor spreading model considering forgetting and remembering mechanisms in inhomogeneous networks," *Physica A: Statistical Mechanics and Its Applications*, vol. 392, no. 4, pp. 987–994, 2013.
- [18] L.-L. Xia, G.-P. Jiang, B. Song, and Y.-R. Song, "Rumor spreading model considering hesitating mechanism in complex social networks," *Physica A: Statistical Mechanics and Its Applications*, vol. 437, pp. 295–303, 2015.
- [19] D. J. Watts and S. H. Strogatz, "Collective dynamics of 'small-world' networks," *Nature*, vol. 393, no. 6684, pp. 440–442, 1998.
- [20] X. Li, J. Guo, C. Gao, L. Zhang, and Z. Zhang, "A hybrid strategy for network immunization," *Chaos, Solitons & Fractals*, vol. 106, pp. 214–219, 2018.
- [21] L.-L. Xia, Y.-R. Song, C.-C. Li, and G.-P. Jiang, "Improved targeted immunization strategies based on two rounds of selection," *Physica A: Statistical Mechanics and Its Applications*, vol. 496, pp. 540–547, 2018.
- [22] L. K. Allen, A. D. Likens, and D. S. McNamara, "Modeling the dissemination of misinformation through study dynamics," *Misinformation and Fake News in Education*, vol. 281, pp. 159–164, 2019.
- [23] A. Vazquez, R. Dobrin, and D. Sergi, "The topological relationship between the large-scale attributes and local

interaction patterns of complex networks,” *Proceedings of the National Academy of Sciences of the United States of America*, vol. 101, no. 52, pp. 1–5, 2004.

- [24] T. Carnes, C. Nagarajan, and S. M. Wild, “Maximizing influence in a competitive social network: a follower’s perspective,” in *Proceedings of the Ninth International Conference on Electronic Commerce*, pp. 351–360, Minneapolis, MN, USA, August 2007.

## Research Article

# Enhancing Healthcare through Detection and Prevention of COVID-19 Using Internet of Things and Mobile Application

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The main symptoms of COVID-19 are high temperature, throat infection, and irregular heartbeat. An integrated wearable device has been presented in this paper for the measurement of temperature and heartbeat in real time using different sensors and NodeMCU ESP8266. For temperature, the DHT11 sensor is used and, for heartbeat, the pulse sensor is used. After reading the data from the sensors processed by NodeMCU ESP8266, it is sent to the firebase database using wireless connection (Wi-Fi module). From the database, the data are displayed in an android application. On the basis of certain conditions of the data, the user as well as the administrator is notified regarding the user's current health. For the social distancing, an ultrasonic sensor is used. The sensor will warn the user, if he/she is in close contact with someone within a specified distance. The user's current location is also tracked using the location services of android. A module named COVID-meter, based on the disease.sh-Open Disease Data API, was also included in the research for reading of real-time data of different countries related to COVID-19 like total cases, total deaths, total recovered patients, and so on. The proposed device can be used in both populated and rural areas, but in rural areas it will be much more important because people are unable to reach a doctor on time; thus, they can check their health conditions remotely using the proposed device.

## 1. Introduction

The outbreak of COVID-19 has started in the city of Wuhan, China in 2019. Severe acute respiratory disease coronavirus 2 (SARS-CoV-2), the seventh human coronavirus, caused the pandemic. Due to the massive spread and infection, the World Health Organization (WHO) on March 12, 2020, has acknowledged the novel coronavirus (COVID-19) outbreak as a universal pandemic [1]. The infection started spreading all over the world, and by May 20, 2020, it has infected 4,806,299 people and caused 318,599 deaths [1]. To date, the world has suffered a lot in this pandemic in terms of human lives, education, economy, and amplified poverty. At the start of the pandemic, temperature was considered as the main symptom of COVID-19 infection and the people were screened out on the basis of their body's temperature by

using a noncontact device. But there were some challenges while using that device. People were unable to follow the social distancing as directed by WHO due to the use of the device. Some people especially in illiterate regions were unaware of the correct usage of that meter. In order to check one person at a time, there were crowds of people waiting for their turn and hence caused to speed up the spread of COVID-19. There was a risk of infection to the person, who was screening out the people.

We are residing in contemporary and computational advanced world. The revolution in the field of computer-based technology has made the world a global village, and access to the information is now easier and faster. Humans are directly or indirectly dependent on computers in their everyday lives. Computers and smartphones have become a necessary household items and an important part of health,

education, and businesses. Different fields like artificial intelligence, Internet of things (IoT), intelligent sensors, and portable devices have made our lives very easy and secure. By the advancement in the field of IT and IoT, the health sector has changed a lot and diverse extraordinary solutions were supplied. There is no need for face-to-face consultation and checking of patients in hospital. By using different wearable devices and online services, the doctors can now monitor and diagnose the patients remotely. With the development of online applications in healthcare, it can help, manage and analyze data, make decisions, and conduct conversations by using different artificial intelligence algorithms and IoT solutions. These systems can even prescribe medicines to the patient based on their current health condition.

According to the instructions of WHO [1], a person with temperature or irregular heart beat should stay at home and away from the people. The device can help the person wearing the mask to find out the temperature and heartbeat. In case of emergency, a patient and the medical staff along with a doctor can know about the health condition of that patient. People will be able to keep social distancing from that patient and hence can minimize the spread of the virus. Some people do not know about their health conditions and do not go for a checkup in early stage. The device will warn them to see the doctor. We proposed a wearable device consisting of hardware and android application. The system is very effective to be used for the detection and prevention of COVID-19. The proposed system has the following contributions in brief:

- (i) Bring advancement in the remote health monitoring system and measurement of temperature and heart beat remotely through sensors.
- (ii) Use firebase database instead of server to increase the processing of data in real time and the user can check the health data through the android application.
- (iii) Buzzer along with LEDs is used to keep the people aware of the health condition and ultrasonic sensor is used for social distancing to keep the spread of virus limited.
- (iv) Real-time location tracking is implemented with the android location services and information about COVID-19 statistics can be seen by the users on country basis.

## 2. Related Work

Various approaches have been devised for facilitating healthcare through detecting and preventing COVID-19. The study presents a system consisting of different sensors for facilitating healthcare. The heartbeat sensor is used to read the data of heartbeats and the temperature sensor is used to read the temperature data of a patient and send it to the microcontroller ATmega328 (Arduino Uno) for transmission to display it on receiving end and the data are then shown on LCD. The patient can be monitored in real-time basis and can also use a wireless scheme to communicate

data from distant locality [2]. A system is proposed based on IoT which can combine data with different rapid decisions and actions and send these data to the associated doctor through a mobile or server. The system constantly monitors the temperature of a patient using CC3200 microcontroller with built-in Wi-Fi and data are stored in a database. This data are sent to the doctor in the form of an application (Android) through web server. The proposed design system collects the data and communicates it to the cloud where it is managed and examined [3]. The study presents the development of a microcontroller grounded on heartbeat and body temperature using fingertip and temperature sensor. This system can measure heartbeat using optical heartbeat sensor and temperature by means of temperature sensor. The readings from both sensors are sort out and sent through GSM module to the receiving end using wireless technology where it can be displayed on a mobile phone for additional processing and patient caring [4]. The authors presented a study for familiarizing a system to monitor the patient health and proposed an android application to examine the health of a patient so the doctor can check the patient properly. This system involves a temperature sensor and pulse sensor which can read patient body temperature and heartbeat. The read data are sent to the server via an android application of the nurse, where all processing will be performed. This data will also be accessible to the doctor with this android application [5]. Research introduces a system which is able to give information about user health condition by measuring heartbeat through fingertip sensor and body temperature using LM35 sensor. The fingertip sensor takes data from the blood flow on the index finger for 60 seconds; after this it will be displayed on LCD. Variation in sensor heat would be transformed into electricity, interpreted into digital form through a 10-bit ADC, processed by the ATmega16 microcontroller, and shown on LCD [6]. The research has developed a system which consists of Arduino Uno, transmission system and android application. The device gives information of heartbeat and temperature consecutively assimilated on the portable system in real time and display it on connected android application immediately [7]. The research scheme consists of a wireless heartbeat and temperature observing system built on a microcontroller. The arrangement comprises sensors measuring the heartbeat and temperature of a patient which is organized by a microcontroller. Both readings are lastly displayed on screen. A wireless means is used to communicate the recorded data to a faraway position [8].

The core objective of the research was to develop a consistent patient monitoring arrangement by means of IoT to monitor the patient, either the being hospitalized or at home. This system contains sensors, data acquisition unit, Arduino, and software application. This mobile centered wireless healthcare monitoring scheme provides real-time data like heartbeat rate, temperature, and EEG information of a patient checked, presented, deposited by the system, and directed to the doctor's mobile having the application [9]. A system was designed with the main work to develop an application for monitoring heartbeat and temperature of a user of the device and guide them for the treatment

continuously; each individual health condition can be checked with 24-hours service. The system can be unpremeditated, by integrating ECG, EMG, EEG systems, dental sensors, and annunciation systems, thus making it valuable in hospitals as a right, efficient, and dedicated patient care system [10]. The research study involves the design of an android application and pulse sensor. Pulse sensors are used to sense heart rate of the patient. The proposed device is based on android healthcare management system. This development of designing an android application and pulse sensor is linked with Arduino Uno. The microcontroller Arduino Uno reads the sensor indications and refers it to the Bluetooth shield of the circuit. Furthermore, this shield guides the sensor signals to the android application by linking with the Bluetooth of a cell phone and sends the heart rate to software user interface. After this, the application sends the particulars of heart rate and present locality of consumer by means of GPS of the mobile phone and all the constraints to the cardiac doctor directly [11]. The research has suggested a healthcare monitoring method established on Arduino Uno, heart rate sensor and temperature sensor to monitor and sustain the patient health condition in steady intermissions. Both sensors are analyzing patient body temperature and heart rate. If a high change occurs in regular intervals, then the buzzer will run to alert the hospital staff and doctor. The detail will be stored in cloud "ThingSpeak" and the doctor can note the patient health situation on Virtuino Simulator to reduce the health risk by tracing the patient medical condition [12]. The study presented a comprehensive review of the idea to solve health issues using IoT. This system architecture will measure the body parameters on real-time basis. It is based on different sensors to collect patient data and transfer data to Arduino Uno which can further handover to the cloud by Wi-Fi module. The data are kept in MYSQL database server which manages and provides approachability to data. User can view data through the android application installed on his/her smart phone. If user data are anomalous, then the patient gets a notification and care takers get an e-mail. With the help of different verdict-making algorithms, deduction can be made and people will have the permission to access the database. A patient can also check his/her health record [13]. A system consisting of MAX30205 sensor, SEN11574 sensor, NodeMCU ESP8266 was proposed in a research study. The MAX30205 sensor is used to measure temperature and the SEN11574 sensor is used to measure heart rate. The composed data from both sensors are directed through NodeMCU ESP8266 microcontroller associated to mobile application through internet. The data are displayed on a mobile application and then noticed by the guardian. The patient can remotely send his/her heart rate and temperature information from home to the hospital or clinic [14].

A system was introduced consisting of wearable devices including different sensors like temperature sensor, pulse sensor, and ATMEGA 32-bit AVR microcontroller. The device sends measured data from both sensors to the server through the patient android application and these data are accessible on the doctor desktop computer. This prototype of an automated electronic system includes a Bluetooth module

and ATMEGA 32-bit AVR microcontroller which are able to measure the heart rate and body temperature no matter where the patient is and sends a wireless request in case of any emergency for the rescue help. The proposed system gives benefit when equated to wired system with the observation that the doctor can get remotely the information of the parameters as well as the location of patient for tracking such that instant medication can be provided in case of any emergency [15]. A complete healthcare system was developed in order to check and analyze the health condition of a patient remotely and send it to the medical worker using IoMT. This system allows doctors to check the patients at a distance. Health parameters are identified like pulse rate, temperature, ECG, and blood pressure through wearable sensors. The sensors are coupled to an Intel Edison Board. Just once the Intel Edison board is connected to internet, it collects data from sensors and sends them to the server. The important constraints are monitored on any smart device connected under the same network. The proposed system enables users to boost monitoring of health-related risks [16]. A research study was presented with the objective of developing an IoT-based health observing arrangement which measures temperature, heart rate, and blood pressure of a patient distantly by means of different sensors and sends data to the doctor for checkup the patient condition. The optical light sensor is used to check light condition in the patient room, on the basis of which light can be controlled (ON/OFF). The system is instigated using BeagleBone Black development board and GSM module, and the patient data are sent to the cloud over which the doctor can screen the parameters anywhere using a web page or smart phone application [17]. The study proposed a method using different sensors like temperature and heartbeat oxygen level sensor to monitor patient body temperature and heart rate by connecting to the ARM controller. Further, the controller is connected to the ESP8266 built-in Wi-Fi module, to trace the patient health microcontroller perfectly interfaced to LCD digital exhibition and Wi-Fi association to send the data to the android application using web server. In case of irregular changes in patient heart rate or dynamic signal, an alert is sent to the patient using IoT which is mostly based on an android application. This application furthermore displays the patients' temperature and heartbeat traced live information with timestamps over the Internetwork [18]. A system comprising different sensors to measure health parameters like temperature and heart rate as input has been proposed [19]. Responses taken from sensors are managed in raspberry pi and presented on LCD. The device in the proposed system sends data over internet through a sever by creating entrance on raspberry pi so that the doctor uninterruptedly monitor the health condition of the patient, and also at patient side a camera is set to check the live status of the patient on the internet by the doctor. An android application and a web application were planned to access the sensor data any time they need so. A research work was presented for the implementation of health monitoring device using LilyPad Arduino microcontroller, pulse sensor and ESP8266 built-in Wi-Fi module [20]. The system is developed for checking the temperature and heart rate of a



patient. The LilyPad temperature sensor measures the body temperature and pulse sensor measures the heart rate of a patient. The data measured by LilyPad are shifted to the Wi-Fi module; furthermore, it transfers the taken data wirelessly to the android smart phone. The study describes a system which monitors the person health through different sensors like temperature and heartbeat sensors [21]. This wearable device measures the main health parameters like temperature and heart rate of a person using different sensors like temperature and heartbeat sensors. Whenever there is any change found in the health parameters like temperature and heart rate, the proposed system sends an SMS containing health information including person location and health parameters in the message.

A research work was presented with the focus of building an android-based application using the concept of IoT [22]. The system monitors temperature and pulse rate and generates ECG using different sensors. Sensors takes data from the user body and sends it to the application of android smart phone. The system also sends a message to the guardian of the patient in case of an emergency, and an appointment is obtained for patient at the hospital. The important purpose of the study is to improve a health and protection system for dementia-affected patients with sensors like heartbeat sensor and temperature sensor. To get the patient's medical attributes at night and remote locality, a healthcare communication by means of GPS and Real Time Clock (RTC) for alarm for suppository technique is renewed. The main aim of this device is to send the affected person's health details via unguided media, and in case of unavailability of network, the data are stored into SD card. Moreover, given data are kept in cloud server or into memory card and transported to the PC and mobile for health care workers and clinicians [23]. The study presents a cell-phone-based wireless healthcare monitoring system that can give real-time information about patient health [24]. The suggested system is considered to measure and monitor important parameters like heartbeat, temperature, muscles, blood pressure, blood glucose level, and ECG data of a patient to correctly define his/her health status and fitness. This system consists of different sensors, data acquirement, and microcontroller (Arduino). Furthermore, the planned system sends a message about the patient's critical health data through text message or e-mail report. With the assistance of the enclosed statistics, healthcare qualified staff offers essential medicinal counseling. The calculated data are checked, displayed, and stored by the system. A system was designed with different sensors applied on a patient body, and composed data from sensors are sent to the smart phone [25]. Mobile application is used to show parameters like heart rate, temperature, and blood pressure. The smart phone is connected to the server to update the complete data in the server. By using GSM module, a message is sent to the doctor and if the patient is in serious condition, then the doctor can react instantly and visit the patient. With the help of this system, all the patients in the hospital are monitored and proceedings of patients are stored in the database which are easily accessible. A smart mask incorporated with a remote, noncontact multiplexed sensor device is designed

for monitoring respiration sicknesses, which includes COVID-19 [26]. The system has used different sensors to screen the coronary heart rate, blood oxygen inundation, blood pressure, and body temperature related with symptoms of pneumonia created by coronaviruses in real time. Due to this remote tracking device, frontline healthcare workforce can reduce the contact they have from being in touch with the patients condensing the threats of being infected. In this research, authors presented a mobile-based method to widely as well as automatically trace the interactions of COVID-19 confirmed cases [27]. The goal of this analysis is to make a proficient dataset of X-ray and CT scan images from several sources and provide convenient but efficient COVID-19 finding procedure based on deep learning and transfer learning algorithm. The experimental outcomes indicate that the utilized models are accurate up to 98 percent through pretrained network. It was also found that it provides accuracy up to 94.1 percent by using modified convolution neural network. A novel framework is presented in this study to diagnose COVID-19 on the basis of different available built-in sensors in mobile phones [28]. The proposed device is economical and affordable. The device is based on the smart phones because of increased usage by healthcare workers as well as by general public. With the help of AI-based techniques, the data from the sensors are recorded in order to check the level of pneumonia along with forecasting the consequences of the disease.

### 3. The Proposed System

In the proposed system, a portable device has been presented in order to help people fight against the COVID-19 pandemic. The system consists of NodeMCU ESP8266 with built-in Wi-Fi module and an android application both for user and an admin (Doctor). The main COVID-19 symptoms like temperature and heartbeat are measured using DHT11 and pulse sensor, respectively. After reading the data, it is processed in the NodeMCU and sent to the firebase database. By applying different conditions on the user's data, the system will notify the user from time to time. In case of an emergency, the user will be warned by using red LED and a buzzer, while the admin will be notified by an email containing the user's temperature, heartbeat, and current location. For normal conditions, a green LED is used as an indicator. As we know that social distancing plays a vital role in controlling the COVID-19 pandemic. So, we used an ultrasonic sensor in order to enable the user to keep him/her away from other people. If the distance between the user and other person is less than a certain condition, the user will be notified by using red LED and a buzzer, also for alerting the user while touching his/her face. In order to keep the people aware of real-time data related to COVID-19 about different countries, the COVID-meter is used in the system. It is based on the disease.sh-Open Disease Data API. The proposed device can be used both in populated and rural areas, but in rural areas it will be much more important because people are unable to reach doctor on time; thus, they can check their health conditions remotely using the proposed device.



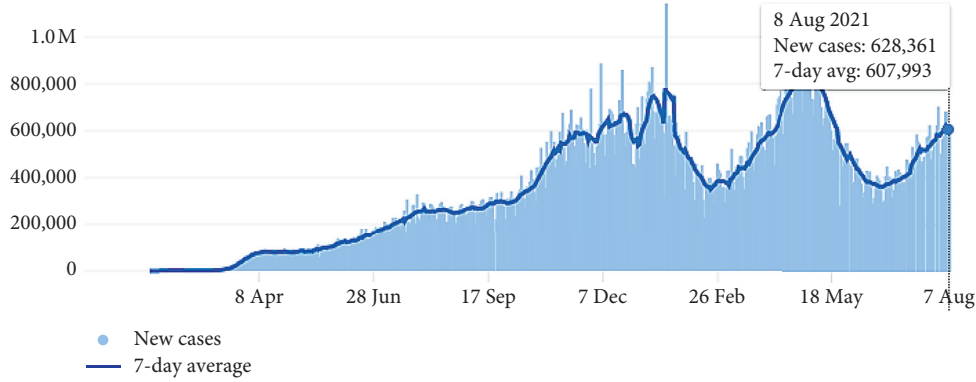


FIGURE 1: New cases around the world [29].

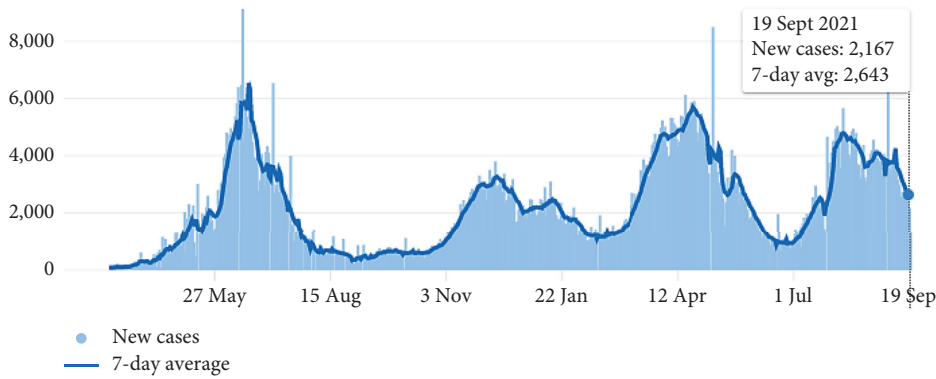


FIGURE 2: New cases statistics [29].

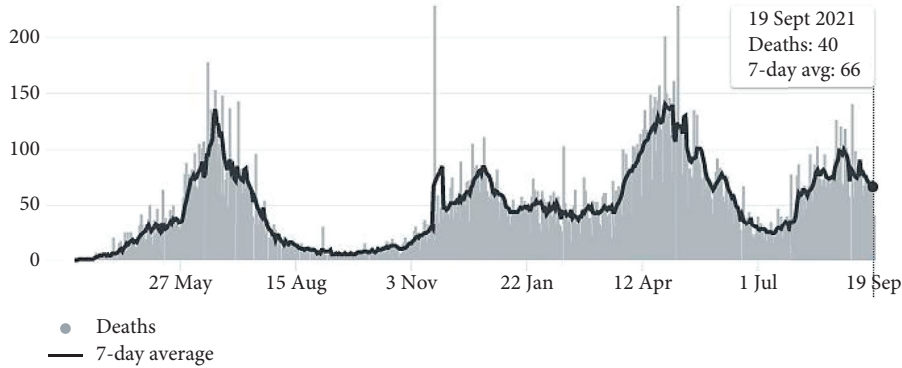


FIGURE 3: Death statistics [29].

Figure 1 shows the cases of COVID-19 infected patient around the globe [29].

Figure 2 represents the new cases statistics of Pakistan.

Figure 3 shows the death statistics of Pakistan.

Figure 4 represents the flowchart of the proposed system which shows the working of separate activities in a sequential order. The figure represents the working of hardware and android application of the proposed system. First of all, the user will need to connect the hardware with the available internet network. After that, the device will start sending data recorded from sensors to the firebase database. The user has to login to the android application in order to check the temperature and heartbeat data read from the

firebase. Different conditions are applied on the data in order to keep the user along with the doctor aware of the health status of the user.

## 4. Methodology

**4.1. System for Monitoring the Temperature.** Temperature represents an indication if a body is hot or cold. It shows the average kinetic energy of particles presented in an object. The normal human body's temperature ranges from 36.5–37.5°C, and fever is greater than 37.5°C or 38.3°C. For the measurement of temperature, we have used DHT11 sensor in our device. It is an inexpensive digital sensor for

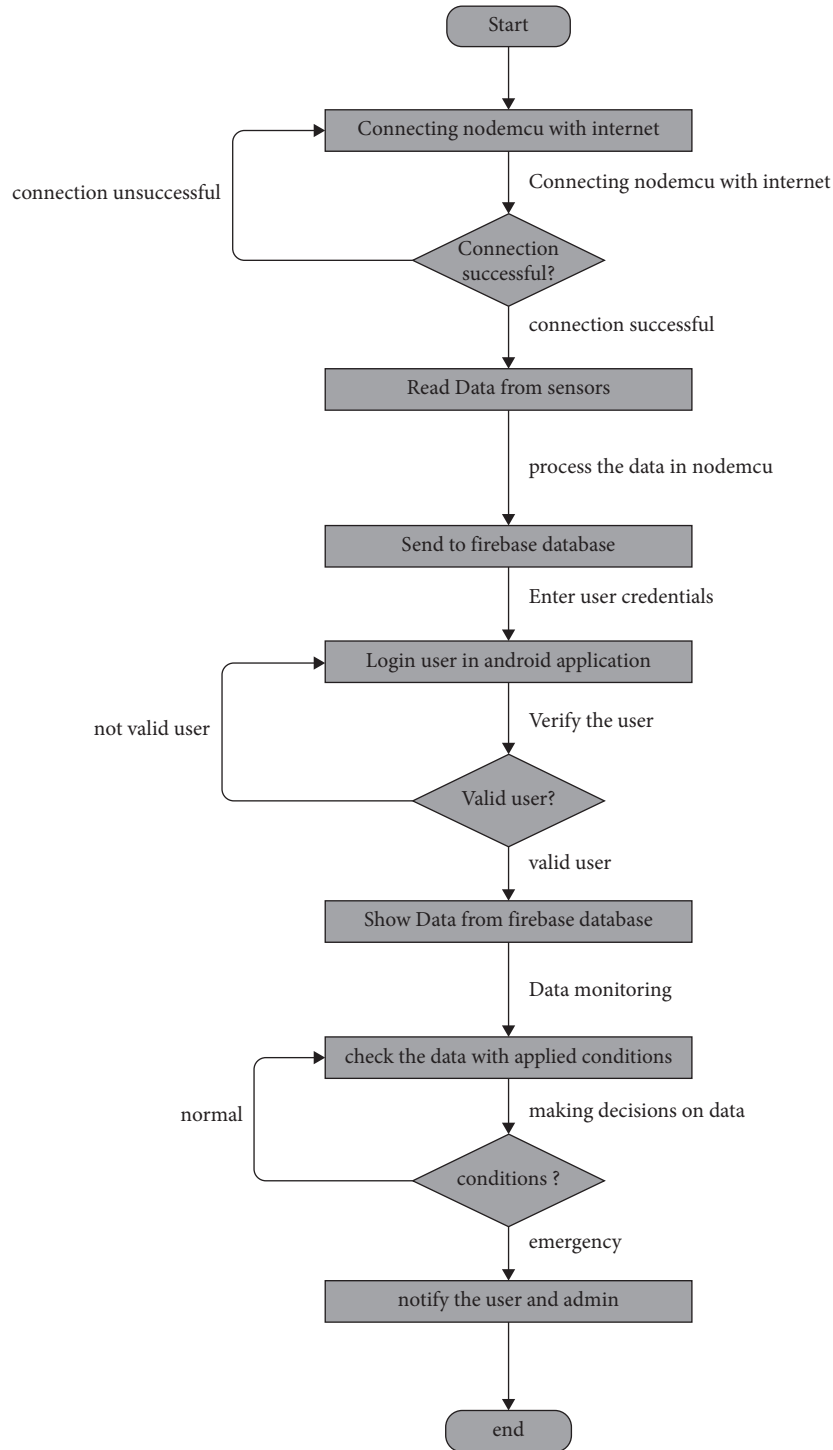


FIGURE 4: Flowchart of the overall activities of the proposed system.

sensing temperature as well as humidity. For measuring temperature, this sensor makes use of a negative temperature coefficient thermistor, which reasons a reduction in its resistance value with boom in temperature. To get greater resistance value even for the smallest alternate in temperature, this sensor is normally crafted from semiconductor ceramics. The temperature range of DHT11 is from zero to fifty degree Celsius using a two-degree accuracy [30].

Algorithm 1 shows the procedure of reading temperature from the DHT11 sensor.

**4.2. Monitoring Heartbeat.** Heart is a muscular organ that pumps oxygen-rich blood to the overall body. Normal heart rate for a resting person is 70 bpm for male adults and 75 bpm for female adults. The heart rate shows the

```

Step 1: start.
Step 2: [check NodeMCU connection].
If(connected) {
  Read temperature of the user.
} else {
  NodeMCU connection failed.
}
Step 3: [read the temperature].
Get data from DHT11 sensor.
Step 4: send the temperature data to firebase real-time database.
Step 5: display the data in user and admin android application.
Step 6: check the data with applied conditions.
Step 7: if (temperature > normal) {
  Buzzer = ON.
  Red LED = ON.
  Notify the user and admin.
} else {
  Green LED = ON.
}
Step 8: repeat steps 3 to 7.
Step 9: end.

```

ALGORITHM 1: Procedure to read temperature from DHT11 Sensor.

```

Step 1: start.
Step 2: [check NodeMCU connection].
If(connected) {
  Read heartbeat of the user.
} else {
  NodeMCU connection failed.
}
Step 3: [read the heartbeat].
Get data from pulse sensor.
Step 4: send the heartbeat data to firebase real-time database.
Step 5: display the data in user and admin android application.
Step 6: check the data with applied conditions.
Step 7: if (heartbeat > normal) {
  Buzzer = ON.
  Red LED = ON.
  Notify the user and admin.
} else {
  Green LED = ON.
}
Step 8: repeat steps 3 to 7.
Step 9: end.

```

ALGORITHM 2: Procedure to read heartbeat from pulse sensor.

soundness of the heart and overall cardiovascular system. For measurement of heartbeat, a pulse sensor is used. It is a plug-and-play sensor for the measurement of heartbeat placed on the top of a vein at fingertip or earlobe. The light in the pulse sensor helps in the measurement of heartbeat by using the reflection of light. The light reflected from the body will reveal any alteration grounded on the volume of blood inside the capillary blood vessels. The variation of blood in the capillary vessels will cause changes in the reflection of light, which is used for the calculation of heartbeat.

Algorithm 2 represents the procedure of reading heartbeat from pulse sensor.

4.3. *Social Distancing to Prevent COVID-19.* As COVID-19 pandemic is an infectious disease and can spread from one person to another very speedily. So social distancing can play a very important role in order to keep people safe from the infected patients of COVID-19. To help the people in following the social distancing, an ultrasonic sensor is used in

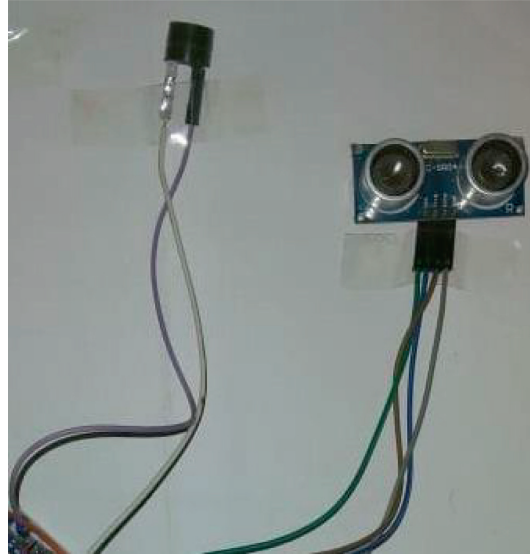


FIGURE 5: Procedure to calculate the distance from ultrasonic sensor.

```

Step 1: start.
Step 2: [check NodeMCU connection].
If((connected) {
  Calculate the distance.
} else {
  NodeMCU connection failed.
}
Step 3: [calculating distance].
Get data from ultrasonic sensor.
Step 4: check the data with applied conditions.
Step 5: if (distance > normal) {
  Buzzer = ON.
  Red LED = ON.
  Notify the user and admin.
} else {
  Green LED = ON.
}
Step 6: repeat steps 3 to 7.
Step 7: end.

```

ALGORITHM 3: Work of an ultrasonic sensor.

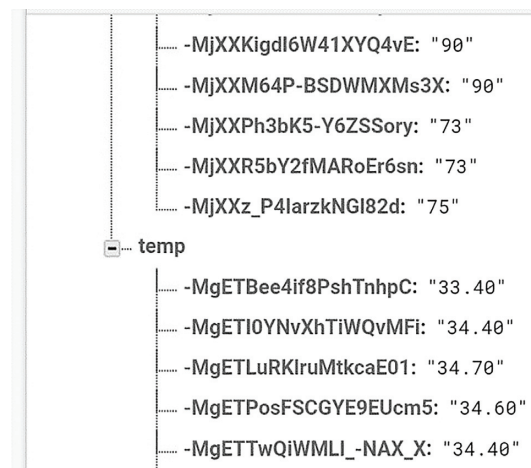


FIGURE 6: Firebase database.

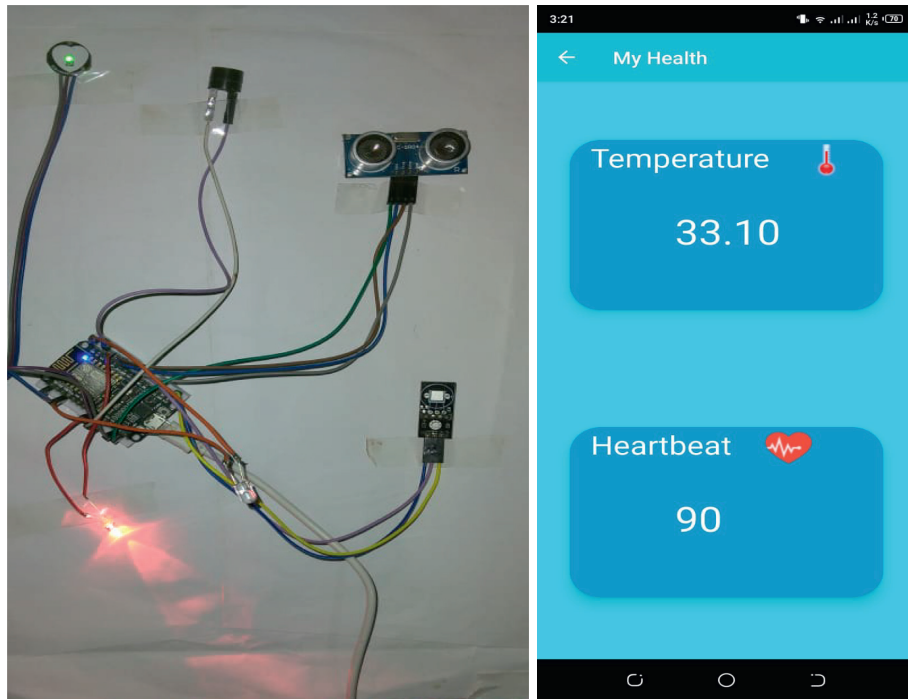


FIGURE 7: Proposed system configuration.

the device as part of the proposed system. The ultrasonic sensor is used in order to find the distance of a target object with the use of ultrasonic sound waves, transforming the reflected waves to an electrical signal. A single transducer is used in the sensor in order to send the pulse towards the target and receive the echo back. The distance is measured by calculating the time lapses among the sending and receiving ultrasonic pulse. Figure 5 depicts the procedure to calculate the distance from ultrasonic sensor.

Algorithm 3 depicts the work of an ultrasonic sensor in order to find out the distance between the person and the target.

**4.4. Firebase Database.** All the data of the proposed system were stored on the firebase real-time database which is a cloud-hosted NoSQL database and allows the developers to store and sync data among the users in real time. The data are stored in the form of JSON object and updated in real time with every connected client. Google Analytics allows to check how the end users interact with your product. Although firebase is not more secure than MySQL, it is faster and allows the user authentication, reset of password, and verification e-mail services without connecting to the server. Figure 6 shows the health data stored in firebase database.

**4.5. System Configuration.** The proposed system presents a wearable, cheap, and easy-to-use device in order to easily and effectively detect and prevent COVID-19 and enhance the healthcare system. Figure 7 shows the system configuration of the proposed system. In the figure, on the left side, the configuration of wearable devices for the proposed

system is used, while on the right side the software application is shown where the temperature and heart beat score is shown.

## 5. Results and Discussions

The key goal of the proposed system is to improve the remote health monitoring system against the COVID-19 pandemic by measuring the main symptoms of COVID-19 like temperature and heartbeat by using the DHT11 and pulse sensor, respectively, integrated with NodeMCU ESP8266 built-in Wi-Fi module and an android application both for end user and an admin (Doctor). For keeping the social distancing, an ultrasonic sensor is used and for current location tracking android location services are used. The last two decades have seen growing interest in development of health care system using android and IoT-based platforms for the remote monitoring of patients. Our analysis on this project shows that there have been very few automated and portable devices for the prevention and detection of COVID-19 symptoms. We can also get the data of COVID-19 related to different countries by using disease.sh-Open Disease Data API. The proposed architecture has been enclosed in a mask and tested on a several specimens as shown in Table 1. The results show that the device is very effective to be used in the COVID-19 pandemic. Technology has now directly or indirectly affected our lives and the bond between people and technology is becoming strong day by day. With the proposed system, people will take full advantage and will keep themselves safe from COVID-19 along with other diseases. Table 1 shows the data recorded from the volunteers by using this wearable device. In

TABLE 1: Recorded data.

Test specimens	Heartbeat (BPM)	Temperature (°C)
A	72	34.20
B	76	36.80
C	77	36.90
D	82	39.40
E	71	35.80
F	70	34.60
G	88	35.90
H	90	36.70
I	75	35.00
J	72	38.30
K	79	36.90
L	85	35.40
M	90	37.70
N	78	35.60
O	73	36.10
P	77	38.30
Q	84	37.80
R	80	35.00
S	90	33.10

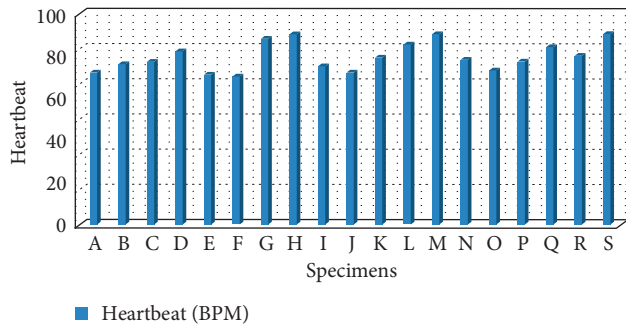


FIGURE 8: Graphical representation of heartbeat.

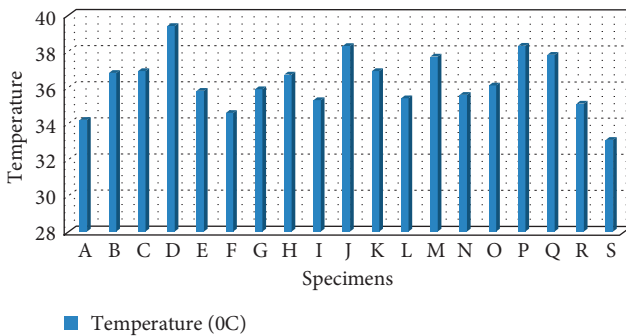


FIGURE 9: Graphical representation of temperature.

order to check the working and performance of the proposed device, it was tested on several volunteers. The recorded data were very impressive in terms of accuracy and precision. Table 1 shows that read data of the experiment.

Figure 8 briefly shows the pictorial representation of the recorded heartbeat data via chart.

Figure 9 depicts the pictorial representation of recorded temperature via chart.

## 6. Conclusions

The developed device steadfastly records the temperature and heartbeat of the patient and sends it to both the patient and admin inside the android application and help in remote monitoring of the patient. The device can be used in normal conditions as well, but it is more suitable for the situations like COVID-19 pandemic where going to the clinic or hospital is a great risk to the health of patients as well as other people. By tracing the current location of the patient, it helps the doctor find the infected person as well as make statistics about the COVID-19 cases in that particular area. The device will help the frontline workers against COVID-19 to perform their duties without any worries. The proposed device is very cheap and affordable. It can be used very efficiently in the detection and prevention of COVID-19.

## Data Availability

No data were used to support this study.

## Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this study.

## References

- [1] M. Ciotti, M. Ciccozzi, A. Terrinoni, W.-C. Jiang, C.-B. Wang, and S. Bernardini, "The COVID-19 pandemic," *Critical Reviews in Clinical Laboratory Sciences*, vol. 57, no. 6, pp. 365–388, 2020.
- [2] V. R. Parihar, A. Y. Tonge, and P. D. Ganorkar, "Heartbeat and temperature monitoring system for remote patients using Arduino," *International Journal of Advanced Engineering Research and Science*, vol. 4, no. 5, Article ID 237161, 2017.
- [3] R. Karthikamani, P. Y. Prasath, M. V. Sree, and J. Sangeetha, "Wireless patient monitoring system," *International Journal of Scientific & Technology Research*, vol. 8, no. 8, pp. 1081–1084, 2019.
- [4] M. W. Alam, T. Sultana, and M. S. Alam, "A heartbeat and temperature measuring system for remote health monitoring using wireless body area network," *International Journal of Bio-Science and Bio-Technology*, vol. 8, no. 1, pp. 171–190, 2016.
- [5] N. Mutha, E. Meel, R. Rokade, and P. G. Deshmukh, "Patient health monitoring using android application," *International Journal of Innovative Research in Computer And Communication Engineering*, vol. 4, no. 3, 2016.
- [6] N. H. Wijaya, F. A. Fauzi, E. T. Helmy, P. T. Nguyen, and R. A. Atmoko, "The design of heart rate detector and body temperature measurement device using ATmega16," *Journal of Robotics and Control (JRC)*, vol. 1, no. 2, pp. 40–43, 2020.
- [7] M. A. Miah, M. H. Kabir, M. S. R. Tanveer, and M. A. H. Akhand, "December. Continuous heart rate and body temperature monitoring system using Arduino UNO and Android device," in *Proceedings of the 2015 2nd International Conference on Electrical Information and Communication Technologies (EICT)*, pp. 183–188, IEEE, Khulna, Bangladesh, December 2015.
- [8] C. K. Das, M. W. Alam, and M. I. Hoque, "May. A wireless heartbeat and temperature monitoring system for remote



- patients,” in *Proceedings of the International Conference on Mechanical Engineering and Renewable Energy*, Sikkim, India, December 2013.
- [9] C. Senthilarasi, J. J. Rani, B. Vidhya, and H. Aritha, “A smart patient health monitoring system using IoT,” *International Journal of Pure and Applied Mathematics*, vol. 119, no. 16, pp. 59–70, 2018.
  - [10] G. Kavya, P. Sasireka, S. Ganesh, M. Gopinath, A. Jafar Hussain, and K. J. Kumar, “Android app based human pulse monitoring system,” *Fronteiras ? Estudos Midiáticos*, vol. 6, 2017.
  - [11] P. A. A. Bughio, F. H. Chandio, H. F. Naqvi, and A. A. Bughio, “HelpMe-App: android based health management system,” *University of Sindh Journal of Information and Communication Technology*, vol. 2, no. 2, pp. 130–134, 2018.
  - [12] P. Kaviya, “Intelligent healthcare monitoring in IoT,” *International Journal of Advanced Engineering, Management and Science*, vol. 4, no. 6, 2018.
  - [13] Z. M. Kalarthi, “A review paper on smart health care system using internet of things,” *International Journal of Research in Engineering and Technology*, vol. 5, no. 3, Article ID 8084, 2016.
  - [14] A. Abu Bakar, S. S. A. Rahim, A. R. Razali, E. Noorsal, R. Radzali, and A. F. Abd Rahim, “Wearable heart rate and body temperature monitoring device for healthcare,” *Journal of Physics: Conference Series*, vol. 1535, no. 1, Article ID 012002, 2020.
  - [15] U. Gogate, M. Marathe, J. Mourya, and N. Mohan, “Android-based health monitoring system for cardiac patients,” *International Research Journal of Engineering and Technology (Irjet)*, vol. 4, no. 4, pp. 1628–1634, 2017.
  - [16] S. K. Polu and S. K. Polu, “IoMT based smart health care monitoring system,” *International Journal for Innovative Research in Science & Technology*, vol. 5, no. 11, pp. 58–64, 2019.
  - [17] K. D. Saranya, R. Krishnamurthy, K. N. H. Srinivas, T. S. Rao, and I. S. Amiri, “IoT-based health monitoring system using BeagleBone Black with optical sensor,” *Journal of Optical Communications*, 2019.
  - [18] G. U. K. Akash, M. Rathod, and R. S. Bansode, “IOT based patient monitoring system,” *International Research Journal of Modernization in Engineering Technology and Science*, vol. 2, no. 7, 2020.
  - [19] A. Kumar, G. Chattree, and S. Periyasamy, “Smart healthcare monitoring system,” *Wireless Personal Communications*, vol. 101, no. 1, pp. 453–463, 2018.
  - [20] K. Ajithkumar, P. Nallusamy, and T. Suriyaraj, “Wi-Fi based health monitoring system using LilyPad,” *GRD Journal for Engineering*, vol. 3, 2018.
  - [21] V. V. Mali and D. M. Chandwadkar, “Wearable system for vital signs measurement,” *International Research Journal of Engineering and Technology*, vol. 4, 2017.
  - [22] S. R. Pindiprolu, H. Marathe, M. R. Mallesh, M. S. Palase, and P. Kulkarni, “Smart health monitoring system using sensors,” *International Journal on Recent and Innovation Trends in Computing and Communication*, vol. 5, no. 12, pp. 54–56, 2017.
  - [23] A. Babar, K. Jadhav, M. Vispute, and S. Daundkar, “Health monitoring system for dementia affected patients using RTC,” *Mukt Shabd Journal*, vol. 13, 2020.
  - [24] A. Abdullah, A. Ismael, A. Rashid, A. Abou-ElNour, and M. Tarique, “Real time wireless health monitoring application using mobile devices,” *International Journal of Computer Networks & Communications*, vol. 7, no. 3, pp. 13–30, 2015.
  - [25] V. Shiva and T. Anuradha, “Patient Monitoring and Spontaneous alerting system using ADT,” *Indian Journal of Science and Technology*, vol. 9, no. 30, 2016.
  - [26] L. Pan, C. Wang, H. Jin et al., “Lab-on-mask for remote respiratory monitoring,” *ACS Materials Letters*, vol. 2, no. 9, pp. 1178–1181, 2020.
  - [27] H. S. Maghdid and K. Z. Ghafoor, “A smartphone enabled approach to manage COVID-19 lockdown and economic crisis,” *SN Computer Science*, vol. 1, no. 5, pp. 271–279, 2020.
  - [28] H. S. Maghdid, K. Z. Ghafoor, A. S. Sadiq, K. Curran, D. B. Rawat, and K. Rabie, “A novel AI-enabled framework to diagnose coronavirus COVID-19 using smartphone embedded sensors: design study,” in *Proceedings of the 2020 IEEE 21st International Conference on Information Reuse and Integration for Data Science (IRI)*, pp. 180–187, IEEE, Las Vegas, NV, USA, August 2020.
  - [29] “Covid-19 world statistics-google Search,” 2009, [https://www.google.com.pk/search?q=covid-19+world+statistics&sxsrf=AOaemvJuD4imJaM1EspH6m\\_ADSwhRDKEBA%3A1632157665969&source=hp&ei=4b9IYdTFONGK4-EPo66aUA&ifsig=ALs-wAMAAAAAYUjN8YnyHwrVekwrAAZrSsn6WMoYc4G4&oq=covid-19+world+s&gs\\_lcp=Cgdnd3Mtd2l6EAMYADIFCAAQgAQyBQgAEIAEMgUIABCABDIFCAAQgAQyBQgAEIAEMgUIABCABDIFCAAQgAQ6BAGjECc6BQguEJECCoggIABCxAXCRAjoLCAAQgAQQsQMqgwE6CAGAEIAEELEDOhEILHCABBCxAXCDARDHARDRAzoFCAAQkQI6BQguEIAEUJIHWPAYMhJaABwAHgAgAHTAogBhRiSAQYyLTEwLjKYAQcGAE&scient=gws-wiz](https://www.google.com.pk/search?q=covid-19+world+statistics&sxsrf=AOaemvJuD4imJaM1EspH6m_ADSwhRDKEBA%3A1632157665969&source=hp&ei=4b9IYdTFONGK4-EPo66aUA&ifsig=ALs-wAMAAAAAYUjN8YnyHwrVekwrAAZrSsn6WMoYc4G4&oq=covid-19+world+s&gs_lcp=Cgdnd3Mtd2l6EAMYADIFCAAQgAQyBQgAEIAEMgUIABCABDIFCAAQgAQyBQgAEIAEMgUIABCABDIFCAAQgAQ6BAGjECc6BQguEJECCoggIABCxAXCRAjoLCAAQgAQQsQMqgwE6CAGAEIAEELEDOhEILHCABBCxAXCDARDHARDRAzoFCAAQkQI6BQguEIAEUJIHWPAYMhJaABwAHgAgAHTAogBhRiSAQYyLTEwLjKYAQcGAE&scient=gws-wiz).
  - [30] T. Agarwal, “DHT11 sensor definition, working and applications, elprocus,” <https://www.elprocus.com/a-brief-on-dht11-sensor/>.

## Research Article

# Agent-Based Simulators for Empowering Patients in Self-Care Programs Using Mobile Agents with Machine Learning

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E-health sustainable systems can be optimized by empowering patients in self-care programs through artificial intelligence ecosystems in which both doctors and patients interact in an agile way. This work proposes agent-based simulators as a mechanism for predicting the repercussions of certain self-care programs in certain patients for finding the most appropriate ones. In order to make this easy for both doctors and patients, mobile agents are used to configure an app for each patient, and this app provides the resources to each self-care program. Mobile agents include a machine-learning module for learning which programs are the most appropriate for each patient. This approach is illustrated with two agent-based simulators for respectively reducing negative emotions such as depression and controlling heart rate variability extreme values related to stress. The resulting app was evaluated with a group of users with the Usefulness, Satisfaction and Ease of use (USE) scale and obtained 73% in usefulness, 77% in satisfaction, and 68% in ease of use. This trial is registered with According to the recommendations of the International Committee of Medical Journal Editors (ICMJE), this manuscript states that all experiments have been approved with the ethical committee CEICA from Community of Aragon (Spain) with registration number C.I.PI18/099.

## 1. Introduction

E-health sustainable systems can be supported by providing tools to instruct patients in conducting self-care programs [1]. Self-care behaviors are important in patients with heart failures to avoid the progression of their diseases. In a similar way, self-care programs can help in motor rehabilitation [2], as one can observe in the effects of the studies with augmented-reality and virtual-reality applications and serious games for this purpose. In the context of emotions, self-care mindfulness programs have an influence on pain relief [3] and reduction of anxiety [4]. Self-care programs can be especially useful for patients with chronic conditions for achieving sustainable primary care [5].

Mindfulness has proved to have several benefits in health indicators. Demarzo et al. [6] presented a theoretical review of the mechanisms for including mindfulness-based interventions in healthcare systems. They encouraged the development of mobile applications for providing introductory courses of mindfulness for patients. A recent study has proven that mindfulness programs reduce anxiety in students in the COVID-19 pandemic circumstances [7].

Although self-care programs are well known, the simulation of their repercussion on specific patients given their initial features remains a challenge. In this research line, our previous works about agent-based simulators (ABSs) for simulating mindfulness programs reveal the potential utility for estimating this mindfulness repercussion in patients with

certain features. An ABS is a multiagent system composed of autonomous entities that simulate the interactions and evolution of several actors in an environment, usually for predicting a future outcome departing from an initial setting [8]. In particular, we developed and validated an ABS of emotions in mindfulness programs (ABSEM) [9] and an ABS of the influence of mindfulness programs on heart rate variability (HRV) called ABS-MindHeart [10]. However, these systems lacked the proper mechanism for transferring self-care programs into an app that could guide patients. It also lacked the proper machine-learning (ML) mechanism for improving the initial configuration of these programs and the supervised learning for adapting to users' needs based on their feedback.

In this context, this work proposes the usage of ABSs in combination with ML for providing a customized experience for patients extracting knowledge from doctors or instructors through mobile agents. More concretely, ABSs allow simulating the effects of certain self-care programs in patients. Mobile agents use the selected self-care programs to instruct patients through mobile apps with resources for guiding different exercises. These mobile agents use ML for improving their programs through supervised learning from the specific patient, as well as for initial configuration learned from existing datasets. The main contribution of this work is the integration of ABSs and ML as a mechanism for improving the user experience of apps for empowering self-care programs by properly predicting the effects of different programs and guiding the user through the selected one.

The remainder of the article is organized as follows: the next section introduces the related work highlighting the gaps of the literature covered by this work. Section 3 introduces the proposed approach for using ABSs for empowering the selection of self-care programs, its transmission to a mobile app through mobile agents for guiding patients, and ML for a customized experience, illustrated with mindfulness self-care programs. Section 4 focuses on the experimentation of the novel parts of this approach discussing the most relevant findings. Section 5 mentions the main conclusions and depicts some future research lines.

## 2. Related Work

**2.1. Mobile Agents.** Mobile agents have raised several problems from the perspective of theoretical computer science. Among others, one of these problems is the partial gathering of mobile agents. In this problem, agents should move to a node and terminate so that each node has at least a certain number of agents at the end. Shibata et al. [11] proposed three algorithms for solving this problem. One algorithm is randomized, while the others are deterministic. They prove that the movement complexities of two of these algorithms are asymptotically optimal. One of these optimal solutions is randomized, while the other requires a unique identifier for each agent. The remaining algorithm is deterministic and does not require unique identifiers, but its complexity has not proven to reach asymptotic optimality. Moreover, Dereniowski et al. [12] introduced the rendezvous problem for two heterogeneous mobile agents in an

undirected graph. These are required to traverse certain edges at different times. These know the whole graph and the initial positions of both agents, but each agent ignores the traversal times of the other agent. The evaluation compares the meeting time of this problem with the meeting time in the offline scenario where each agent has all the information about the other agent, such as its speed. The complexity of their solution is the optimal offline meeting time multiplied by the number of nodes. By contrast, the current approach is not aimed at solving a theoretical problem related to mobile agents. Instead, the current work is focused on simulating the specific repercussions of a practical domain-specific context of self-care programs (e.g., mindfulness programs), and the goal of the mobile agent is to customize an app with the appropriate mindfulness program after several simulations.

Mobile agents have also been used to solve the mobile user coordination problem. In this problem, users schedule and reschedule their tasks through mobile devices when they change their goals. In particular, Lin and Lin [13] formulated this problem as a multiobjective context-dependent distributed constraint optimization problem. In particular, they proposed a two-stage distributed optimality reaching approach and implemented it with a multiagent system (MAS) that integrated simulated and physical agents. They evaluate the performance of their approach with several experiments with a traveling backpacker problem. Both this work and the current one are related to mobile applications. However, that work is mainly focused on the coordination of the users, while the current one is aimed at simulating the influence of self-care programs on certain features of the practitioners.

**2.2. Applications for Supporting Self-Care Programs.** There are several mobile applications that support the practice of self-care programs, such as mindfulness programs. To begin with, Chittaro and Vianello [14] introduced an app for assisting mindfulness practitioners. This app is available from the main online stores. Their app has been experienced by a group of meditators with the app over a four-week period. The feedback of the participants showed their positive feelings about the usage of the app. In addition, AEON [15] is another app for supporting thought distancing in the context of mindfulness. Practitioners write their thoughts in the app. Then, the app shows their thoughts with a hand-writing appearance within the water. The app displays a smooth transition that dissolves these thoughts. This app increased the mindfulness and pleasantness of naive meditators compared to the common thought distancing technique with paper. However, these apps cannot be automatically customized from certain self-care programs. In addition, these works do not allow users to simulate the repercussions of distinct self-care programs for selecting the appropriate one and automatically adapting the app accordingly.

Moreover, other computer-based applications assist practitioners in training self-care programs. For instance, the work of Hudlicka [16] is aimed at virtually coaching the training of mindfulness. Her approach includes a conversational character that can maintain a natural-language dialog. It customizes the training plan for each user

according to their responses. Nonetheless, the customization of this work is not based on the simulation of several self-care programs for estimating their repercussions in certain features of practitioners.

**2.3. ABSs in Healthcare.** Some ABSs have been applied in healthcare. For example, Kim and Yoon [17] presented an ABS that estimates future trends of customers and strategies of firms. They applied their approach in the healthcare industry. In addition, Cabrera et al. [18] introduced an ABS for optimizing the healthcare emergency department. Their ABS supports the decisions of emergency department managers for designing the strategies for handling emergencies when prioritizing efficiency.

Furthermore, Macklin et al. [19] used an ABS for simulating the spread of cells with DCIS (ductal carcinoma in situ), which is a precursor to breast cancer. They consider the interactions of these cells with certain membranes. Their simulations assist researchers and doctors in understanding the growth and calcifications of DCIS. They assessed their approach by analyzing the differences between the simulated outcomes and the real ones from existing mammograms.

Thereupon, several ABSs have been applied in healthcare. These ABSs assist researchers in understanding certain diseases and support decisions for emergencies and industry in healthcare. However, none of these ABSs estimates the influence of self-care programs on health indicators.

**2.4. ML in Healthcare.** ML has been applied for healthcare in different contexts. Although ML brings advantages in the improvement of automatic recommendations, there are several challenges around the application of ML to healthcare [20], such as finding the appropriate pre-processing, model training based on appropriate data, and the refinement of the system according to the specific clinical problem. In fact, Futoma et al. [21] identified the myth of generalisability of the application of ML to healthcare. ML is usually applied in a given context with data collected in certain circumstances and can be useful in certain domains, but it may not work when applied in different domains, contexts, or circumstances. This motivates the current approach for exploring ML in particular contexts of self-care programs.

In the context of ML applied to self-care programs, the review of Fatehi et al. [22] showed that self-care programs are widely used in the context of diabetes and indicated that ML is likely to be applied for personalized recommendations as one of the future directions. In this domain, ML has been applied in predicting type 2 diabetes through a decision tree. Prediction of specific types of diabetes is one of the first steps towards personalized self-care programs. However, these approaches miss the usage of ML for actually recommending a self-care program with an app guiding each step of the customized program, as the current work does. The aforementioned approaches are more focused on the diagnosis and its treatment rather than customized self-care programs.

ML has also been applied to estimate specific information of patients for properly applying self-care programs.

For instance, ML was applied to estimate the indoor location of patients for properly applying the virtual care of patients [23]. Nevertheless, in this work, ML was not applied to directly obtain customized self-care programs based on the information of patients.

In conclusion, ML is considered to be one of the most promising lines for improving self-care although some challenges remain. In diseases such as diabetes, some ML approaches can estimate the type of diabetes for the application of the right treatment. In addition, ML can estimate some missing information such as the indoor location for properly applying virtual self-care. Nonetheless, to the best of the authors' knowledge, there is no approach for obtaining self-care programs in the psychological field by using ML combined with ABSs integrated with proper automatic guidance through appropriate resources. This gap in the literature is covered by the current approach presented in the next section.

### 3. ABSs for Empowering Patients in Self-Care Programs Using Mobile Agents with ML

**3.1. Overview.** An overview of the current approach is illustrated in Figure 1. The current approach is illustrated with two ABSs about self-care mindfulness programs. First, mABSEM simulates the repercussion of these programs on the emotions of practitioners. Second, mABS-Heart simulates the influence of these programs on the HRV of practitioners. The former ABS was firstly developed as a desktop application. Then, the latter ABS was developed as an app and an online tool to reach a wider range of users and places. Both ABSs followed the Process for developing Efficient ABSs (PEABS) [24] using its simulation engine and framework. In particular, mABSEM used the original framework of PEABS adapted for Java, while mABS-Heart needed to use an adaptation of this process and framework for developing apps.

In the current approach, both mABSEM and mABS-Heart have been adapted to be able to export mobile agents with mindfulness programs. In order to unify the format of the mobile agents, the current approach uses a unified unrolled simple text format. In fact, in both ABSs, the instructor agent automatically records the activities that are instructed for each session of the last simulation. In this way, each instructor agent can be exported as a mobile agent in both approaches with this unified unrolled text.

From an internal working perspective, a mobile agent is a plain-text code file in a simple domain-specific language, in which each line indicates one exercise. This file is transferred to the app. The app runs this mobile agent by considering each exercise and including it in the self-care program for guiding the patient. This file could be considered software in a domain-specific language defined by us. However, this language does not provide any instruction to access the user file system or communicate to any external source. Thus, there is no way that this mobile agent can be used to install any malware program on the user device as far as the authors know.

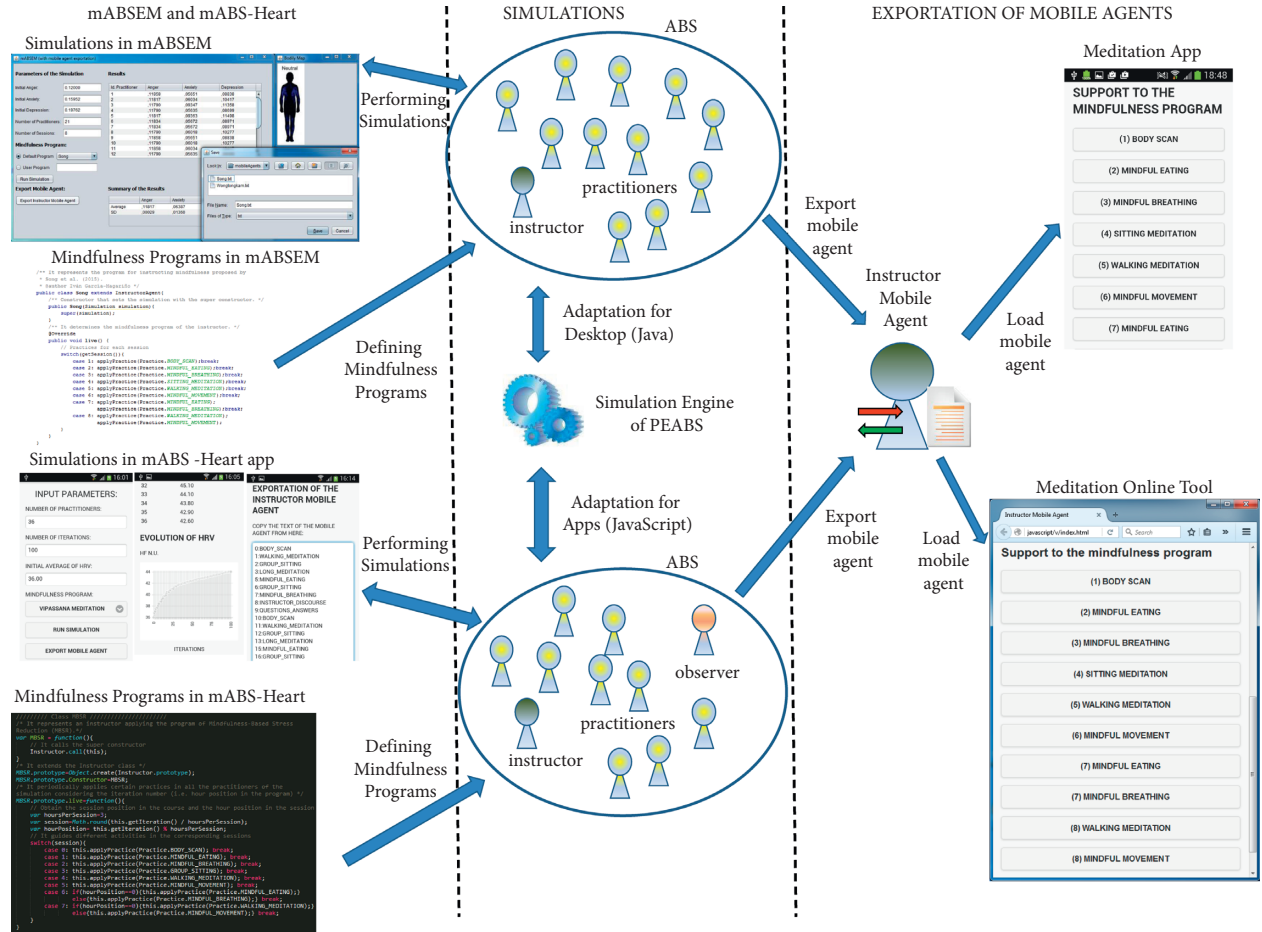


FIGURE 1: Overview of the current approach.

Finally, the mobile agent can be loaded in a meditation application for supporting mindfulness. The agent customizes the meditation application in order to support the particular mindful activities in the specific sessions. There are two versions of the meditation application: the first one is a mobile application, while the second is an online tool. In this way, the mobile agent can be loaded into an app or online tool and customize any of these applications.

In the proposed approach, the steps from the user viewpoint considering the aforementioned approach and its integration with ML are as follows: (1) The user selects which skill, aspect, or feature they would like to train from the available options; (2) the user replies the corresponding surveys for identifying their initial state; (3) the program applies ABS for providing information about existing programs and their potential impact; (3) the user selects a type of program; (4) the ML approach provides an expected impact of the selected training program, and the user can optionally return to the previous step; (5) the mobile agent guides the user in the application of the intervention considering the selected program; and (6) the user can optionally provide feedback for both improving the customized recommendation of the program and decreasing the errors considering their postintervention measurements.

**3.2. ML Module for Improving Self-Care Program Recommendations with Supervised Learning.** General knowledge can be useful in proposing new self-care programs at the first stage. However, users, even with similar features, may have specific preferences. Thus, this approach uses supervised learning for updating the ML model when having specific feedback from a given user.

This ML model uses regression for predicting the level of patient satisfaction for a given self-care program. The input features used for training the model are the number of activities of each exercise type in the self-care programs, the total duration of the self-care programs, and the initial states of patients (e.g., anxiety level). The programs are associated with the target feature of satisfaction provided by patients for training the model.

Figure 2 shows the block diagram related to this supervised learning. The user can optionally provide feedback of a given experienced self-care program in the app, and this supervised learning will be used to update the local ML learned model, customizing the predictions considering the particular user.

In order to have a noticeable impact on the ML model, this model applies a weighting mechanism based on adding the same case from the user a certain number of times. The



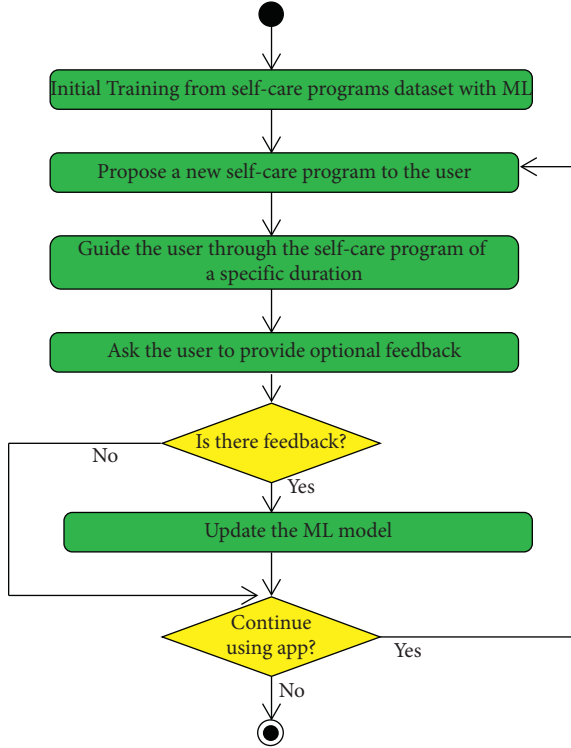


FIGURE 2: Block diagram of the ML module for improving self-care programs with supervised learning.

number of additions of the same case is calculated considering the total size of the initial dataset and the confidence of the user on their feedback.

In particular, we applied the following formula for calculating the number of times to add a case in supervision for weighting it up:

$$n = K * |T| * \frac{c - c_{\min}}{c_{\max} - c_{\min}} + 1, \quad (1)$$

where  $n$  is the number of cases added for the ML,  $K$  is a constant value (e.g., 0.10 standing for 10%),  $|T|$  is the size of the original training dataset,  $c$  is the confidence of the user (usually in five-point Likert scale), and  $c_{\min}$  and  $c_{\max}$  are the minimum and maximum limits of the used confidence Likert scale.

In the case of using natural-language text as input, such as the written comments of patients, this methodology proposes applying ELMo and Bidirectional Encoder Representations from Transformers (BERT). These techniques use word embedding strategies for capturing not only the words but also the semantic and syntactic similarity relations with other words.

**3.3. mABSEM.** Figure 3 shows the user interface of mABSEM. The “Export Instructor Mobile Agent” button allows the user to export the mobile agent and saves it on a file with the preferred name and location selected through a file chooser. In order to facilitate the exportation of the instructor mobile agent from different possible applications, the current approach has selected a simple unrolled notation

text. In this way, the self-care mindfulness programs of ABSEM can be exported as shown in the current approach, and the ABS-Heart app can export self-care mindfulness programs. Notice that the instructor agents are represented with different programming languages in these two ABS. In particular, ABSEM and ABS-Heart, respectively, use Java and JavaScript.

The mobile agent is represented with an unrolled representation of the mindfulness program. It just contains several lines, and each line determines a session number and the activity type separated by a colon. If there is a session with several activities, it is represented with several lines in which the session number is repeated. If an activity takes more than one session, this activity is only associated with the first session, and it is assumed that the practitioner continues with this activity until there is another explicit activity in the program.

Figure 4 presents a relevant excerpt of the class diagram of mABSEM. The different instructor agent types can be defined by extending the abstract “Instructor Agent” class. The different instructor types (e.g., the Song class and the Wongtongkam class) only need to implement the live method. This method can access the session number by the “Get Session” method. It can apply different mindfulness practices by calling the “Apply Practice” method with values of the “Practice” enumeration.

The Instructor Agent class internally manages the internal representation of the instructor mobile agent for all its subclasses in a transparent way. In this way, developers do not need to perform any specific action for making specific instructor agents available as mobile agents.

In each simulation, the instructor agent is created, and the constructor starts with an empty representation of the schedule of the mindfulness program. Each time the “Apply Practice” method is called from any subclass, the parent class records the session number and the practice identifier name, with the particular textual notation. After the simulation, when the instructor agent is required to move, the parent class provides this schedule as the unrolled representation of the mobile instructor agent with all the necessary information about the application of practices for a given number of iterations.

**3.4. mABS-Heart.** The influence of self-care mindfulness programs on HRV is simulated with mABS-Heart. Figure 5 presents the most relevant parts of the interface of this simulator. As one can observe in the initial interface of Figure 5(a), this system receives input from the self-care mindfulness program, the number of practitioners, the number of iterations, and the initial average of HRV measured with the high-frequency power in the normalized unit (HF n.u.). The initial interface has buttons for, respectively, running the simulation and exporting the instructor agent as a mobile one.

This system simulates the evolution of HRV considering different influences for the particular mindful activities. Among other aspects, it takes into account the integral of the normal distribution with the mean centered in the initial



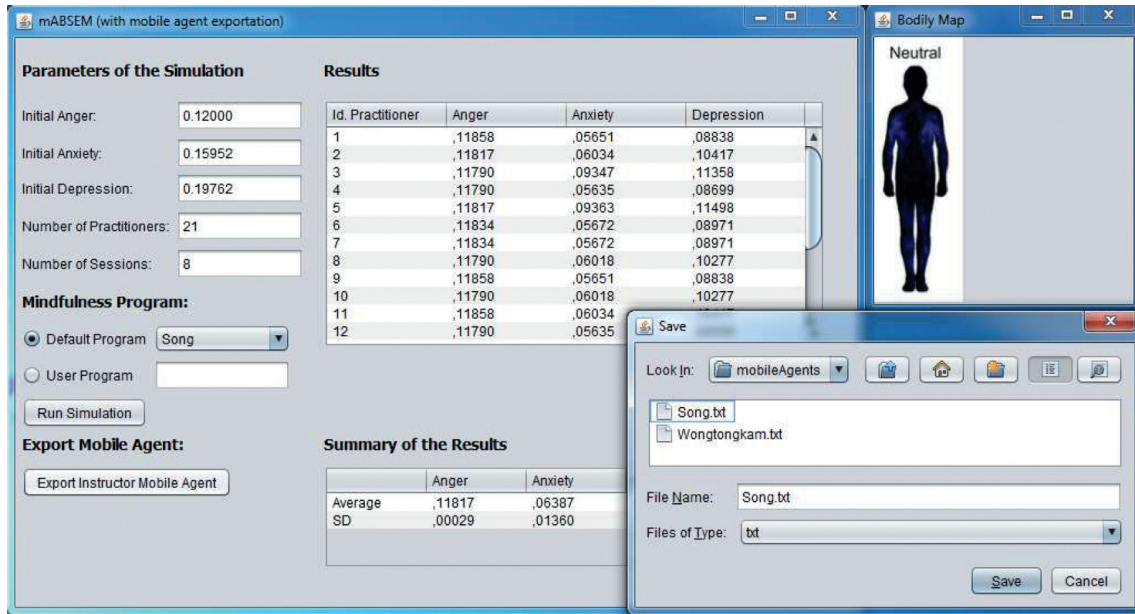


FIGURE 3: User interface of the mABSEM.

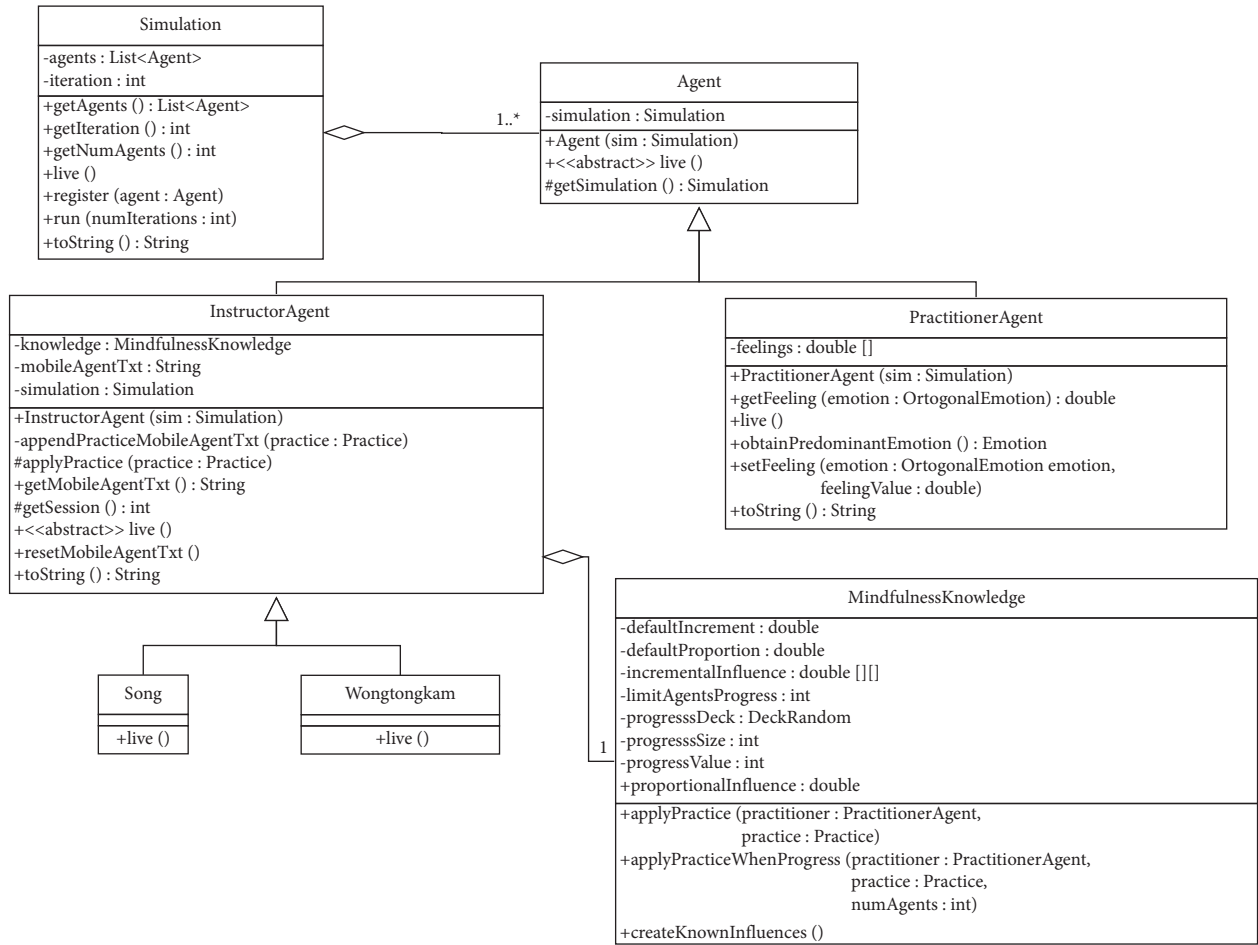


FIGURE 4: Class diagram excerpt of mABSEM.

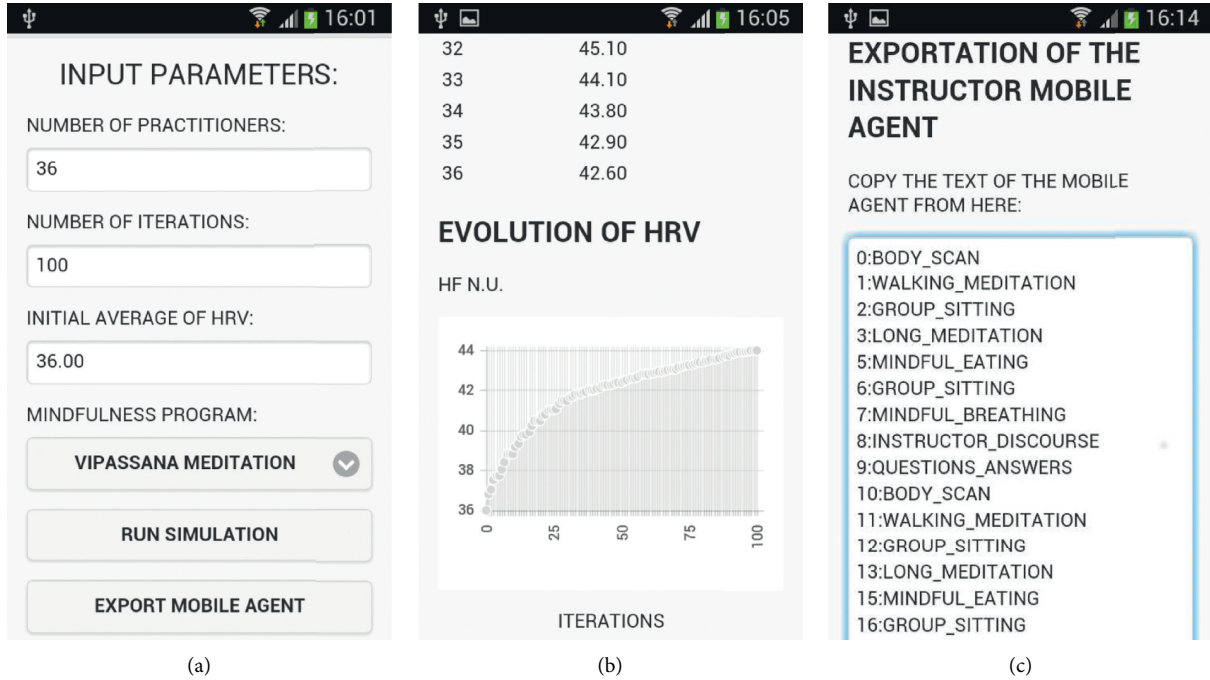


FIGURE 5: User interface of mABS-Heart. (a) Initial interface. (b) Results with the evolution. (c) Exportation of the mobile agent.

mean of the group for implicitly considering aspects such as their age and their usual sport activity. This system provides the simulated HRV of all the practitioners, as well as their average and standard deviation. It also presents the evolution of the average HRV with a chart like in the execution example of Figure 5(b).

Moreover, mABS-Heart can export the instructor agent as a mobile one, with the same text notation as in the previous ABS (i.e., mABSEM). The system presents the content of the mobile agent in a text area as shown in Figure 5(c). Users can directly copy this content of the mobile agent to the meditation app, or into a text file for saving it.

In mABS-Heart, the self-care mindfulness programs are defined by extending the instructor agent and implementing its “Live” method like in the previous ABS. mABS-Heart uses JavaScript, as it is implemented for developing the app with the Cordova framework and for being used as an online tool. The implementation of the exportation is also transparent to the definition of mindfulness programs as specific types of instructor agent. The implementations of these specific types invoke a method of the parent for applying each practice. Besides simulating the particular practice, this method appends the iteration and the practice to the textual representation of the agent. After the simulation, the mobile agent is ready to be exported to the self-care Meditation app or the online tool.

**3.5. Self-Care Meditation App and Online Tool.** Figure 6 shows the user interface of the self-care Meditation app. In particular, the user needs to open the text file with the mobile agent and paste its content in the corresponding text area of the mediation app as shown in Figure 6(a). When the

user presses the “Load Mobile Agent” button, the mobile agent is loaded. Then, the agent customizes the meditation app. Figure 6(b) shows an example of the meditation app customized for the mindfulness program of Song and Lindquist [25]. Notice that the whole program can be accessed by scrolling. One can observe all the activities of the program on the unrolled text of the mobile agent of the previous figure. The customized meditation app has one or several buttons for assisting the mindful activity (IES) of each session of the mindfulness program. Each button has the session number between parentheses and the name of the activity type. In this way, the practitioner knows which mindful activities are assigned to each session. When pressing on a button, the app shows a new page with informative and/or audiovisual content for assisting the practice of the corresponding activity type. As an example, Figure 6(c) shows the page that supports the body scan activity.

The current approach also includes the Meditation online tool, which is similar to the Meditation app. It has the same functionalities and a similar appearance. This tool also loads the specific instructor agents with the same text notation like in the app. This allows reaching a larger number of users, considering that some of them might want to use or test it without installing it.

## 4. Experimentation

In order to experience the proposed approach, we applied it using the dataset about the application of different mindfulness programs such as the Vipassana meditation and using the validated and online-available Kaggle repository about the Kentucky Inventory of Mindfulness Skills

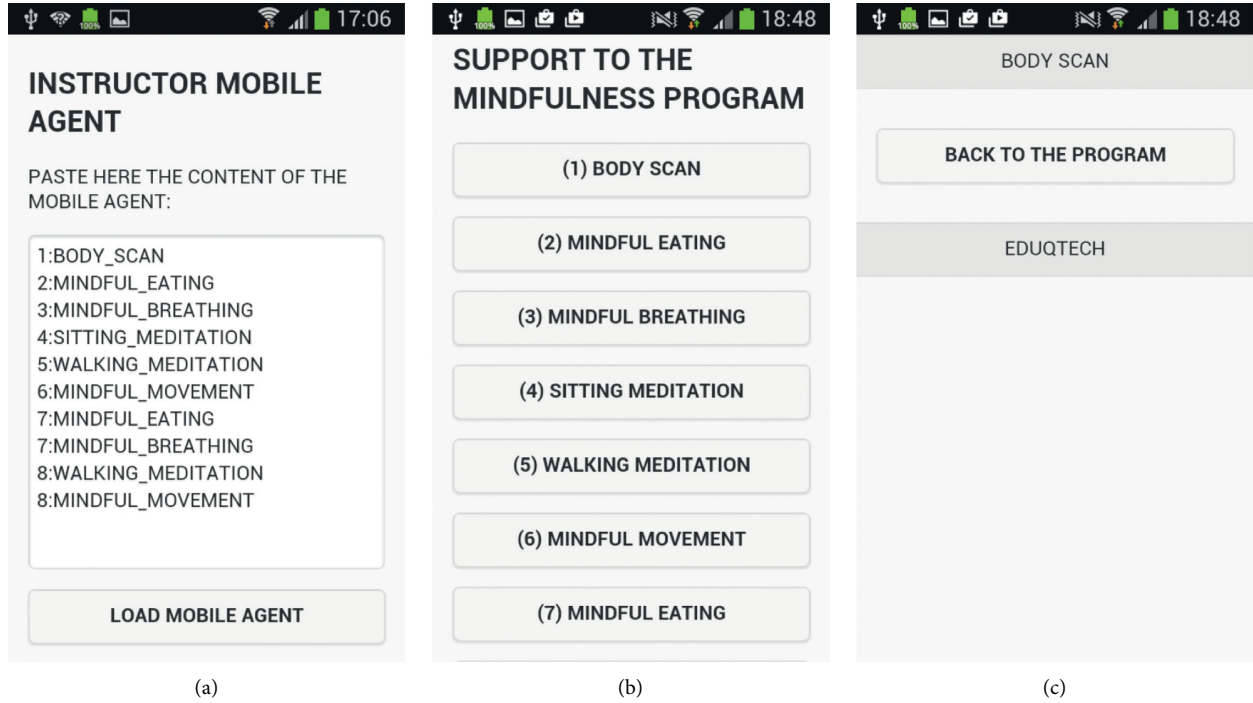


FIGURE 6: User interface of the meditation app. (a) Loading of the instructor mobile agent. (b) Support to the mindfulness program. (c) Content for the body scan activity.

Responses <https://www.kaggle.com/lucasgreenwell/kentucky-inventory-of-mindfulness-skills-responses>(lastaccessed01/15/2021) with data from 601 participants.

In particular, we have used age, gender, observing skill, and describing skill as features of the user of the app, and we have used our approach for predicting the repercussion of the self-care mindfulness program on the acquisition of self-acceptance and situation acceptance, measured with the acceptance skill of the Kentucky inventory [26].

As ML techniques, we used Multilayer Perceptron (MLP) regressor, K-Nearest Neighbors (KNN), and decision trees. The MLP used two hidden layers of, respectively, 5 and 2 neurons and a maximum number of iterations of 100. In KNN, we used two neighbors (i.e.,  $K=2$ ). We randomly divided the dataset into two separate sets for, respectively, training and testing, in which the size of the test set was 0.33 of the original dataset size. We compared the predicted values with the real values, and Figure 7 shows the boxplot of the errors for the three different techniques of MLP, KNN, and decision tree.

In this experimentation, we also applied a CNN with the Tensorflow library, with two dense layers of, respectively, activations called “ReLU” and “softmax” with a middle dropout layer with 0.3 value and the necessary flatten layers. The average error of the CNN was 2.21, which was very similar to the average error of 2.17 obtained by MLP. These results of the CNN may be explained by the fact that this particular scenario only used several one-dimensional psychological measurements of participants instead of images or time series in which CNNs have widely proven to be useful. Since the CNN did not provide an improvement in

the results and required more computational capacity, we did not include this in the final system used by the users.

In the prediction results, one can observe that KNN obtained the lowest errors in this particular domain of the repercussion of self-care mindfulness programs in the Kentucky acceptance skill. Notice that the most appropriate ML technique may vary depending on the domain or the preprocessing, and we suggest prescreening in the particular domain of self-care programs.

As the difference between these two techniques was noticeable, we selected KNN as the most appropriate technique. We configured different numbers of neighbors to test which may be the best value for this parameter. Figure 8 presents a boxplot for comparing the errors of KNN when applying different configurations of numbers of neighbors. We considered the common range between one and five neighbors. In this range, as one can observe in the boxplot, the best results were obtained with three neighbors.

We also measured the execution time of the three ML techniques for both the training and the prediction, and Table 1 shows the resulting times. One can observe that KNN is the fastest in training and decision tree is the fastest in the time prediction. Thus, the decision tree would be the best option for real-time prediction if one just considered execution time.

This ML mechanism was integrated into the mobile agent so that it is firstly deployed with a KNN approach with three neighbors and the original dataset. Then, each mobile agent increased its initial dataset with the feedback from the user about the acquired Kentucky acceptance skill. The ABS used the common Vipassana mindfulness self-care program

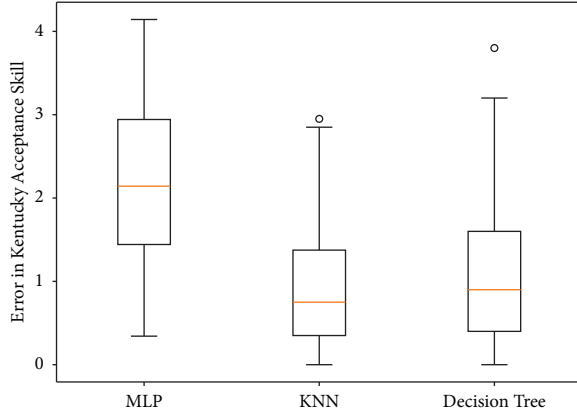


FIGURE 7: Boxplot of errors of ML techniques.

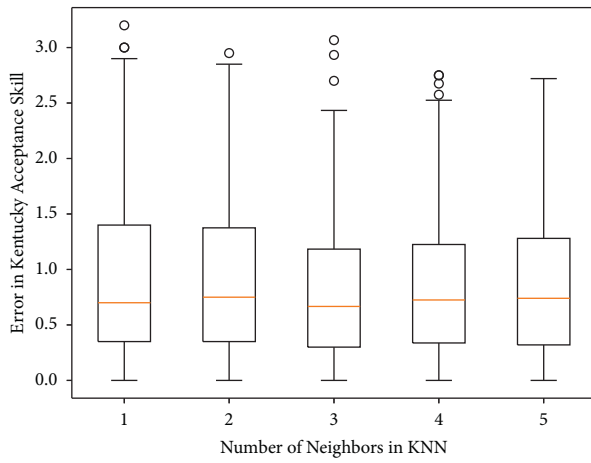


FIGURE 8: Boxplot for comparing errors for different numbers of neighbors in KNN.

TABLE 1: Execution times.

Regressor	Training time (s)	Prediction time (s)
MLP	0.1201453	0.0002239
KNN	0.000678	0.0008244
Decision tree	0.0012355	0.000134

as the basis with minor modifications concerning the particular exercises guided in the specific instruction program as explained in the presentation of the current approach.

The resulting app was suggested to a group of 29 potential beginner meditators. Twelve users actually decided to participate in this study. They followed all the steps, including replying to the surveys for their initial emotional state, and they conducted the recommended program and provided their feedback.

In the supervision stage, we applied the formula presented in equation (1) with  $K = 0.10$  and a five-point Likert scale for confidence. Consequently, the number of cases added for each feedback was either 1, 16, 31, 46, or 61 depending on the confidence level indicated by each user, respectively, for 1 to 5 confidence values.

All the participants were asked to repeat the experience at least once considering their new emotional state and the improvement with ML. After their experience, they evaluated their experience Usefulness, Satisfaction and Ease of use (USE) questionnaire, and the average results were 73% in the dimension usefulness, 77% in satisfaction dimension, and 68% in ease of use.

## 5. Conclusions and Future Work

This work has presented a novel approach of ABSs with mobile agents for simulating the repercussion of self-care programs on specific patients considering their features. In this way, instructors can simulate and recommend programs through mobile agents, which will guide each user on following the program with resources for each specific exercise. In addition, these mobile agents include a ML approach for supervising the learning from each specific user, using an original dataset incrementally improved with the data from the user.

From the results about usefulness and satisfaction provided by the app users, we conclude that the integration of the ABSs and ML for predicting the repercussion of self-programs integrated in an app for the guidance through the programs has achieved a great user experience in terms of usefulness and satisfaction. As shown in this article, this approach has applicability in both the prediction of (1) reduction of negative emotions, such as anger, anxiety, and depression, and (2) HRV health indicators associated with stress. However, the experimentation of this work is now limited to the context of self-care programs based on mindfulness meditation, and we cannot extrapolate our findings to other self-care programs such as the ones that include medication.

As future work, we plan to present this approach to doctors of different fields of medicine, physiotherapy, and psychology to gain perspective on which other fields in this approach can be safely applied. Later, we plan to apply our approach to another field based on the feedback from doctors and develop an app for the selection and guidance of self-care programs. This app will have a paid option to let users be supervised by and communicate with doctors, so the app is more useful for patients and contributes to sustainable healthcare.

## Data Availability

All the relevant data are included in the manuscript.

## Conflicts of Interest

The authors declare that there are no conflicts of interest regarding this article.

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## References

- [1] M.-Y. Hsu, C.-W. Chiang, and A.-F. Chiou, “The effects of a self-regulation programme on self-care behaviour in patients with heart failure: a randomized controlled trial,” *International Journal of Nursing Studies*, vol. 116, Article ID 103778, 2020.
- [2] G. Palacios-Navarro, S. Albiol-Pérez, and I. García-Magariño García, “Effects of sensory cueing in virtual motor rehabilitation. a review,” *Journal of Biomedical Informatics*, vol. 60, pp. 49–57, 2016.
- [3] A. L. Adler-Neal, C. E. Waugh, E. L. Garland, H. A. Shaltout, D. I. Diz, and F. Zeidan, “The role of heart rate variability in mindfulness-based pain relief,” *The Journal of Pain*, vol. 21, no. 3–4, pp. 306–323, 2020.
- [4] I. Papenfuss, M. J. J. Lommen, C. Grillon, N. L. Balderston, and B. D. Ostafin, “Responding to uncertain threat: a potential mediator for the effect of mindfulness on anxiety,” *Journal of Anxiety Disorders*, vol. 77, Article ID 102332, 2020.
- [5] E. Talboom-Kamp, P. Ketelaar, and A. Versluis, “A national program to support self-management for patients with a chronic condition in primary care: a social return on investment analysis,” *Clinical eHealth*, vol. 4, pp. 45–49, 2021.
- [6] M. M. P. Demarzo, A. Cebolla, and J. Garcia-Campayo, “The implementation of mindfulness in healthcare systems: a theoretical analysis,” *General Hospital Psychiatry*, vol. 37, no. 2, pp. 166–171, 2015.
- [7] O. Simonsson, O. Bazin, S. D. Fisher, and S. B. Goldberg, “Effects of an eight-week, online mindfulness program on anxiety and depression in university students during COVID-19: a randomized controlled trial,” *Psychiatry Research*, vol. 305, Article ID 114222, 2021.
- [8] E. Pantano, G. Pizzi, E. Bilotta, and P. Pantano, “Enhancing store layout decision with agent-based simulations of consumers’ density,” *Expert Systems with Applications*, vol. 182, Article ID 115231, 2021.
- [9] I. García-Magariño and I. Plaza, “ABSEM: an agent-based simulator of emotions in mindfulness programs,” *Expert Systems with Applications*, vol. 84, pp. 49–57, 2017b.
- [10] I. García-Magariño and I. Plaza, “ABS-MindHeart: an agent based simulator of the influence of mindfulness programs on heart rate variability,” *Journal of Computational Science*, vol. 19, pp. 11–20, 2017a.
- [11] M. Shibata, S. Kawai, F. Ooshita, H. Kakugawa, and T. Masuzawa, “Partial gathering of mobile agents in asynchronous unidirectional rings,” *Theoretical Computer Science*, vol. 617, pp. 1–11, 2016.
- [12] D. Dereniowski, R. Klasing, A. Kosowski, and Ł. Kuszner, “Rendezvous of heterogeneous mobile agents in edge-weighted networks,” *Theoretical Computer Science*, vol. 608, pp. 219–230, 2015.
- [13] S.-M. Lin and F.-R. Lin, “Coordinating mobile activities by integrating simulated and physical software agents,” *Information Sciences*, vol. 348, 2016.
- [14] L. Chittaro and A. Vianello, “Evaluation of a mobile mindfulness app distributed through on-line stores: a 4-week study,” *International Journal of Human-Computer Studies*, vol. 86, pp. 63–80, 2016.
- [15] L. Chittaro and A. Vianello, “Computer-supported mindfulness: evaluation of a mobile thought distancing application on naive meditators,” *International Journal of Human-Computer Studies*, vol. 72, no. 3, pp. 337–348, 2014.
- [16] E. Hudlicka, “Virtual training and coaching of health behavior: example from mindfulness meditation training,” *Patient Education and Counseling*, vol. 92, no. 2, pp. 160–166, 2013.
- [17] S. Kim and B. Yoon, “A systematic approach for new service concept generation: application of agent-based simulation,” *Expert Systems with Applications*, vol. 41, no. 6, pp. 2793–2806, 2014.
- [18] E. Cabrera, M. Taboada, M. L. Iglesias, F. Epelde, and E. Luque, “Optimization of healthcare emergency departments by agent-based simulation,” *Procedia computer science*, vol. 4, pp. 1880–1889, 2011.
- [19] P. Macklin, M. E. Edgerton, A. M. Thompson, and V. Cristini, “Patient-calibrated agent-based modelling of ductal carcinoma in situ (DCIS): from microscopic measurements to macroscopic predictions of clinical progression,” *Journal of Theoretical Biology*, vol. 301, pp. 122–140, 2012.
- [20] K. Y. Ngiam and I. W. Khor, “Big data and machine learning algorithms for health-care delivery,” *The Lancet Oncology*, vol. 20, no. 5, pp. e262–e273, 2019.
- [21] J. Futoma, M. Simons, T. Panch, F. Doshi-Velez, and L. A. Celi, “The myth of generalisability in clinical research and machine learning in health care,” *The Lancet Digital Health*, vol. 2, no. 9, pp. e489–e492, 2020.
- [22] F. Fatehi, A. Menon, and D. Bird, “Diabetes care in the digital era: a synoptic overview,” *Current Diabetes Reports*, vol. 18, no. 7, pp. 38–8, 2018.
- [23] W. Van Woensel, P. C. Roy, S. S. R. Abidi, and S. R. Abidi, “Indoor location identification of patients for directing virtual care: an AI approach using machine learning and knowledge-based methods,” *Artificial Intelligence in Medicine*, vol. 108, Article ID 101931, 2020.
- [24] I. García-Magariño, A. Gómez-Rodríguez, J. C. González-Moreno, and G. Palacios-Navarro, “PEABS: a process for developing efficient agent-based simulators,” *Engineering Applications of Artificial Intelligence*, vol. 46, pp. 104–112, 2015.
- [25] Y. Song and R. Lindquist, “Effects of mindfulness-based stress reduction on depression, anxiety, stress and mindfulness in Korean nursing students,” *Nurse Education Today*, vol. 35, no. 1, pp. 86–90, 2015.
- [26] R. A. Baer, G. T. Smith, and K. B. Allen, “Assessment of mindfulness by self-report,” *Assessment*, vol. 11, no. 3, pp. 191–206, 2004.



## Research Article

# Application to Engineering and Medical Data Using Three-Parameter Exponential Model

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This paper is devoted to a new lifetime distribution having three parameters by compound the exponential model and the transmuted Topp-Leone-G. The new proposed model is called the transmuted Topp-Leone exponential model; it is useful in lifetime data and reliability. The new model is very flexible; its pdf can be right skewness, unimodal, and decreasing shaped, but the hrf of the suggested model can be unimodal, constant, and decreasing. Numerous statistical characteristics of the new model, notably the quantile function, moments, incomplete moments, conditional moments, mean residual life, mean inactivity time, and entropy are produced and investigated. The system's parameters are estimated using the maximum likelihood approach. All estimators should be theoretically convergent, which is supported by a simulation analysis. Finally, two real-world datasets from the engineering and medical disciplines explore the new model's relevance and adaptability in comparison to the alternatives models such as the beta exponential, the Marshall–Olkin generalized exponential, the exponentiated Weibull, the modified Weibull, and the transmuted Burr type X models.

## 1. Introduction

Many experts have offered a wide range of methods for including an extra parameter in distributions, and all these new families have been used to describe data from a wide variety of fields, covering engineering, economics, biological studies, environmental sciences, and so on. These families are created by adding an additional shape parameter to the parent distribution to enhance the capabilities and validity of the data modeling in reality. The

statistical literature has demonstrated several new families, the transmuted-G by [1], the logistic-X family by [2], Topp-Leone-G (TL-G) by [3], type II half logistic G [4], odd-Burr G by [5], transmuted exponentiated generalized G by [6], Topp-Leone odd Lindley G by [7], odd Frechet G by [8], truncated inverted Kumaraswamy G [9], and truncated Cauchy power G [10], among others.

Reference [11] recently published the TTL-G, a distinct family of continuous distributions with the next distribution function (cdf) and density function (pdf),



$$F(x) = (1 + \lambda) \left[ 1 - (1 - G(x))^2 \right]^\theta - \lambda \left[ 1 - (1 - G(x))^2 \right]^{2\theta}, \quad x > 0, \theta > 0, |\lambda| < 1, \quad (1)$$

$$f(x) = 2\theta g(x) (1 - G(x)) \left[ 1 - (1 - G(x))^2 \right]^{\theta-1} \left[ 1 + \lambda - 2\lambda \left\{ 1 - (1 - G(x))^2 \right\}^\theta \right]. \quad (2)$$

The cdf and pdf corresponding to the  $E$  model, respectively, are

$$G(x) = 1 - e^{-\alpha x}; \quad x > 0, \alpha > 0, \quad (3)$$

$$g(x) = \alpha e^{-\alpha x}, \quad (4)$$

where  $\alpha$  is the scale parameter. Many authors developed the  $E$  model recently like [12–14].

The major goal of this research is to employ the  $E$  model as a baseline model in the TTL-G to create a novel extension of the  $E$  model called the TTLE model. Inserting equations (3) and (4) in equations (1) and (2), then the cdf and pdf of the proposed model are

$$F_{\text{TTLE}}(x) = (1 + \lambda) \left( 1 - e^{-2\alpha x} \right)^\theta - \lambda \left[ \left( 1 - e^{-2\alpha x} \right) \right]^{2\theta}, \quad (5)$$

$$f_{\text{TTLE}}(x) = 2\theta \alpha e^{-2\alpha x} \left( 1 - e^{-2\alpha x} \right)^{\theta-1} \cdot \left[ 1 + \lambda - 2\lambda \left( 1 - e^{-2\alpha x} \right)^\theta \right]. \quad (6)$$

The random variable (RV) with pdf (6) is now indicated as  $X \sim \text{TTLE}(\lambda, \theta, \alpha)$ .

Figure 1 demonstrates plots of the pdf of the TTLE model for number of model parameter values. We can note from Figure 1 that the pdf can be decreasing, right skewed, and unimodal shaped.

The remainder of this article is organized as follows: Section 2 focuses on the various new models' statistical characteristics. Section 3 presents reliability measurements such as survival function (sf), hazard rate (hr) function, MREL, and MINT. Section 4 introduces the parameter maximum likelihood estimates by using MATHCAD (14) statistical software. In Section 5, two real-world examples demonstrate the potential and adaptability of the offered model. Results are summarized in Section 6.

## 2. Structural Properties

In this part, we covered the TTLE distribution's characteristics such as the QuF, Mos, Mo generating function, InMos, CMos, MREL, mean inactivity time (MINT), and entropy (EN).

**2.1. Quantile Function.** The QuF of the TTLE is

$$Q(u) = F^{-1}(u) = \frac{-1}{2\alpha} \ln \left\{ 1 - \left[ \frac{(1 + \lambda) - \sqrt{(1 + \lambda)^2 - 4\lambda u}}{2\lambda} \right]^{1/\theta} \right\}, \quad (7)$$

where  $u$  is a uniform distribution on  $(0, 1)$ . The Bowley's skewness (BS) measure is dependent on a quantile, see [15], and it is defined by

$$\text{BS} = \frac{Q_{0.75} + Q_{0.25} - 2Q_{0.5}}{Q_{0.75} - Q_{0.25}}. \quad (8)$$

On the other hand, Moors [16] proposed measure of kurtosis (MK) also based on quantiles and it is

$$\text{MK} = \frac{Q_{0.875} - Q_{0.625} + Q_{0.375} - Q_{0.125}}{Q_{0.75} - Q_{0.25}}, \quad (9)$$

where  $Q(\cdot)$  represents the QuF. Outliers have less of an impact on the measures BS and MK, which exist even for distributions that do not have moments. Figure 2 depicts how BS and MK behave in response to a TTLE distribution. The BS and MK are decreasing from Figure 2.

**2.2. Moments.** The  $r^{\text{th}}$  Mo of TTLE model is computed from

$$\begin{aligned} \mu'_r(x) &= \int_0^\infty x^r f(x) dx \\ &= 2\theta\alpha(1 + \lambda) \int_0^\infty x^r e^{-2\alpha x} \left( 1 - e^{-2\alpha x} \right)^{\theta-1} dx \\ &\quad - 4\lambda\theta\alpha \int_0^\infty x^r e^{-2\alpha x} \left( 1 - e^{-2\alpha x} \right)^{2\theta-1} dx. \end{aligned} \quad (10)$$

If  $|w| < 1$  and  $a > 0$  is the positive real noninteger, then the binomial series expansion holds.

$$(1 - w)^{b-1} = \sum_{j=0}^{\infty} (-1)^j \binom{a-1}{j} w^j, \quad (11)$$

using equation (11), and after some algebraic simplification, the  $r^{\text{th}}$  Mo can be expressed as

$$\mu'_r(x) = \sum_{i=0}^{\infty} (-1)^i \frac{\theta \Gamma(r+1)}{(2\alpha)^r (i+1)^{r+1}} \left[ (1+\lambda) \binom{\theta-1}{i} - 2\lambda \binom{2\theta-1}{i} \right]. \quad (12)$$

Similarly, the Mo generating function of TTLE model can be deduced from equation (6) as follows:

$$\begin{aligned} M_X(t) &= E(e^{tX}) = \int_0^{\infty} e^{tx} f(x) dx \\ &= \sum_{i=0}^{\infty} (-1)^i \frac{2\alpha\theta}{[2\alpha(i+1)-t]} \left[ (1+\lambda) \binom{\theta-1}{i} - 2\lambda \binom{2\theta-1}{i} \right]. \end{aligned} \quad (13)$$

**2.3. Conditional Moments.** The  $s^{\text{th}}$  upper InMo of TTLE distribution can be computed as

$$\begin{aligned} \vartheta_s(t) &= E(X^s | X > t) = \int_t^{\infty} x^s f(x) dx \\ &= \sum_{i=0}^{\infty} (-1)^i \frac{\theta \Gamma(s+1, 2\alpha(i+1)t)}{(2\alpha)^s (i+1)^{s+1}} \left[ (1+\lambda) \binom{\theta-1}{i} - 2\lambda \binom{2\theta-1}{i} \right], \end{aligned} \quad (14)$$

where  $\Gamma(s, t) = \int_t^{\infty} x^{s-1} e^{-x} dx$  is the upper in gamma function. Similarly, the  $s^{\text{th}}$  lower InMo of TTLE model is

$$\begin{aligned} \phi_s(t) &= E(X^s | X < t) = \int_0^{\infty} x^s f(x) dx \\ \phi_s(t) &= \sum_{i=0}^{\infty} (-1)^i \frac{\theta \gamma(s+1, 2\alpha(i+1)t)}{(2\alpha)^s (i+1)^{s+1}} \left[ (1+\lambda) \binom{\theta-1}{i} - 2\lambda \binom{2\theta-1}{i} \right], \end{aligned} \quad (15)$$

where  $\gamma(s, t) = \int_0^t x^{s-1} e^{-x} dx$  is the lower in gamma function.

$$I_R(\rho) = \frac{1}{1-\rho} \log \left[ \int_0^{\infty} f^\rho(x) dx \right], \quad \rho > 0, \rho \neq 1, \quad (16)$$

**2.4. Entropy.** The Rényi EN is calculated from

Using equation (6), we have

$$\begin{aligned} \int_0^{\infty} f^\rho(x) dx &= (2\theta\alpha)^\rho \int_0^{\infty} e^{-2\rho\alpha x} (1 - e^{-2\alpha x})^{\rho(\theta-1)} \left[ 1 + \lambda - 2\lambda(1 - e^{-2\alpha x})^\theta \right]^\rho dx \\ &= (2\theta\alpha)^\rho \sum_{j,k=0}^{\infty} (-1)^{j+k} \left( \frac{2\lambda}{1+\lambda} \right)^j \binom{\theta(\rho+j)-\rho}{k} \left( \frac{1}{2\alpha(\rho+k)} \right). \end{aligned} \quad (17)$$

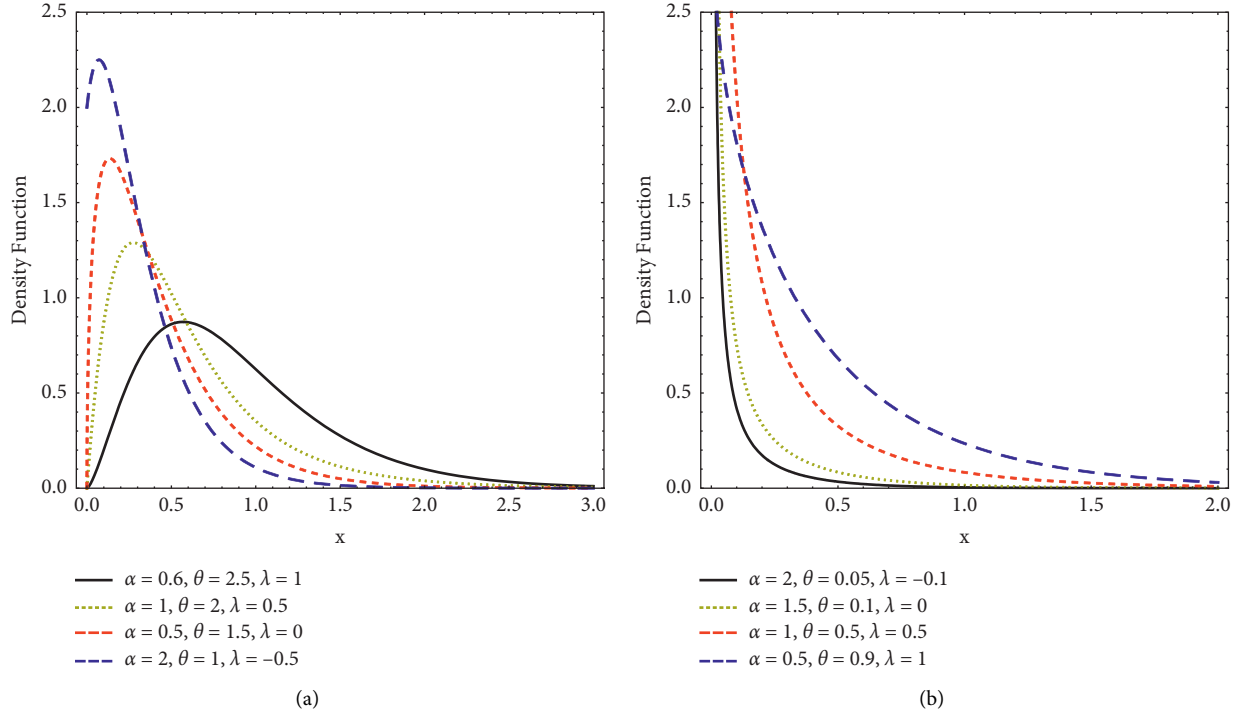


FIGURE 1: The TTLE pdf shown against various parameter values.

Thus,

$$I_R(\rho) = \frac{\rho}{1-\rho} \log(2\theta\alpha) + \log \left\{ \sum_{j,k=0}^{\infty} (-1)^{j+k} \left( \frac{2\lambda}{1+\lambda} \right)^j \binom{\theta(\rho+j)-\rho}{k} \left( \frac{1}{2\alpha(\rho+k)} \right) \right\}. \quad (18)$$

### 3. Reliability Measures

We discussed reliability metrics such as the sf, hr function, MREL, and MINT in this part.

The reliability function (or the sf) of TTLE model is derived by

$$\bar{F}_{TTLE}(x) = 1 - (1 - e^{-2\alpha x})^\theta \left[ (1 + \lambda) - \lambda(1 - e^{-2\alpha x})^\theta \right]. \quad (19)$$

The hr (or failure rate) function represents the time it takes for a unit to fail or component or a device. It is useful in important measures of ageing.

For the purposes of distribution, the hr function is deduced as follows:

$$h_{TTLE}(x) = \frac{f(x)}{\bar{F}(x)} = \frac{2\theta\alpha e^{-2\alpha x} (1 - e^{-2\alpha x})^{\theta-1} \left[ 1 + \lambda - 2\lambda(1 - e^{-2\alpha x})^\theta \right]}{1 - (1 - e^{-2\alpha x})^\theta \left[ (1 + \lambda) - \lambda(1 - e^{-2\alpha x})^\theta \right]}. \quad (20)$$

Figure 3 illustrates the shapes of sf and hr functions for various values of the distribution parameters. The sf of the TTLE distribution is constantly decreasing, as shown

in Figure 3(a). On the other hand, this distribution has the unimodal, constant, and decreasing hr shapes (Figure 3(b)).

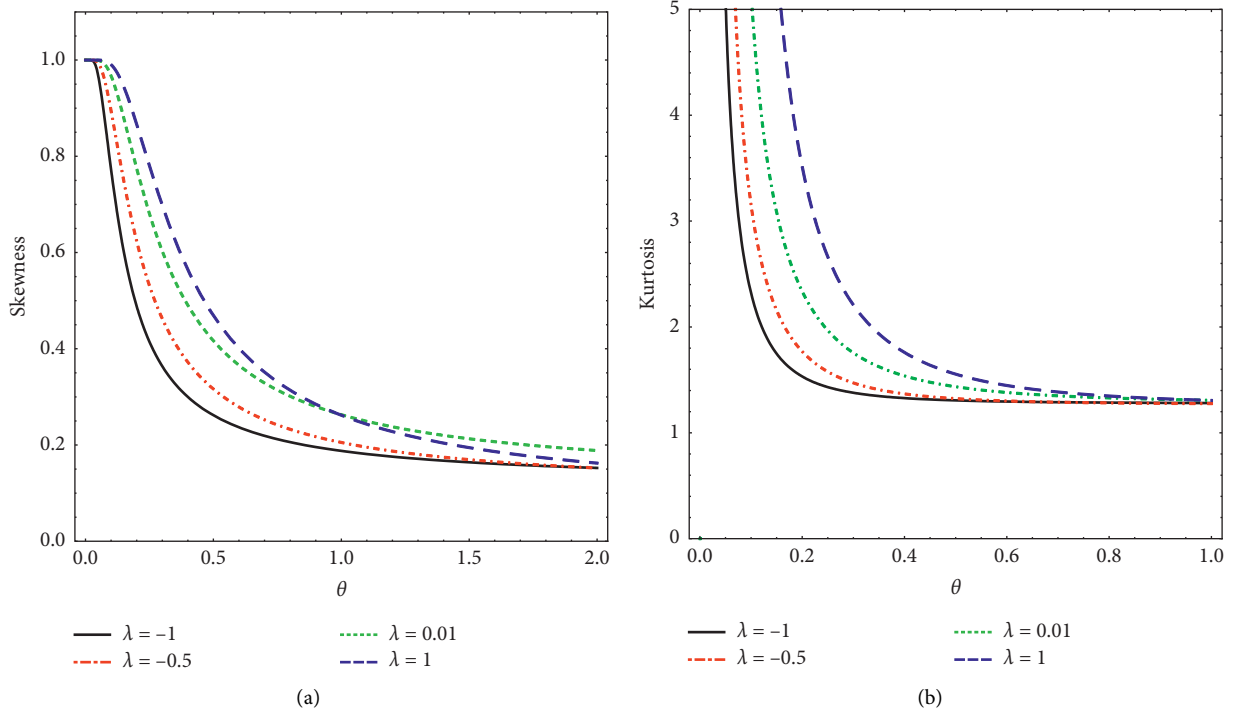


FIGURE 2: The BS and MK of TTLE distribution.

In the estimation of a sf for left-censored lifetimes, the reversed hr (Rhr) function is crucial. The TTLE distribution's Rhr is calculated by

$$\tau_{\text{TTLE}}(x) = \frac{f(x)}{F(x)} = \frac{2\theta\alpha e^{-2\alpha x} [1 + \lambda - 2\lambda(1 - e^{-2\alpha x})^\theta]}{(1 - e^{-2\alpha x}) [(1 + \lambda) - \lambda(1 - e^{-2\alpha x})^\theta]} \quad (21)$$

The MREL function is essential in reliability survival analysis and it is used to model the burn-in and conservation of the component. MREL for TTLE distribution is

$$\mu(t) = E((X - t)|X > t) = \frac{1}{\bar{F}(t)} \int_t^\infty x f(x) dx - t. \quad (22)$$

Then,

$$\mu(t) = \frac{1}{\bar{F}(t)} (-1)^i \frac{\theta \Gamma(2, 2\alpha(i+1)t)}{(2\alpha)^2 (i+1)^2} \left[ (1 + \lambda) \binom{\theta-1}{i} - 2\lambda \binom{2\theta-1}{i} \right] - t. \quad (23)$$

The MINT function is also exciting because it indicates the time that has passed since a component failed, assuming that its lifespan is less than or equal to  $t$ . That RV is indeed

referred to as the time since failure. The MINT is symbolized with

$$\begin{aligned} m(t) &= E((X - t)|X < t) = t - \frac{1}{F(t)} \int_0^t x f(x) dx \\ &= t - \frac{1}{F(t)} \sum_{i=0}^{\infty} (-1)^i \frac{\theta \gamma(2, 2\alpha(i+1)t)}{(2\alpha)^2 (i+1)^2} \left[ (1 + \lambda) \binom{\theta-1}{i} - 2\lambda \binom{2\theta-1}{i} \right]. \end{aligned} \quad (24)$$

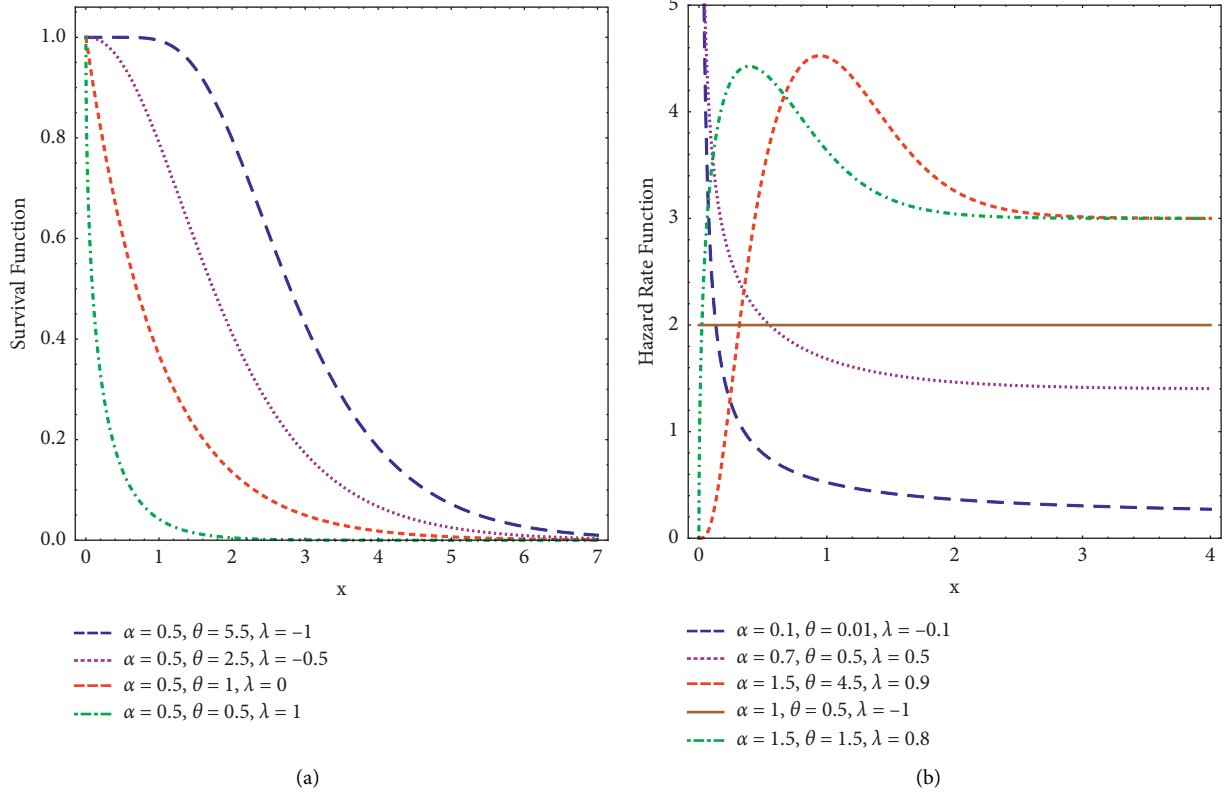


FIGURE 3: (a) Plots of TTLE sf. (b) Plots of TTLE hr function.

Table 1 displays the MREL and the MINT for the proposed model at the point  $t = 0.5$  for some selected values of distribution parameters  $(\theta, \lambda)$ , namely,  $(5.5, -1)$ ,  $(2.5, -0.5)$ ,  $(1, 0)$ ,  $(0.5, 0.5)$ , and  $(0.01, 1)$ , with fixed parameter  $\alpha = 2$ . It is observed that the MREL is decreasing and the MINT is increasing when  $\theta$  decreases and  $\lambda$  increases.

Figure 4 illustrates the behavior of the MREL and MINT for some different levels of distribution parameters. It is seen that the MREL (Figure 4(a)) is decreasing while the MINT (Figure 4(b)) is increasing.

#### 4. Maximum Likelihood Estimation

MLL estimates (MLEs) were used to estimate the TTLE distribution's unknown parameters. Suppose  $x_1, x_2, \dots, x_n$  be an  $n$ -th random sample from the TTLE distribution given by equation (6). The TTLE distribution's log-likelihood formula is represented by

$$L_n = n \log(2\theta) + n \log(\alpha) - 2\alpha \sum_{i=1}^n x_i + (\theta - 1) \sum_{i=1}^n \log(1 - e^{-2\alpha x_i}) + \sum_{i=1}^n \log[1 + \lambda - 2\lambda(1 - e^{-2\alpha x_i})^\theta]. \quad (25)$$

The likelihood equations for the TTLE distribution can indeed be managed to obtain by differentiating equation (25)

with respect to the parameters  $\lambda$ ,  $\theta$ , and  $\alpha$  which are offered by

$$\frac{\partial L_n}{\partial \lambda} = \sum_{i=1}^n \frac{1 - 2(1 - e^{-2\alpha x_i})^\theta}{1 + \lambda - 2\lambda(1 - e^{-2\alpha x_i})^\theta} \quad (26)$$

$$\frac{\partial L_n}{\partial \theta} = \frac{n}{\theta} + \sum_{i=1}^n \log(1 - e^{-2\alpha x_i}) + \sum_{i=1}^n \frac{-2\lambda \log(1 - e^{-2\alpha x_i})(1 - e^{-2\alpha x_i})^\theta}{1 + \lambda - 2\lambda(1 - e^{-2\alpha x_i})^\theta}, \quad (27)$$

TABLE 1: The MREL and MINT of TTLE distribution.

$\theta \downarrow$	$\lambda \uparrow$	$\alpha = 2, t = 0.5$	MREL $\downarrow$	MINT $\uparrow$
5.5	-1		0.343799	0.095978
2.5	-0.5		0.278279	0.201663
1	0		0.250000	0.328259
0.5	0.5		0.237418	0.419510
0.01	1		0.119110	0.499943

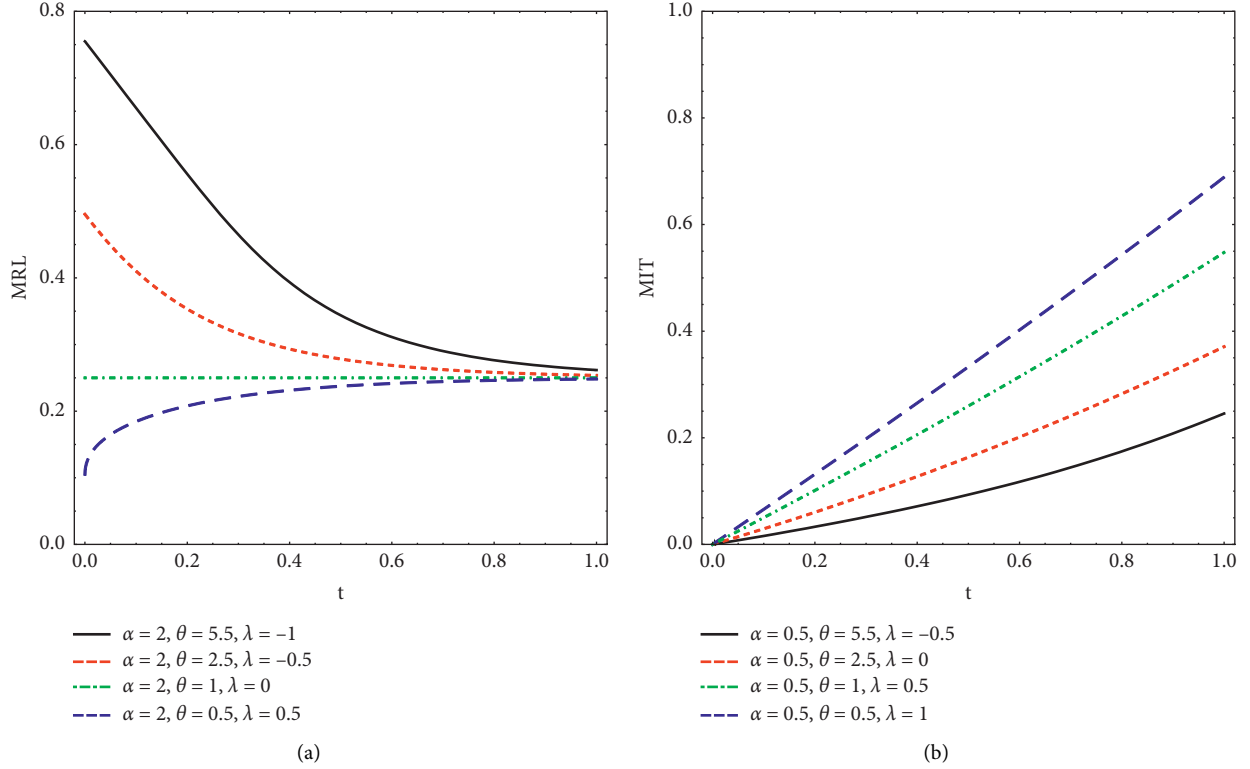


FIGURE 4: (a) Plot of MREL and (b) plot of MINT for selected parameter values.

$$\frac{\partial L_n}{\partial \alpha} = \frac{n}{\alpha} - 2 \sum_{i=1}^n x_i + (\theta - 1) \sum_{i=1}^n \frac{2xe^{-2\alpha x}}{(1 - e^{-2\alpha x})} - \sum_{i=1}^n \frac{4\lambda\theta xe^{-2\alpha x}(1 - e^{-2\alpha x})^{\theta-1}}{1 + \lambda - 2\lambda(1 - e^{-2\alpha x})^{\theta}}. \quad (28)$$

The MLEs, say  $\hat{\lambda}$ ,  $\hat{\theta}$ , and  $\hat{\alpha}$  of parameters  $\lambda$ ,  $\theta$ , and  $\alpha$ , can be acquired by trying to equate and finding solutions of the nonlinear system equations (26)–(28) instantaneously.

**4.1. Simulation Results.** The output of the MLLEs of the parameters of the TTLE distribution is analyzed through Monte-Carlo simulation inside this subsection. The high accuracy of MLEs is explored utilizing bias and mean square errors (MSEs). This study is evaluated based on 1000 replicates. Different samples of sizes 25, 50, 75, and 100 are generated by using equation (7). The parametric

values are considered to be  $\lambda = 0.5$ ,  $\theta = 1$ , and  $\alpha = 2$ . The average MSEs and the average bias of the simulated estimates  $\hat{\epsilon}_i$  can be computed by the following equations:

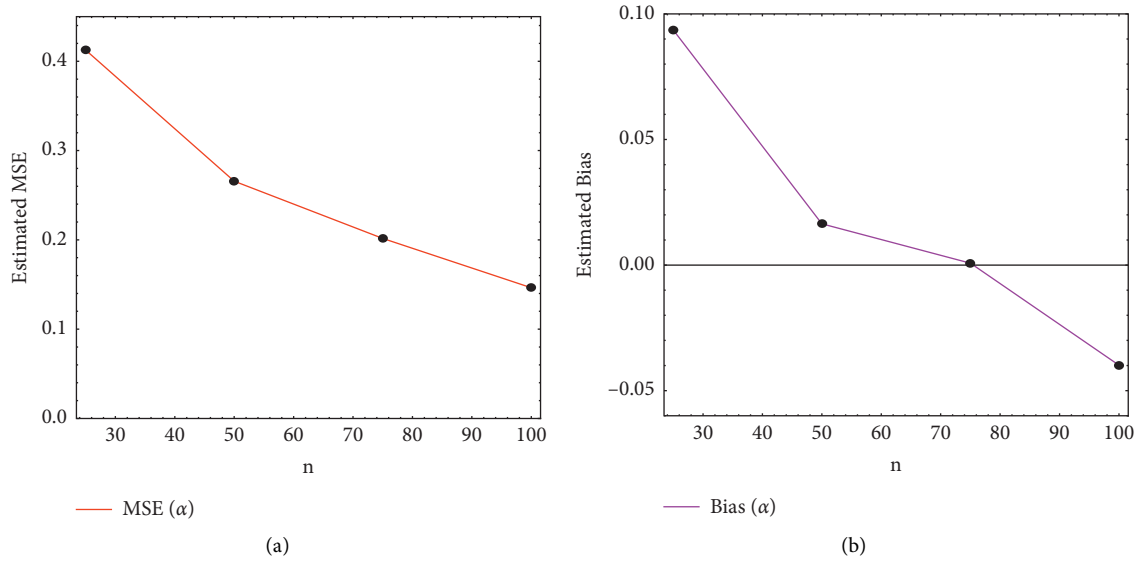
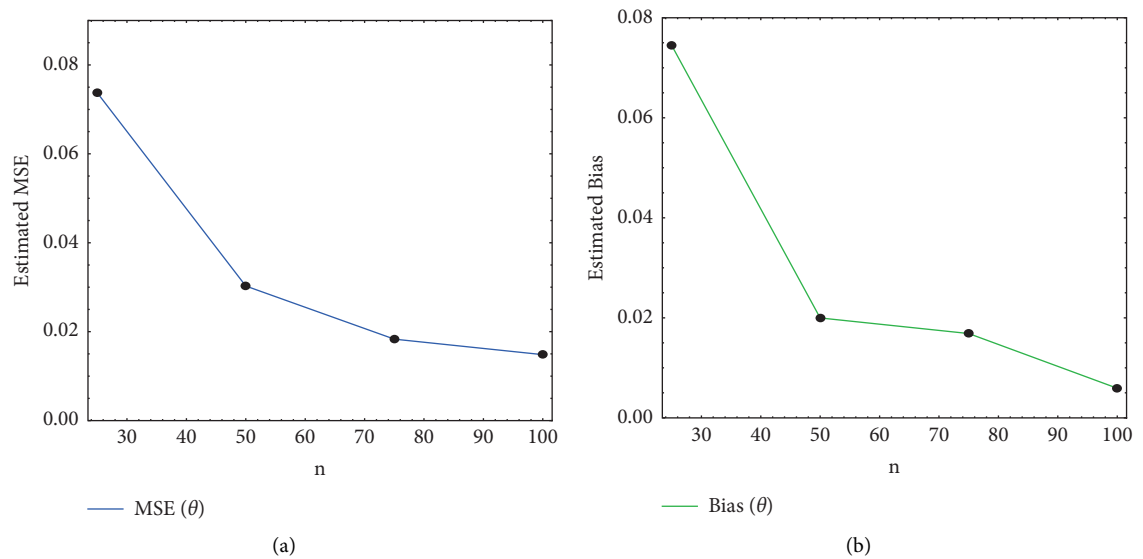
$$\begin{aligned} \text{MSE}_{\epsilon}(n) &= \frac{1}{N} \sum_{i=1}^N (\hat{\epsilon}_i - \epsilon)^2, \\ \text{Bias}_{\epsilon}(n) &= \frac{1}{N} \sum_{i=1}^N |\hat{\epsilon}_i - \epsilon|, \end{aligned} \quad (29)$$

where  $\epsilon = (\lambda, \theta, \alpha)$ .



TABLE 2: Simulation results for TTLE distribution.

	$n = 25$	$n = 50$	$n = 75$	$n = 100$
$\alpha = 2$				
$\hat{\alpha}$	2.0936	2.01643	2.00074	1.96012
MSE	0.41260	0.2657	0.20158	0.14632
Bias	0.09360	0.01643	0.00074	0.0399
$\theta = 1$				
$\hat{\theta}$	1.07447	1.0200	1.01687	1.00593
MSE	0.07374	0.03027	0.01832	0.01483
Bias	0.07447	0.01998	0.01687	0.00593
$\lambda = 0.5$				
$\hat{\lambda}$	0.52932	0.52916	0.52839	0.52754
MSE	0.07073	0.06495	0.05926	0.04992
Bias	0.02932	0.02916	0.02839	0.02754

FIGURE 5: The MSE and bias term of parameter  $\alpha$ .FIGURE 6: The MSE and bias term of parameter  $\theta$ .

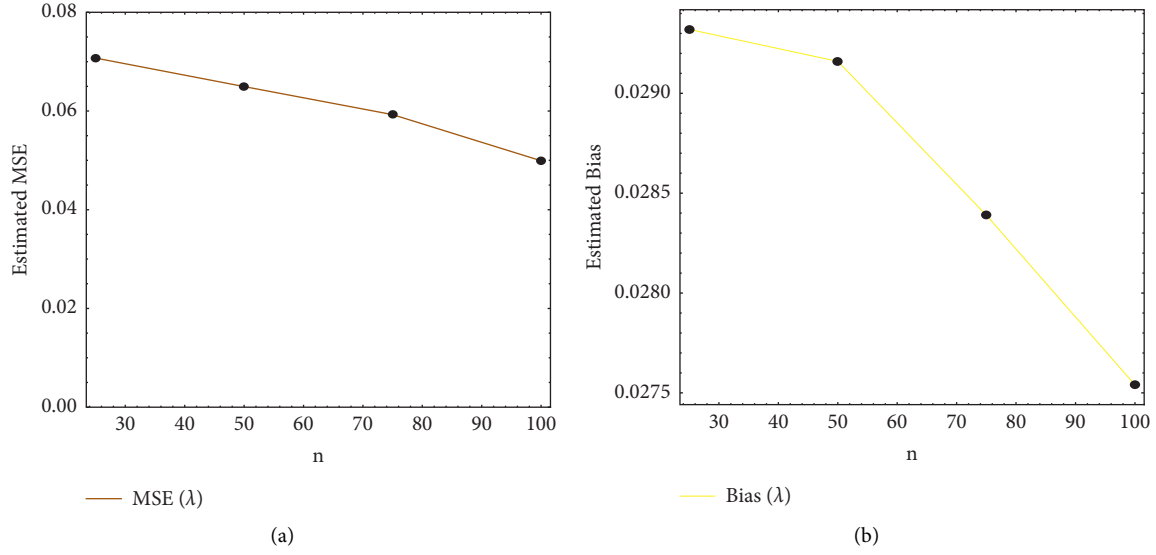
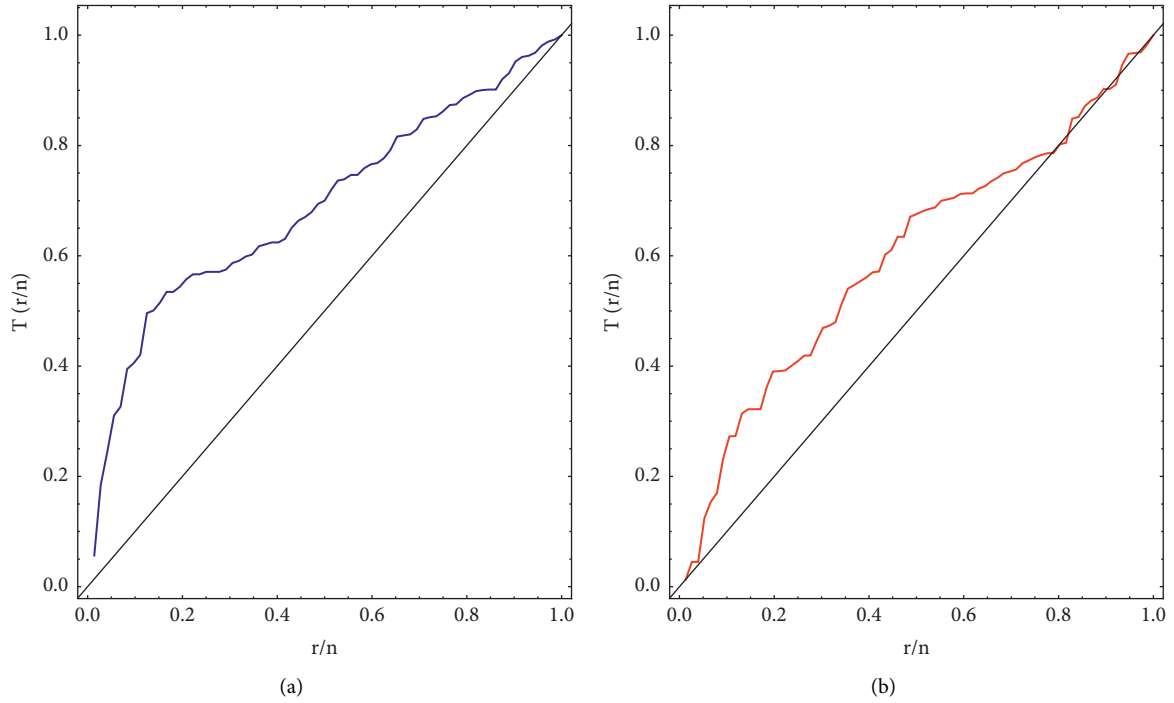
FIGURE 7: The MSE and bias term of parameter  $\lambda$ .

FIGURE 8: The TTT plots for (a) Guinea Pig data and (b) Kevlar data.

The estimated values of the distribution parameters, the MSEs, and the bias terms of the simulated estimates are listed in Table 2.

The graphical representations of the simulation process are displayed in Figures 5–7. The following conclusions can be drawn from these figures: when the sample size is increased, the MSEs and estimated biases decrease. Furthermore, for large samples, the approximated values of the parameters approach the parametric values.

## 5. Applications

Within this section, the practical use of the TTLE distribution is explored via two sources of data. The first set of data (Guinea Pig data) was published by [17], while the second set of data (Kevlar data) has been presented by [18].

Reference [19] demonstrated that the TTT plot is convex (or concave) for decreasing (or increasing) failure rate and straight diagonal for constant failure rate. The empirical

TABLE 3: The MLEs and StErs for the Guinea Pig data.

Models	Estimates		
TTLE	$\hat{\lambda} = -0.83494$ (0.2045)	$\hat{\theta} = 2.38752$ (0.691)	$\hat{\alpha} = 0.00607$ (0.0007)
BE	$\hat{a} = 3.34584$ (0.964)	$\hat{b} = 1.70820$ (3.386)	$\hat{\alpha} = 0.00737$ (0.0119)
MoGE	$\hat{\delta} = 1.03273$ (1.217)	$\hat{\theta} = 3.60839$ (1.0456)	$\hat{\alpha} = 0.01136$ (0.0036)
EW	$\hat{\theta} = 2.65358$ (1.53599)	$\hat{\beta} = 1.16045$ (0.30896)	$\hat{\alpha} = 0.00886$ (0.0036)
MW	$\hat{\eta} = 5.86338 \times 10^{-13}$ (0.0019)	$\hat{\delta} = 6.32978 \times 10^{-5}$ (0.00009)	$\hat{\alpha} = 1.82535$ (0.224648)
TBX	$\hat{\lambda} = 0.63259$ (0.272)	$\hat{\mu} = 1.03896$ (0.147)	$\hat{\alpha} = 0.00417$ (0.0006)

TABLE 4: The values of AINC, BINC, and HQINC for the Guinea Pig data.

Models	AINC	BINC	HQINC
TTLE	855.805	862.635	858.524
BE	857.479	864.309	860.198
MoGE	857.616	864.446	860.335
EW	857.312	864.142	860.031
MW	860.724	867.554	863.443
TBX	858.575	865.405	861.294

TABLE 5: The values of AND, CVM, A1, and A2 for Guinea Pig data.

Models	AND	CVM	A1	A2
TTLE	0.46117	0.07596	0.07854	0.76609
BE	0.53583	0.08439	0.09096	0.59054
MoGE	0.52015	0.08021	0.09312	0.56021
EW	0.54409	0.08689	0.08912	0.616723
MW	1.01808	0.16916	0.10479	0.40789
TBX	0.77854	0.13183	0.08577	0.664677

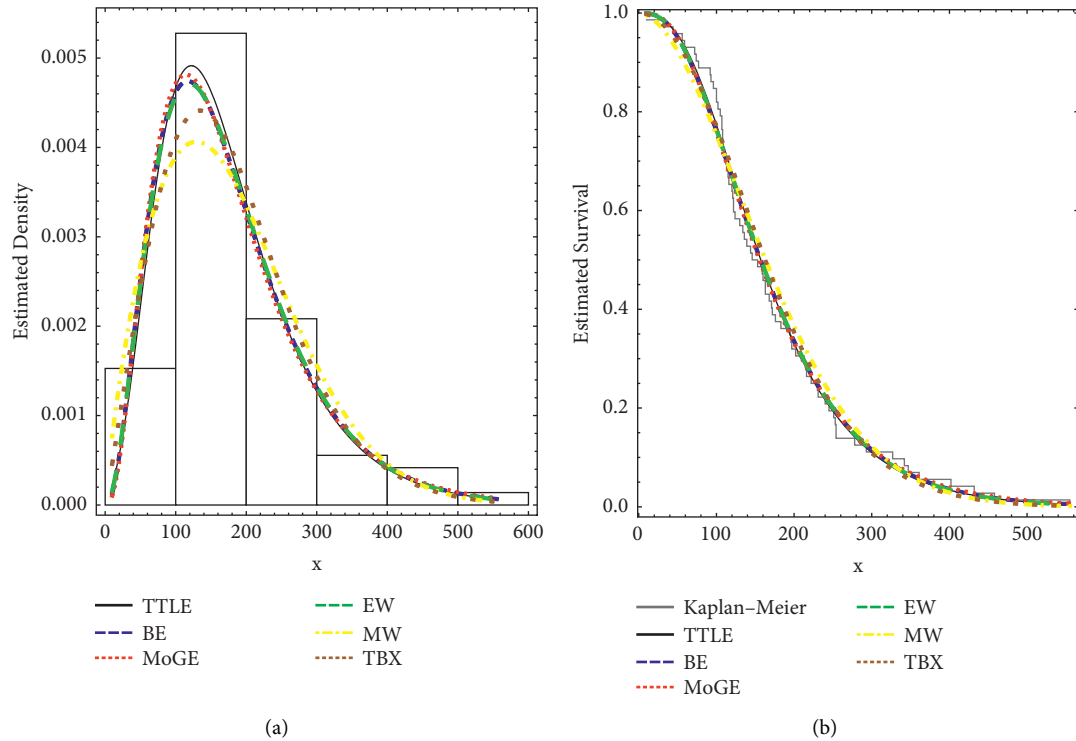


FIGURE 9: (a) Estimated density and (b) estimated survival for the Guinea Pig data.

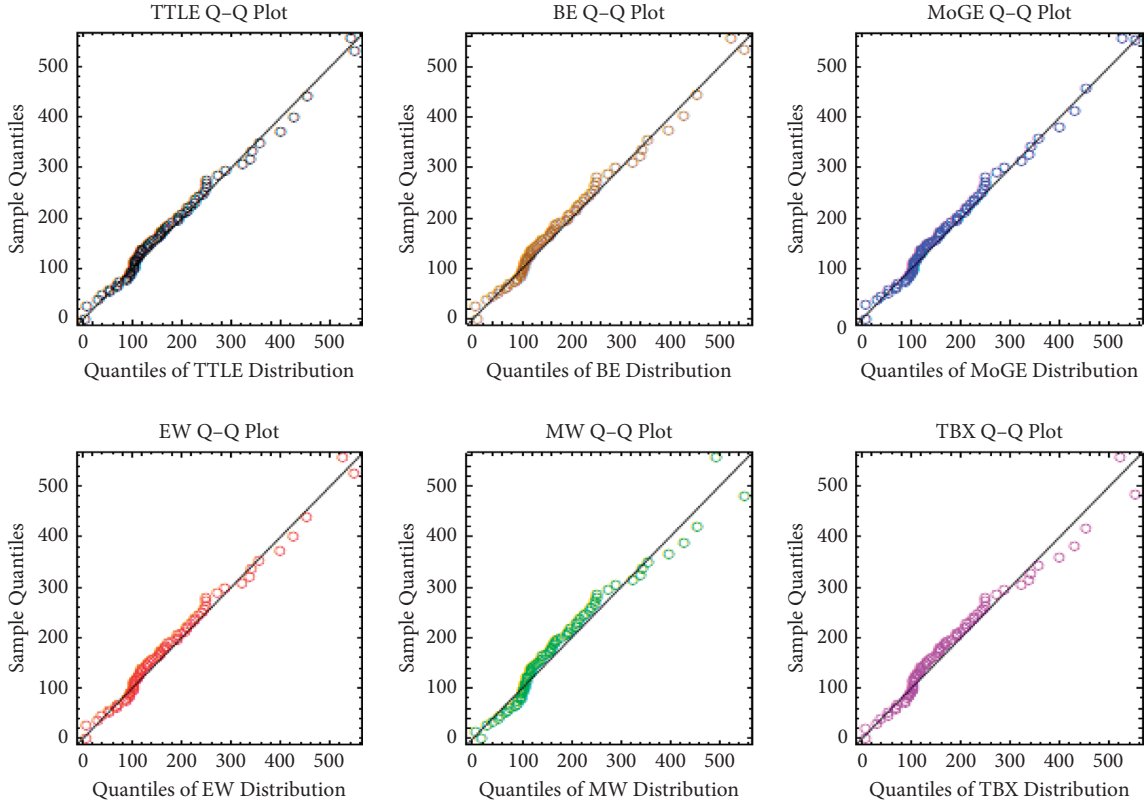


FIGURE 10: The Q-Q plot of the fitted distributions for the Guinea Pig data.

TABLE 6: The MLEs and StErs for the Kevlar data.

Models	MLEs and StErs		
TTLE	$\hat{\lambda} = 0.84235$ (0.34102)	$\hat{\theta} = 1.70158$ (0.30981)	$\hat{\alpha} = 0.22912$ (0.07342)
BE	$\hat{a} = 1.67972$ (0.31737)	$\hat{b} = 1.50842$ (4.53703)	$\hat{\alpha} = 0.48496$ (1.32951)
MoGE	$\hat{\delta} = 1.77828$ (1.46381)	$\hat{\theta} = 1.44242$ (0.49195)	$\hat{\alpha} = 0.82161$ (0.00362)
EW	$\hat{\theta} = 1.44263$ (0.64364)	$\hat{\beta} = 1.10131$ (0.26291)	$\hat{\alpha} = 0.60944$ (0.21806)
MW	$\hat{\eta} = 0.36638$ (0.33046)	$\hat{\delta} = 1.32561$ (0.26353)	$\hat{\alpha} = 3.69082 \times 10^{-9}$ (0.32066)
TBX	$\hat{\lambda} = 0.75459$ (0.21087)	$\hat{\mu} = 0.62374$ (0.07648)	$\hat{\alpha} = 0.25985$ (0.03859)

failure rate of the data becomes bathtub-shaped if the TTT plot is convex and then concave; otherwise, the failure rate is upside-down bathtub-shaped.

The scaled TTT plot for every dataset is shown in Figure 8, and it is evident that both sets of data have quite a concave shape, which is indicated that the empirical failure rate of these two datasets is increasing; as a result, the TTLE distribution may be a suitable model for both these datasets. The TTLE distribution is shown to be adaptable using these two examples. The recommended model's goodness-of-fit indicators are compared to the fits of the relevant lifetime models: the BE by [20], the MOGE by [21], the EW by [22], the MW by [23], and the TBX by [24].

We used the MLL technique to estimate the parameters of every model with every set of data. We computed the values of the following information criterion (INC) focusing on the estimations of the unknown parameters: Akaike INC (AINC), Bayesian INC (BINC), and Hannan–Quinn INC (HQINC). The Anderson–Darling (AND), the Cramer–von Mises (CVM) tests, and the Kolmogorov–Smirnov (A1) statistic, as well as the accompanying probability value, are also included (A2). Generally, the optimal model for fitting the data is one with lower values of these measures and a higher A2 of the A1 statistic. Furthermore, for all fitted models, the estimated pdf, estimated sf, and Q-Q plot of the fitted models are taken into account.

TABLE 7: The values of AINC, BINC, and HQINC for the Kevlar data.

Models	AINC	BINC	HQINC
TTLE	249.867	256.859	252.661
BE	250.455	257.447	253.25
MoGE	250.027	257.019	252.821
EW	250.327	257.319	253.122
MW	251.049	258.042	253.844
TBX	251.669	258.661	254.463

TABLE 8: The values of AND, CVM, A1, and A2 for the Kevlar data.

Models	AND	CVM	A1	A2
TTLE	0.593897	0.0976829	0.0864138	0.621551
BE	0.672793	0.111907	0.095684	0.48970
MoGE	0.648171	0.105902	0.100006	0.432777
EW	0.663042	0.11002	0.0987571	0.448846
MW	0.797027	0.136277	0.10993	0.317345
TBX	0.828701	0.141499	0.117892	0.241425

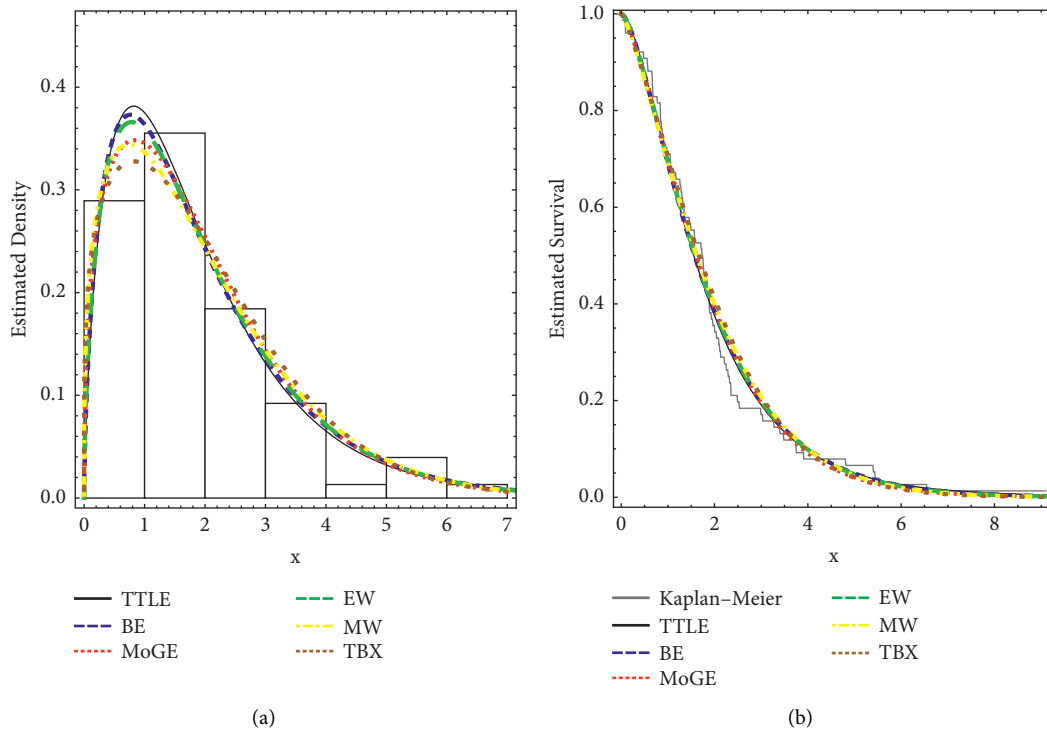


FIGURE 11: (a) The estimated density and (b) estimated survival for the Kevlar data.

Table 3 exhibits the MLEs of the distribution parameters and associated standard errors (StEr) for the current proposal model as well as the challenging distributions for the Guinea Pig data. Likewise, we contrasted the fits of the TTLE model to those of the other models listed in Table 4, including the AINC, BINC, and HQINC. Furthermore, the AND, CVM, and A1 statistics, as well as the equivalent A2, are provided in Table 5. Figures 9 and 10 depict the estimated pdf, estimated sf, and Q-Q plots of the fitted models using Guinea Pig data. These tables and

figures show that the suggested model outperforms all competitive distributions in terms of fit. As a consequence, the TTLE distribution may be ranked as the top data fitting model.

For the Kevlar data, the MLEs for the fitted models and their StErs are computed in Table 6. The goodness-of-fit measures: AINC, BINC, and HQINC are listed in Table 7. Furthermore, the values of these statistics AND, CVM, A1, and A2 are given in Table 8. Additionally, the plots of estimated density and estimated survival and the

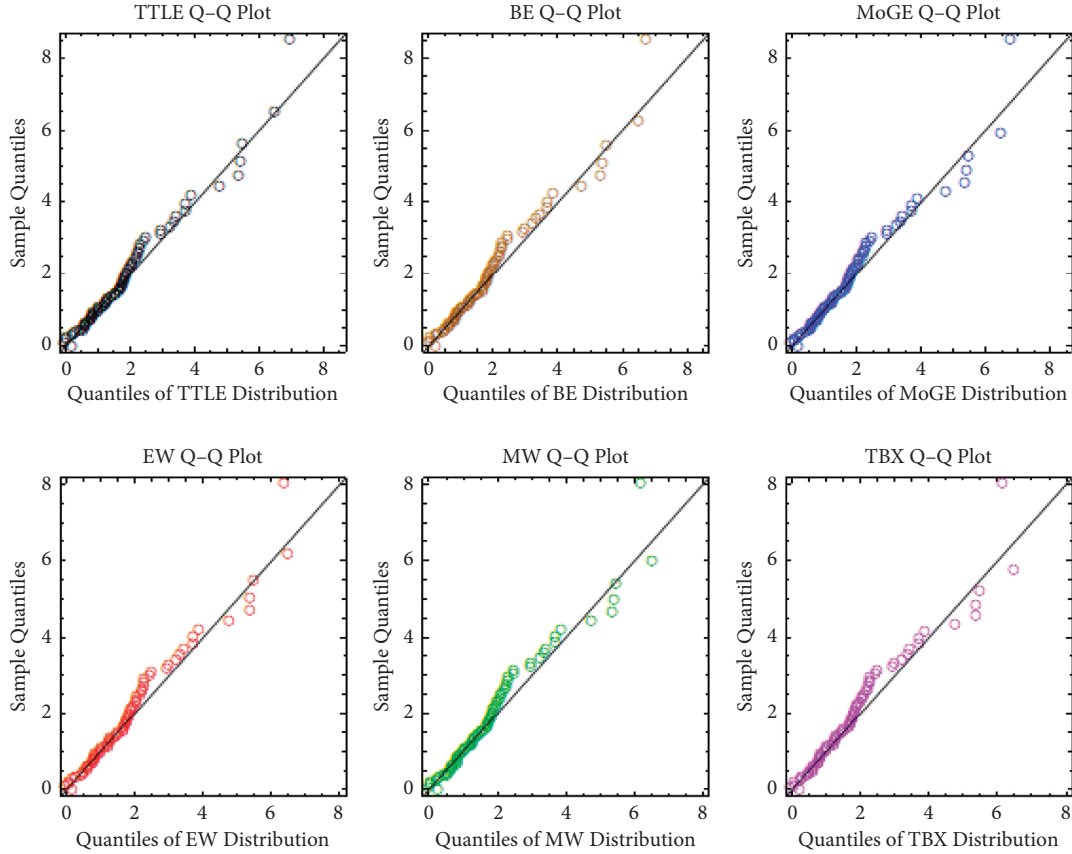


FIGURE 12: The Q-Q plot of the fitted distributions for the Kevlar data.

Q-Q plot are displayed in Figures 11 and 12. It is evident from Tables 7 and 8 that the TTLE distribution has the weakest goodness-of-fit indices; therefore, this model can be chosen as the better one in fitting this kind of data. In addition, it is clear from Figures 11 and 12 that the TTLE model fits the two real-world data superior than the other competing models.

## 6. Conclusion

This work proposes and explores a new lifetime distribution, the TTLE, to enhance the  $E$  distribution. This model's hr function may take the shape of an upside-down bathtub (unimodal), and the constant and diminishing diversity of shapes make the model very adaptable. The suggested model's statistical characteristics and major reliability indicators are deduced. The MLL technique is used to estimate the parameters of the TTLE model. In addition, a numerical result is employed to look into the quality of the estimates. Eventually, real-world data applications are utilized to demonstrate the practicality of TTLE distribution. Also, in the future works, we plan to use this suggested model to study the statistical inference of it using Bayesian estimation under different censored schemes. In the future, other authors can use this model to study its statistical inference using Bayesian and E-Bayesian estimations under complete and different censored schemes.

## Abbreviations

E:	Exponential
TTL-G:	Transmuted Topp-Leone-G
QuF:	Quantile function
Mos:	Moments
InMos:	Incomplete moments
CMos:	Conditional moments
MREL:	The mean residual life
MINT:	The mean inactivity time
EN:	Entropy
MLL:	Maximum likelihood
BE:	The beta exponential
MOGE:	Marshall–Olkin generalized exponential
EW:	Exponentiated Weibull
MW:	The modified Weibull
TBX:	Transmuted Burr type X.

## Data Availability

To get the numerical dataset used to conduct the study reported in the publication, please contact the corresponding author.

## Conflicts of Interest

The authors state that they have no conflicts of interest to disclose in relation to this work.



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## References

- [1] W. T. Shaw and I. R. Buckley, "The alchemy of probability distributions: beyond gram-Charlier and Cornish-Fisher expansions, and skew-normal or kurtotic-normal distributions," *Submitted*, vol. 7, no. 2, p. 64, 2007.
- [2] M. H. Tahir, G. M. Cordeiro, A. Alzaatreh, M. Mansoor, and M. Zubair, "The logistic-X family of distributions and its applications," *Communications in Statistics - Theory and Methods*, vol. 45, no. 24, pp. 7326–7349, 2016.
- [3] A. Al-Shomrani, O. Arif, A. Shawky, S. Hanif, and M. Q. Shahbaz, "Topp-leone family of distributions: some properties and application," *Pakistan Journal of Statistics and Operation Research*, vol. 12, no. 3, pp. 443–451, 2016.
- [4] A. S. Hassan, M. Elgarhy, and M. Shakil, "Type II half logistic family of distributions with Applications," *Pakistan Journal of Statistics and Operation Research*, vol. 13, no. 2, pp. 245–264, 2017.
- [5] M. Alizadeh, G. M. Cordeiro, A. D. C. Nascimento, M. D. C. S. Lima, and E. M. M. Ortega, "Odd-Burr generalized family of distributions with some applications," *Journal of Statistical Computation and Simulation*, vol. 87, no. 2, pp. 367–389, 2017.
- [6] H. M. Yousof, A. Z. Afify, M. Alizadeh, N. S. Butt, G. G. Hamedani, and M. M. Ali, "The transmuted exponentiated generalized-G family of distributions," *Pakistan Journal of Statistics and Operation Research*, vol. 11, no. 4, pp. 441–464, 2015.
- [7] H. Reyad, M. Alizadeh, F. Jamal, and S. Othman, "The Topp Leone odd Lindley-G family of distributions: properties and applications," *Journal of Statistics and Management Systems*, vol. 21, no. 7, pp. 1273–1297, 2018.
- [8] M. A. Haq and M. Elgarhy, "The odd Frechet-G family of probability distributions," *Journal of Statistics Applications and Probability*, vol. 7, pp. 185–201, 2018.
- [9] R. A. R. Bantan, F. Jamal, C. Chesneau, and M. Elgarhy, "Truncated inverted Kumaraswamy generated family of distributions with applications," *Entropy*, vol. 21, no. 11, Article ID 1089, 2019.
- [10] M. A. Aldahlan, J. Farrukh, C. Chesneau, M. Elgarhy, and I. Elbatal, "The truncated Cauchy power family of distributions with inference and applications," *Entropy*, vol. 22346 pages, 2020.
- [11] H. M. Yousof, M. Alizadeh, S. M. A. Jahanshahiand, T. G. Ramires, I. Ghosh, and G. G. Hamedani, "The transmuted Topp-Leone G family of distributions: theory, characterizations and applications," *Journal of Data Science*, vol. 15, no. 4, pp. 723–740, 2017.
- [12] M. A. D. Aldahlan and A. Z. Afify, "The odd exponentiated half-logistic exponential distribution: estimation methods and application to engineering data," *Mathematics*, vol. 8, no. 10, Article ID 1684, 2020.
- [13] M. A. D. Aldahlan and A. Z. Afify, "A new three-parameter exponential distribution with applications in reliability and engineering," *The Journal of Nonlinear Science and Applications*, vol. 13, no. 5, pp. 258–269, 2020.
- [14] M. Ibrahim and H. Yousof, "Transmuted Topp-Leone Weibull lifetime distribution: statistical properties and different method of estimation," *Pakistan Journal of Statistics and Operation Research*, vol. 16, pp. 501–515, 2020.
- [15] J. F. Kenney and E. S. Keeping, *Mathematics of Statistics, Pt. 1*, pp. 100–101, D. Van Nostrand, Princeton, NJ, USA, 3rd ed. edition, 1962.
- [16] J. J. A. Moors, "A quantile alternative for kurtosis," *The Statistician*, vol. 37, no. 1, pp. 25–32, 1988.
- [17] T. Bjerkedal, "Acquisition of resistance in Guinea Pigs infected with different doses of virulent tubercle Bacilli," *American Journal of Epidemiology*, vol. 72, no. 1, pp. 130–148, 1960.
- [18] R. E. Barlow, R. H. Toland, and T. Freeman, "A Bayesian analysis of stress-rupture life of kevlar 49/epoxy spherical pressure vessels," in *Proceedings of the Canadian Conference of Applied Statistics*, Marcel Dekker, New York, NY, USA, May 1984.
- [19] S. Nadarajah and S. Kotz, "The beta exponential distribution," *Reliability Engineering and System Safety*, vol. 91, no. 6, pp. 689–697, 2006.
- [20] M. M. Ristić and D. Kundu, "Marshall-Olkin generalized exponential distribution," *Metron*, vol. 73, no. 3, pp. 317–333, 2015.
- [21] G. S. Mudholkar and D. K. Srivastava, "Exponentiated Weibull family for analyzing bathtub failure-rate data," *IEEE Transactions on Reliability*, vol. 42, no. 2, pp. 299–302, 1993.
- [22] A. M. Sarhan and M. Zaindin, "Modified Weibull distribution," *APPS. Applied Sciences*, vol. 11, no. 1, pp. 123–136, 2009.
- [23] M. S. Khan, R. King, and I. L. Hudson, "Transmuted Burr type X distribution with covariates regression modeling to analyze reliability data," *American Journal of Mathematical and Management Sciences*, vol. 39, no. 2, pp. 99–121, 2020.
- [24] M. V. Aarset, "How to identify a bathtub hazard rate," *IEEE Transactions on Reliability*, vol. 36, no. 1, pp. 106–108, 1987.

## Research Article

# Reformist Framework for Improving Human Security for Mobile Robots in Industry 4.0

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In this paper, the cooperation between human and robot companies plays a significant role in factories, contributing to greater productivity and efficiency. However, this development breaches established safety procedures when the workspaces are separated from the robot and the human being. These changes have been reflected in industrial robotic safety standards for the last 20 years. We have directed the expansion of a broad field of examination, which focuses on avoiding robotic humans' effects and minimizing associated risks and consequences. The paper depicts an analysis of prominent safety systems projected and implemented in engineering robotic surroundings that contribute to safe, collective work between humans and robots. Besides, the current regulation has introduced a review and new concepts. The discussion includes multidisciplinary approaches such as estimating and evaluating human-robot collision injuries, mechanical equipment and software to minimize human-robot impacts, impact detection systems, and collision prevention strategies and minimizing their impact to proposed approach for Human Security with Mobile Robots in Industry 4.0 using SDN and CPS with GMM-GM machine learning model.

## 1. Introduction

The rapidly increasing new challenges have led to the new industrial revolution to make manufacturing processes more productive, independent, and user-friendly. An original industry concept, Industry 4.0 [1], has emerged that today refers to current manufacturing technology automation and data exchange trends through creating a "smart factory." The continuous growth in cyber-physical systems IoT and SDN increased computing ability is the foundation of Industry 4.0. In Figure 1, we represent the nine impotent pillars of

industry 4.0 [2]. The robotic processes are remotely associated with the computer system, which meets the hardware and software requirements. Our job is to provide an intelligence service to the Mobile Robot to establish the connection between the machines. Figure 1 represents Current Application Industry 4.0 [3]. In this regard, we offer a direction-finding design based on integrated control, which monitors robotic navigation and establishes the connection between the machines [4]. Four phases include autonomous Mobile Robot navigation: mapping, location, design, and implementation.

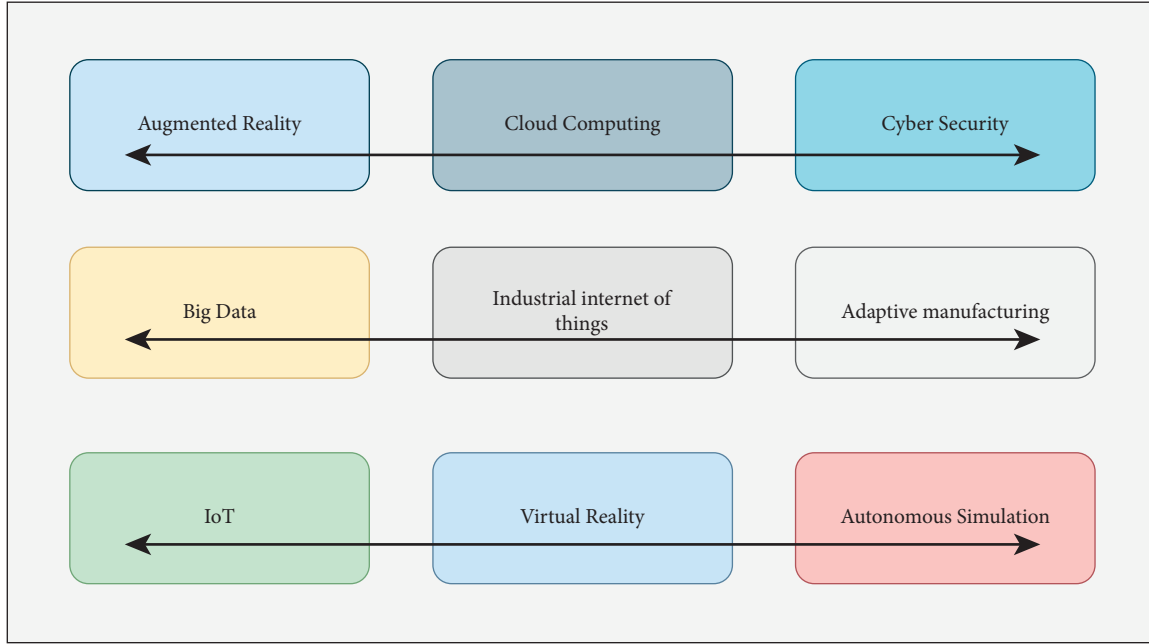


FIGURE 1: The nine components of Industry 4.0.

Therefore, it is sensible to know the environment map before starting the designing phase [5]. As there are numerous methods available to work with robots, we are not going to deal with this problem in the planning and executing of robots. Finally, concerning the classification [6] of the navigation architecture commonly used in the literature, the research paper's architecture can be seen as a mixture of many existing systems: it is primarily planned with subtle fundamentals for tackling difficulties and sudden changes in the environment. The several issues tackled in the designing framework of Industry 4.0 are the nonexistence of concurrent encryption acquiescent to fissures and security breaches and the lack of developed infrastructure that meets Industry 4.0. To fill this security-related gap, upgradation of infrastructure is needed within few years.

## 2. Related Work

Chen et al.'s [7] discussion includes multidisciplinary approaches such as estimating and evaluating human-robot collision injuries, mechanical equipment and software to minimize human-robot impacts, impact detection systems, and collision prevention strategies as well as reducing their impact. Wan et al. [8] represent the outline of IoT and Industry 4.0 because the industry is changing rapidly, and the main objective is to enhance the quality of industry infrastructure and resources. Åblad et al.'s [9] studies have shown that both practices recover industrial wireless sensor networks' dependability when interference occurs. Agarwal et al.'s [10] paper can help you deeply understand the current application of data management in related industries and identify interesting open research opportunities. In industrial environments, Chiang et al. [11] presented an overall Mobile Robot navigation methodology that uses automation to support open-loop robotic behaviour and specifications.

Oztemel and Gursev's [12] paper describes a recently designed architecture for IoT-based networks used for the prominent use of physical layer, network layer, and application layer. In Rajawat et al. [13], simulations show the advantage of reasoning developed IoT and show that CACR can suggestively increase energy efficacy and cost optimization for handling materials. Evjemo et al. [14] presented a program in which robots never intersect and accomplish maximum intervals equivalent to those produced that allow harmonization to be generated. Table 1 shows the comparison of studies for different frameworks and Table 2 shows the comparison of applications of Industry 4.0 for various domains.

## 3. Reformist Framework

The controller can be reconfigured and the production functions can be extended. Modular production units proposed a modular-adaptive autonomous robotic [15, 16] island to improve the workshop's assembly capacity from the point of view of modular production units. Besides, an integrated management framework has enhanced flexible manufacturing skills, which controls and organizes a modular manufacturing unit—which proposed that cognitive robots be vertically integrated into production physically by the cyber—the vertical integration of the cognitive robots in the manufacturing industry and the coordination with the manufacturing system. Cognitive robots can perceive information uncertainty in the context of smart production, change schedules, and adjust production behavior to face a complex production issue independently. Therefore, the intelligence of robot units is essential. The following are several suggestions for building modular production units. Furthermore, the interaction heterogeneity should be considered. The functions of various

TABLE 1: Comparison of studies for different frameworks.

S. no.	Study	Framework name	Highlights
1	Sanz et al. 2021	BiDrac Industry 4.0 framework	Designed to integrate various activities of CASE technologies
2	Di Castro et al. 2018	Cerntauro	Designed to operate in harsh and hazardous environments
3	Kattepur et al. 2020	RoboPlanner	Designed to locate numerous warehouses, data centres, and supply chain operations
4	Jain et al. 2021	Open source framework	Designed as software stack which allows customers to request deliveries

TABLE 2: Comparison of applications of Industry 4.0 for various domains.

S. no.	Study	Domain	Highlights
1	Chen et al. 2021	Reinforcement learning	Application of reinforcement learning used in classification problems
2	Fatorachian et al. 2021	Supply chain management	To optimize the prominent factors used in supply chain management
3	Ammar et al. 2021	Manufacturing industry	The improvements implemented in manufacturing industry with help of Industry 4.0 frameworks
4	Ralph et al. 2021	Manufacturing industry	Major advantages of principles of Industry 4.0 in metal forming

modular production units for a particular product may be redundant, and therefore an optimal or inappropriate combinatorial system is crucial. Each production plant can comply with product manufacturing requirements and self-organize to increase intelligent plant efficiency. Small quantities of various products are disorderly brought into the fabrication system during intelligent manufacturing, leading to an impasse. The approach to preventing impasse in flexible production systems with human security with Mobile Robots in Industry 4.0 [17] is currently a hot research topic. This would make it possible for the production unit to adapt quickly to changes in operating conditions. Use the available software components to adjust the robot to changing operating conditions and upgrade the robot function. Besides, an advanced robot controller design has been introduced that can be used in the new generation of robots. Models of control unit components have been developed for component model since standardization and universality can improve reconfiguration processes. This would make it possible for the production unit to adapt quickly to changes in operating conditions. Use the available software components to adjust the robot [18] to changing operating conditions and upgrade the robot function [19]. Besides, an advanced robot controller design has been introduced that can be used in the new generation of robots for Reformist Framework for improving human security with Mobile Robots in Industry 4.0—developed Reformist Framework for improving human security with Mobile Robots, a new distributed multiagent controller system that is compatible with an intelligent and reconfigurable number control computer (CNC).

The specific implementation steps are as follows:

- Step-1: Initialize the starting point [Open list].
- Step-2: If Open list: Null Search Failure
- Step-3: If node-value: least-value Open List = current node
- Step-4: If node: target-point: Search ends.

Step-5: Expand the node Move in a circular and straight path.

Step-6: If obstacle = present, go to step 5

Step-7: Change motion if exact type of, motion not found.

Step-8: Jump to next open list node.

**3.1. Mobile Robots (MR) in Smart Factories.** Mobile Robot (MR) systems are embedded in intelligent factories with sensors in safe working areas to collaborate with human robots. Compared to traditional industrial robots [20], the Mobile Robot (MR) has several advantages. There are many advantages of Mobile Robot (MR). These robots provide people with safe room and fence protection, and they can provide room for traditional robots. Proximity sensors are used to decrease the speed of robots when people approach it, the limitation of forces to minimize human and environmental risks, and human intent and management accordingly. The prominent ideology is that Mobile Robots (MR) do not harm a person and that controlled force and speed are the means to protect someone. Separation monitoring, hand guidance, and monitored stop-office at safety rates. Planning and control of vision and CAD robots help to avoid long-term manual robot programming. Dynamic motion primitives to parameterize Mobile Robot (MR) motion can also relieve learning by demonstrating the need for manual programming. This will also provide greater flexibility where, for example, changes in production require the plant's interior.

**3.2. Cyber-Physical Systems (CPS).** Cyber-physical systems (CPS) is one of the significant contributing factors involved in Industry 4.0. Cyber-physical systems is connected to physical devices with the help of the internet (internet of things), which depicts that the entire physical and virtual worlds are connected due to CPS. The physical world

contains computer and machinery, cyber-spaces contain applications, software, routines, and analytics activities, and communication network is the interconnection between the physical world and software. The CPS plays an important role where actuators and sensors are linked with the software. The main aim of CPS is to increase the production rate by increasing the efficiency [21] of the system. With the rise of the concept of Industry 4.0, mechanisms have expanded, and an ample amount of importance is given to developing smart systems. Smart and different designs have been considered to handle failures in nonoptimized methods. CPS is very useful in enhancing the flexibility of IoT-based production systems in various domains such as healthcare, agriculture, and financial sectors (banking). The modified human-computer interaction system is developed, which helps us to develop the main ideology of Industry 4.0. Figure 2 is showing Integration of Product Development in Digital and Physical Production.

**3.3. Internet of Robotic Things (IoRT).** Combining IoRT knowledge from several sources can contribute to a consistent and consistent depiction of the robot world. In a summarized view, IoRT information should only be integrated based on approximate environmental models. In the case of monitoring contacts, for example, in selecting impedance parameters or determining the hazardous control points of the Mobile Robot (MR) to be left for the essential individual, data fusion is significant. The proximity could include proximity IoT like pan/tilt/zoom cameras, stereo cameras, deep camera base, or audio/video feedback systems. Adjustable power and force limitation functions (considerable, high speed, and high payload) can be better adapted to conventional robots (PFL robots). Remote interaction sensors include cameras, stereo cameras, 3D Lidar cameras, and a certified safety sensor. Audio/video recovery: HRC sensors may also be fitted with integrated force/torque or grip proximity sensors.

**3.4. Improving Security of Cyber-Physical System Using SDN for Mobile Robotic Industry 4.0.** Conceptual Industry 4.0 has a significant impact and many changes in manufacturing, output, and business modeling processes. This ensures mass adaptation, higher productivity, flexibility, speed of production, and improved product quality. Because machines can be quickly set up to suit customer specifications and additives, mass adaptation allows for the production of small lots, even small lots. It encourages innovation because prototypes or new products can be produced quickly without the need for complex retooling or the establishment of new production lines. Therefore, it can produce one product and many variants, with the use of Industry 4.0 technologies reducing its inventories. Besides, the speed at which the product can be manufactured has been improved by reducing the time between designs, digital strategies, and virtual manufacturing modeling. In India, data-driven supply chains can accelerate the production process by approximately 100 percent in terms of delivery time and 60 percent to bring products onto the market. Increased quality

is an essential factor in cost reduction and, therefore, competitiveness. If all defects were removed, the cost of scrapping or reprocessing defective products would be saved. The productivity of the various effects of Industry 4.0 can also be increased. Advanced analytics in predictive maintenance programs, which results in increased production and decreased downtime, can help avoid machine failure. Some companies may establish factories where automated robots are manufactured at home without light or heat. Robotics have a significant economic impact with security on industrial applications where increased productivity can drive economic growth, self-driving mobile robots are machines equipped with sensors and feedback to navigate an obstacle-filled environment. It is intended to reduce wear in various industrial components while increasing productivity in the manufacturing sector. Reformist Framework for improving human security with Mobile Robots in Industry 4 [22] has a variety of advantages, including lower floor traffic, flexible flooring, dependability, and self-regulation. The basic requirement to use the autonomous mobile robots is as follows:

- (i) Using our approach automatically increasing efficiency and productivity [23]
- (ii) Automatic handling of the material
- (iii) Automatic increase of the security [24] and safety, reducing the stress and high risk
- (iv) Managing the repetitive task with creativity [25]
- (v) Reducing the factory traffic in complex conditions

Production control is a crucial vision of Industry 4.0, [26] including improving human security [27] with Mobile Robots in Industry 4.0 [28] factories to fully connect production. Although it does not yet exist because factory systems have not been linked with a unified framework [29], this capability would allow entire production lines to be checked and optimized in different facilities [30]. Many companies see it as a current and future goal, the realization of which will still rely on improved information infrastructure, better data handling security and safety, and significant improvements [31] to improving human security with Mobile Robots in Industry 4.0, as one company has stated, which will be responsible for “automating automation” [32].

Figure 3 shows the analysis of the attacking data for improving human security with Mobile Robots in Industry 4.0 and represents the autonomous sensor with a decision system working.

At employment, efficient human-robot contact is likely to be harmful to both parties. Consider the hazards listed in Figures 4–6 which are potential human-robot interaction risks. Table 3 represents the human-robot interaction.

## 4. Proposed Real-Time Attack of Data Classification

We proposed Gaussian Mixture Model (GMM) [33] with expectation maximization (EM). The internet of things (IoT) avoids obstacles by updating its path in real time, then



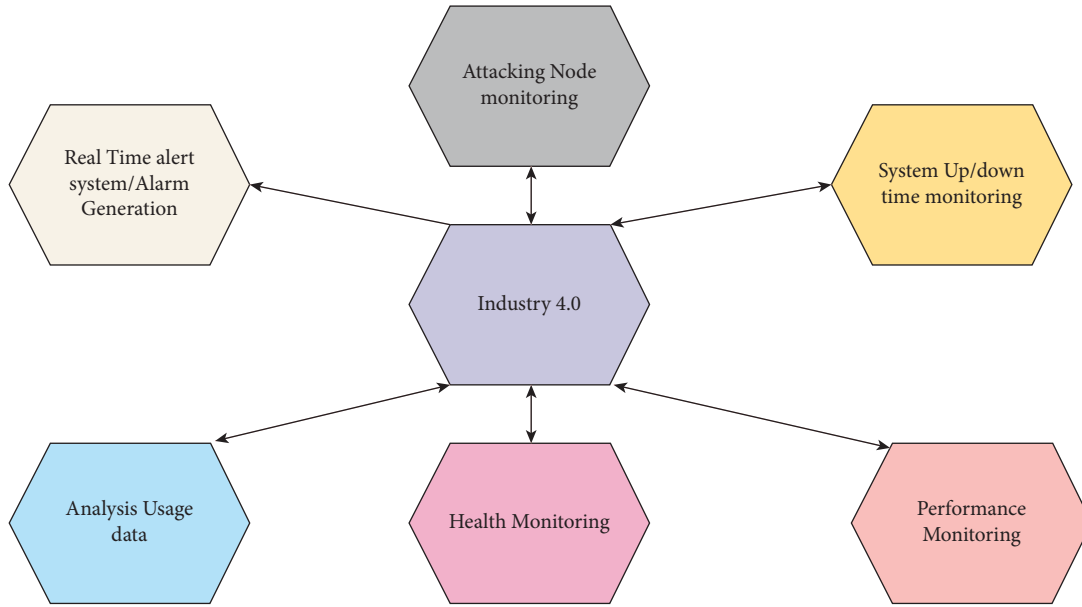


FIGURE 2: Integration of product development in digital and physical production.

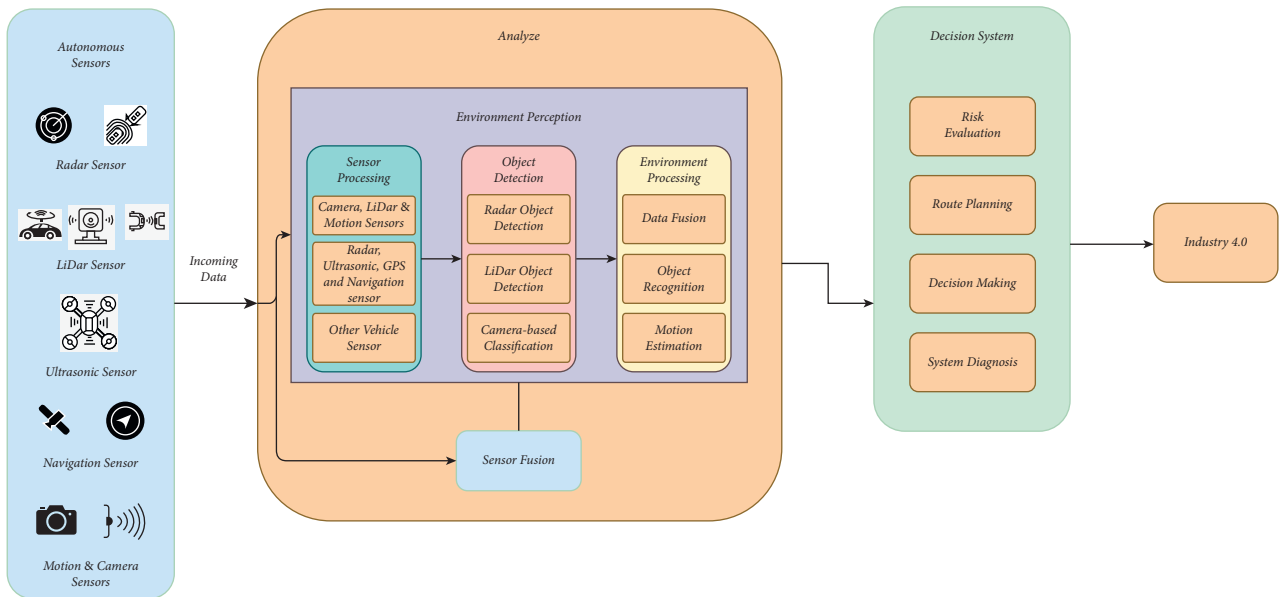


FIGURE 3: Analysis of the attacking data for improving human security with Mobile Robots in Industry 4.0.

bypassing the obstacle and reaching the target point. Anticipating obstacles moving a robot from one area to another is called motion planning. We carried out research on cyber hazards to motion planning. Path and trajectory plans assume that your manipulator's displacement, velocity, and acceleration are all on the same time axis. The trajectory is a path that carries time axis information. Human-robot interaction requires trajectory planning. A static environment with little path planning is their domain—for example, a rapid spreading random tree based on random sampling. Online tracking control is used for most typical robot task pathways. A safety cage protects an operator's workspace. The environment is dynamic, and the problems are

predictable and unpredictable. Online real-time collaborative robot trajectory planning based on sensor inputs replaces offline planning. They are predicting path/route utilizing global environmental data like grid maps and random spanning trees. However, their slow solution speed makes them unsuitable for online obstacle avoidance planning. For online obstacle avoidance trajectory planning of robot arms, it uses local environmental data. The operating arm's online trajectory planning system uses potential fields, feedback control, and null space projection. Others strive to avoid cyber-attacks. The planner is described. An N-point dataset comprising joint angles, hand trajectories, or hands object distance vectors can be used to test the



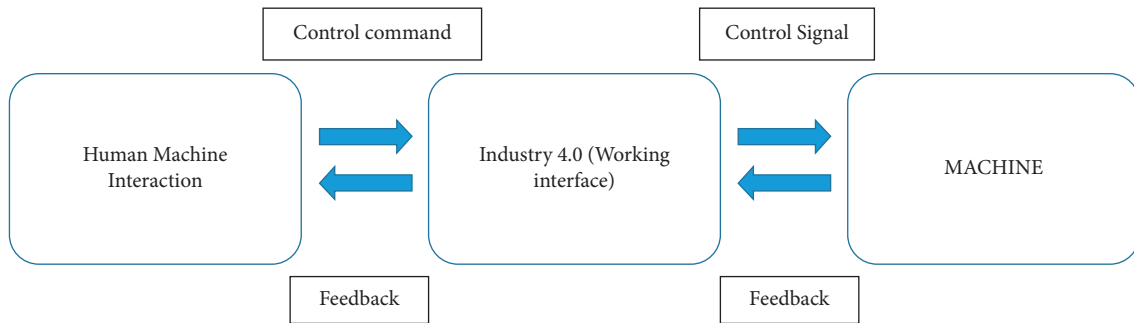


FIGURE 4: Process for human-machine interaction (HMI).

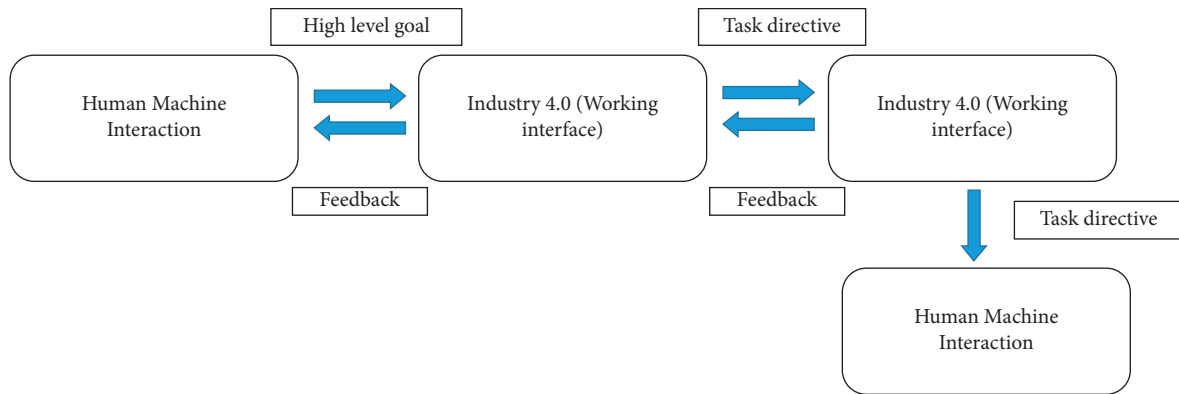


FIGURE 5: Human task interaction.

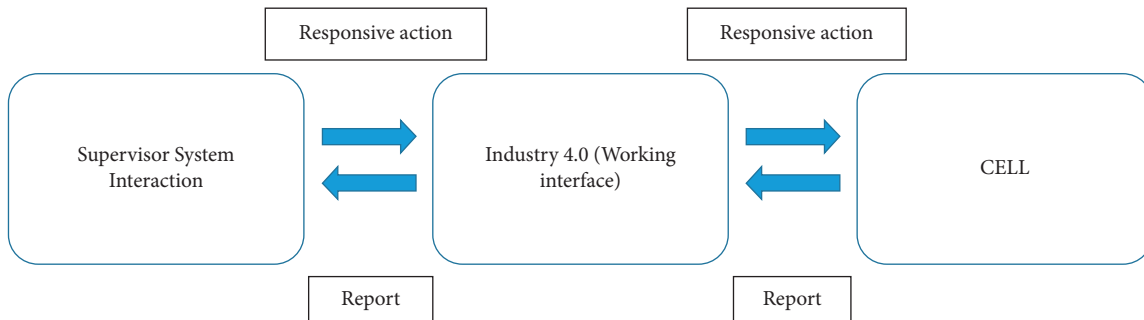


FIGURE 6: Supervisor system interaction.

TABLE 3: Human-robot interaction.

Human security with mobile robots in Industry 4.0	Explanation
Safety of hazardous from Mobile Robot	Increasing the gap between human and Mobile Robot operation The Mobile Robot's pathway and its barriers Psyche-physiology of the human operator industrial process hazards extra care
Safety of unsafe from the industrial process	Inadequate ergonomic solutions for maintenance and operation The work complexity in the working space The influence of operators
Protection from robot control system failure	Errors made by humans while operating robots Creating obstacles for robot sensors to work Priority should be given to control system failures and their implications (cyber-attack)

Gaussian Mixture Model (GMM) with expectation maximization (EM) [34]. In a mixed model with K components, there is probability density.

**4.1. Automated Manufacturing Internet of Robotic Things (IoRT) and Cobots.** Provide solutions to decreasing talent pools, rising labor costs, and increased competitiveness facing manufacturers today and expanding the workforce with IoRT and cobots that improve worker performance, safety, and retention. Screw driving, low-value shipping, palletizing, and machine maintenance are all jobs that humans are doing. A IoRT increases productivity and quality. People have more time to solve challenging production challenges, improve lean processes, and find creative solutions. Permitting employees to produce greater value while avoiding repetitive and dangerous jobs promotes employee satisfaction. Heavy lifting, overreaching, and repetitive motions are not suited for the human body. Injuries, accidents, and quality difficulties arose from this conflict. A cyber-physical attack may not expose product faults until the end of production. Products that do not undergo postproduction quality testing are in danger of failing. Unidentified or uncorrected structural flaws may enter the market. Structurally deficient, this is seen in design flaws that can go unnoticed by a product's design team. So a new postproduction analysis method is required. Goods made using CT, Raman spectroscopy, and other comparable scanning methods could find problems in products before leaving the plant. SDNs and cyber-physical systems provided an IoRT [35] high-level view of scaling information networks. It is a new and promising answer to the current problematic networking issue (SDN-like isolation of network services and hardware). They argue that network decoupling requires the abstraction of the underlying network technology. This treats the network as a whole. A centralized software-defined network controller is the SDN's brain. Network controller software keeps track of all network device connectivity. An SDN network needs all of these elements. Firewalls, switching, and routing are so segregated. Divvying up a network into these three segments allows for individual improvement. Admins oversee routing, firewalls, and policy—the management plane. Load distribution can increase efficiency and lower costs. The forwarding plane sends packets to network switches (hardware or software). The data plane handles packet header inspection, forwarding to controllers and network ports. Packets directed to devices, not in the flow tables, can be refused or rerouted. Figure 7 is showing the self-driving framework for mobile robots are machines equipped for human security.

It is unquestionably true that the IoRT with SDNs will significantly benefit industrial businesses looking for an efficient yet realistic networking solution for equipment interconnection.

**4.2. Attacking Node Termination for Human Security.** Distinguishing cyber-physical components enhanced human-machine interfaces create additional security and

interoperability concerns. An increasing number of industrial customers using automatic and semiautomatic assembly processes desire to integrate their workforce. Technically, industrial concerns vary, but they all revolve around safety and security. Once the cyber-layer is breached, SDN-CPS mitigation methods are ineffective in identifying and actively responding IoRT to cyber-attacks. The current development phase aims to boost penetration by understanding the target (CPS) control system. On the right, you can see attack tactics, targets, consequences, and interdependencies among the IoRT with SDN-CPS-security layers [36]. Because SDN-CPS security has numerous system layers, attacks on different system tiers are feasible. Due to the high degree of interdependency between SDN-CPS-security components at different tiers, unexpected repercussions are likely to occur. They can occur at components in various layers or even separate domains (cyber or physical). Ineffective IoRT and CPS assaults have received little attention. The choice of SDN-CPS-security technology poses various technical issues. Calculating the robot's [37] safe distance from the human workers in the production cell is the most difficult. Tight sensor safety distance constraints will be the technological limit. Reliable components and a cyber-security mitigation plan [38] are required to prevent smart cyber-attacks in a networked environment. Even if the system's cyber layer is breached, workers and PCs must be protected. Covering the robot's surfaces to prevent human contact [39] is another challenge. Camera systems require the most safety distance [40]. A speedier human worker means a wider safety gap. Individual sensor data latency rates and network connectivity difficulties can lead to unwanted findings. IoRT provides solutions to eliminate delays caused by using many sensors from various manufacturers [41]. It was determined that worker speed and safety distance are related. This includes risks that can cause system failure and jeopardise human safety.

## 5. Results and Discussion

This section presents all the results and analyses based on a variety of performance measures and evaluating multiple machine learning model [42] (Decision Tree (DT), Random Forest (RF), support vector machine (SVM), and back-propagation neural network (BPNN)) which are identified as the most safe and effective for classifying attack data on IoRT networks [43].

The table illustrates the GMM and EM confusion matrix and two interesting facts. The first is that the data tested is little and the classes are not equally represented. The lack of test data may be affecting the outcomes. Table 4 shows that, except for DT, the other models score poorly compared to RF, SVM, SVMG-RBF, and BPNN. Increase the test data to examine how it affects the RF, SVM, SVMG-RBF, BPNN model's scores [44]. Table 4 shows the effects of increasing IoRT network attacking data. Increasing the test data by 30% improves recall but not accuracy. After 50%, the model loses complete recall and precision [45]. Due to a paucity of data, the model's outputs vary greatly. Table 5 represents the comparative analysis traditional model and proposed model [46].

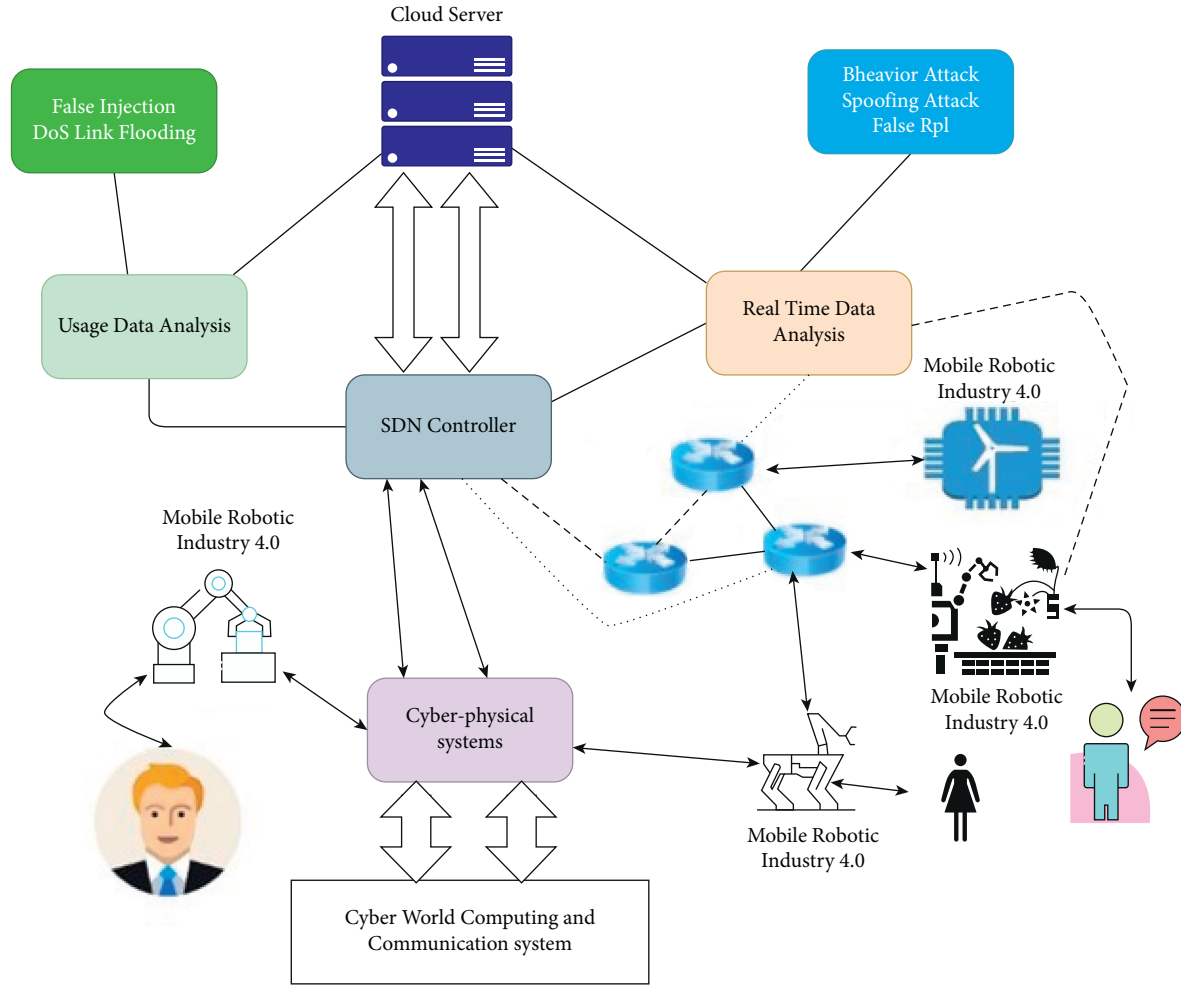


FIGURE 7: Self-driving framework for Mobile Robots are machines equipped for human security.

TABLE 4: Machine learning algorithm for attacking node data classification.

Algorithm used	Accuracy (%)	Precision	Recall	F1 score
DT	0.91	0.843	0.988	0.98
RF	0.93	0.774	0.988	0.97
SVM	0.95	0.874	0.988	0.97
SVMG-RBF	0.95	0.866	0.988	0.99
BPNN	0.94	0.832	0.988	0.98
Proposed	0.98	0.888	0.988	0.99

TABLE 5: The comparative analysis traditional model and proposed model.

Name algorithm	Traditional	Proposed mr-dfl
DT	Large amounts of memory, a large dataset, and a lengthy computation time	Reduce the amount of time it takes to compute and increase accuracy
RF	Cost of computation is really high	Less computation cost
SVM	Error evaluation, very slow	Error evaluation, very high
SVMG-RBF	Data classification, very slow	Data classification, very high response
BPNN	More computing in large datasets	Large datasets with excellent precision
Proposed	Inaccuracy large datasets, significant memory use	Low memory usage, great precision

## 6. Conclusion

In this paper, we discussed the general approach to IoRT steering in industrialized backgrounds in which the Mobile Robot's free behaviour and requirements are all automatically based. To achieve a flexible supervision controller using SDN and CPS that safeguards the accurate direction-finding of the robot in the presence of unforeseeable protects. The proposed method provides a general demonstrating structure for specifications through components that are exclusively dependent on the type of jobs achieved by the automation. Our proposed Gaussian Mixture Model (GMM) with expectation maximization (EM) Tussles of improving human security with Mobile Robots in Industry 4.0 architecture proposed in this research part would serve as research directly in cooperation with several robots. In the future work, we plan to include the research's models into an IDS prototype for testing with various data and threats to confirm model multiclass capability.

## Data Availability

The data that support the findings of this study are available on request from the corresponding author.

## Conflicts of Interest

All the authors declare that they do not have any conflicts of interest.

## Acknowledgments

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## References

- [1] S. Robla-Gomez, V. M. Becerra, J. R. Llata, E. Gonzalez-Sarabia, C. Torre-Ferrero, and J. Perez-Oria, "Working together: a review on safe human-robot collaboration in industrial environments," *IEEE Access*, vol. 5, pp. 26754–26773, 2017.
- [2] M. Aazam, S. Zeadally, and K. A. Harras, "Deploying fog computing in industrial internet of things and industry 4.0," *IEEE Transactions on Industrial Informatics*, vol. 14, no. 10, pp. 4674–4682, 2018.
- [3] M. C. Lucas-Estañ, B. Coll-Perales, and J. Gozalvez, "Redundancy and diversity in wireless networks to support mobile industrial applications in industry 4.0," *IEEE Transactions on Industrial Informatics*, vol. 17, no. 1, pp. 311–320, 2021.
- [4] T. P. Raptis, A. Passarella, and M. Conti, "Data management in industry 4.0: state of the art and open challenges," *IEEE Access*, vol. 7, pp. 97052–97093, 2019.
- [5] A. G. C. Gonzalez, M. V. S. Alves, G. S. Viana, L. K. Carvalho, and J. C. Basilio, "Supervisory control-based navigation architecture: a new framework for autonomous robots in industry 4.0 environments," *IEEE Transactions on Industrial Informatics*, vol. 14, no. 4, pp. 1732–1743, 2018.
- [6] J. Kumar, P. Bedi, S. B. Goyal, A. Shrivastava, and S. Kumar, "Novel algorithm for image classification using cross deep learning technique," *IOP Conference Series: Materials Science and Engineering*, vol. 1099, Article ID 012033, 2021.
- [7] B. Chen, J. Wan, L. Shu, P. Li, M. Mukherjee, and B. Yin, "Smart factory of industry 4.0: key technologies, application case, and challenges," *IEEE Access*, vol. 6, pp. 6505–6519, 2018.
- [8] J. Wan, S. Tang, Q. Hua, D. Li, C. Liu, and J. Lloret, "Context-aware cloud robotics for material handling in cognitive industrial internet of things," *IEEE Internet of Things Journal*, vol. 5, no. 4, pp. 2272–2281, 2018.
- [9] E. Åblad, D. Spensieri, R. Bohlin, and J. S. Carlson, "Intersection-free geometrical partitioning of multirobot stations for cycle time optimization," *IEEE Transactions on Automation Science and Engineering*, vol. 15, no. 2, pp. 842–851, 2018.
- [10] M. Agarwal, S. Biswas, C. Sarkar, S. Paul, and H. S. Paul, "Jampacker: an efficient and reliable robotic bin packing system for cuboid objects," *IEEE Robotics and Automation Letters*, vol. 6, no. 2, pp. 319–326, 2021.
- [11] T.-H. Chiang, Z.-H. Sun, H.-R. Shiu, K. C.-J. Lin, and Y.-C. Tseng, "Magnetic field-based localization in factories using neural network with robotic sampling," *IEEE Sensors Journal*, vol. 20, no. 21, pp. 13110–13118, 2020.
- [12] E. Oztemel and S. Gursev, "Literature review of industry 4.0 and related technologies," *Journal of Intelligent Manufacturing*, vol. 31, no. 1, pp. 127–182, 2020.
- [13] A. S. Rajawat, S. Jain, and K. Barhanpurkar, "Fusion protocol for improving coverage and connectivity WSNs," *IET Wireless Sensor Systems*, vol. 11, no. 4, 2021.
- [14] L. D. Evjemo, T. Gjerstad, E. I. Grøtli, and G. Sziebig, "Trends in smart manufacturing: role of humans and industrial robots in smart factories," *Current Robotics Reports*, vol. 1, no. 2, pp. 35–41, 2020.
- [15] M. A. Bahrin, M. F. Othman, N. H. Nor Azli, and M. F. Talib, "Industry 4.0: a review on industrial automation and robotic," *Jurnal Teknologi*, vol. 78, 2016.
- [16] A. G. Gonzalez, M. V. Alves, G. S. Viana, L. K. Carvalho, and J. C. Basilio, "Supervisory control-based navigation architecture: a new framework for autonomous robots in industry 4.0 environments," *IEEE Transactions on Industrial Informatics*, vol. 14, no. 4, pp. 1732–1743, 2017.
- [17] E. Sanz, J. Blesa, and V. Puig, "BiDrac industry 4.0 framework: application to an automotive paint shop process," *Control Engineering Practice*, vol. 109, Article ID 104757, 2021.
- [18] M. Di Castro, M. Ferre, and A. Masi, "CERNTAURO: a modular architecture for robotic inspection and tele-manipulation in harsh and semi-structured environments," *IEEE Access*, vol. 6, pp. 37506–37522, 2018.
- [19] A. Kattepur and B. Purushotaman, "RoboPlanner: a pragmatic task planning framework for autonomous robots," *Cognitive Computation and Systems*, vol. 2, no. 1, pp. 12–22, 2020.
- [20] A. K. Jain and M. Svetlik, "An open-source framework for last mile delivery with heterogeneous robots," in *Proceedings of the AAAI 2021 Spring Symposium Series, Machine Learning for Mobile Robot Navigation in the Wild*, Palo Alto, CA, USA, 2021.
- [21] P. Kumar Shukla, P. Sharma, P. Rawat, J. Samar, R. Moriwai, and M. Kaur, "Efficient prediction of drug-drug interaction using deep learning models," *IET Systems Biology*, vol. 14, no. 4, pp. 211–216, 2020.
- [22] Q. Chen, B. Heydari, and M. Moghaddam, "Levering task modularity in reinforcement learning for adaptable industry 4.0 automation," *Journal of Mechanical Design*, vol. 143, no. 7, pp. 1–35, 2021.



- [23] H. Fatorachian and H. Kazemi, "Impact of industry 4.0 on supply chain performance," *Production Planning & Control*, vol. 32, no. 1, pp. 63–81, 2021.
- [24] A. S. Rajawat, U. Dwivedi, D. C. Jain, and A. R. Upadhyay, "Efficient web data classification techniques using semi-supervised learning algorithm," in *Proceedings of the 5th ACM COMPUTE Conference on Intelligent & Scalable System Technologies*, pp. 1–8, Pune, India, January 2012.
- [25] M. Ammar, A. Haleem, M. Javaid, R. Walia, and S. Bahl, "Improving material quality management and manufacturing organizations system through industry 4.0 technologies," *Materials Today: Proceedings*, vol. 45, no. 4, 2021.
- [26] B. Ralph and M. Stockinger, "Digitalization and digital transformation in metal forming: key technologies, challenges and current developments of industry 4.0 applications," in *Proceedings of the XXXIX. Colloquium on Metal Forming*, Leoben, Austria, March 2021.
- [27] A. S. Rajawat and A. R. Upadhyay, "Web personalization model using modified S3VM algorithm for developing recommendation process," in *Proceedings of the 2nd International Conference on Data, Engineering and Applications (IDEA)*, pp. 1–6, Bhopal, India, February 2020.
- [28] P. Prabhu, S. Raj, and A. Roy Chowdhury, "Interlinking industry 4.0 and academia through robotics and automation: an Indian perspective," *Convergence of Digitalization on 5G Edge AI Computing*, IntechOpen Limited, London, UK, 2020.
- [29] S. V. Lobova, N. V. Bykovskaya, I. M. Vlasova, and O. V. Sidorenko, "Successful experience of formation of industry 4.0 in various countries," in *Industry 4.0: Industrial Revolution of the 21st Century*, pp. 121–129, Springer, Berlin, Germany, 2019.
- [30] R. Bhatt, P. Maheshwary, P. Shukla, P. Shukla, M. Shrivastava, and S. Changlani, "Implementation of fruit fly optimization algorithm (FFOA) to escalate the attacking efficiency of node capture attack in wireless sensor networks (WSN)," *Computer Communications*, vol. 149, pp. 134–145, 2020.
- [31] R. Rajkumar, I. Lee, L. Sha, and J. Stankovic, "Cyber-physical systems: the next computing revolution," in *Proceedings of the Design Automation Conference*, pp. 731–736, IEEE, Anaheim, CA, USA, June 2010.
- [32] R. Gervasi, L. Mastrogiacomio, and F. Franceschini, "A conceptual framework to evaluate human-robot collaboration," *International Journal of Advanced Manufacturing Technology*, vol. 108, no. 3, pp. 841–865, 2020.
- [33] L. Romeo, A. Petitti, R. Marani, and A. Milella, "Internet of robotic things in smart domains: applications and challenges," *Sensors*, vol. 20, no. 12, p. 3355, 2020.
- [34] A. Ghosh, D. Alonso Paredes Soto, S. M. Veres, and A. Rossiter, "Human robot interaction for future remote manipulations in industry 4.0," *IFAC*, vol. 53, no. 2, pp. 10223–10228, 2020.
- [35] Z. Gao, W. Tom, I. Singh, A. Gadhri, and R. Schmidt, "From industry 4.0 to robotics 4.0—a conceptual framework for collaborative and intelligent robotic systems," *Procedia Manufacturing*, vol. 46, pp. 591–599, 2020.
- [36] A. Khalid, P. Kirisci, Z. Ghairi, K.-D. Thoben, and J. Pannek, "Towards implementing safety and security concepts for human-robot collaboration in the context of industry 4.0," in *Proceedings of the 39th International MATADOR Conference on Advanced Manufacturing*, Manchester, UK, July 2017.
- [37] S. Bragança, E. Costa, I. Castellucci, and P. M. Arezes, "A brief overview of the use of collaborative robots in industry 4.0: human role and safety," *Occupational and Environmental Safety and Health*, Springer, Cham, Germany, pp. 641–650, 2019.
- [38] Y. Li, S. Carabelli, E. Fadda, D. Manerba, R. Tadei, and O. Terzo, "Machine learning and optimization for production rescheduling in industry 4.0," *International Journal of Advanced Manufacturing Technology*, vol. 110, no. 9–10, pp. 2445–2463, 2020.
- [39] Z. Zeng, W. Sun, W. Wu, M. Xue, and L. Qian, "An efficient path planning algorithm for mobile robots," in *Proceedings of the IEEE 2019 IEEE 15th International Conference on Control and Automation (ICCA)*, pp. 487–493, Edinburgh, UK, July 2019.
- [40] H. Li and A. V. Savkin, "An algorithm for safe navigation of mobile robots by a sensor network in dynamic cluttered industrial environments," *Robotics and Computer-Integrated Manufacturing*, vol. 54, pp. 65–82, 2018.
- [41] D. Singh, "Human emotion recognition system," *International Journal of Image, Graphics and Signal Processing*, vol. 4, no. 8, pp. 50–56, 2012.
- [42] H. S. Pannu, D. Singh, and A. K. Malhi, "Multi-objective particle swarm optimization-based adaptive neuro-fuzzy inference system for benzene monitoring," *Neural Computing and Applications*, vol. 31, no. 7, pp. 2195–2205, 2019.
- [43] H. S. Pannu, D. Singh, and A. K. Malhi, "Improved particle swarm optimization based adaptive neuro-fuzzy inference system for benzene detection," *Clean Soil Water*, vol. 46, no. 5, Article ID 1700162, 2018.
- [44] P. K. Shukla, M. Agrawal, and A. U. Khan, "Stock price prediction using technical indicators: a predictive model using optimal deep learning," *International Journal of Recent Technology and Engineering (IJRTE)*, vol. 8, no. 2, pp. 2297–2305, 2019.
- [45] S. B. Goyal, P. Bedi, J. Kumar, and V. Varadarajan, "Deep learning application for sensing available spectrum for cognitive radio: an ECRNN approach," *Peer-to-Peer Networking and Applications*, vol. 14, no. 5, 2021.
- [46] P. Bedi, S. B. Goyal, R. Sharma, D. K. Yadav, and M. Sharma, "Smart model for big data classification using deep learning in wireless body area networks," in *Micro-Electronics and Telecommunication Engineering. Lecture Notes in Networks and Systems*, D. K. Sharma, L. H. Son, R. Sharma, and K. Cengiz, Eds., vol. 179, Springer, Singapore, 2021.

## Research Article

# Spatiotemporal Analysis of Residents in Shanghai by Utilizing Chinese Microblog Weibo Data

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Mobile applications are really important nowadays due to providing the accurate check-in data for research. The primary goal of the study is to look into the impact of several forms of entertainment activities on the density dispersal of occupants in Shanghai, China, as well as prototypical check-in data from a location-based social network using a combination of temporal, spatial, and visualization techniques and categories of visitors' check-ins. This article explores Weibo for big data assessment and its reliability in a variety of categories rather than physically obtained information by examining the link between time, frequency, place, class, and place of check-in based on geographic attributes and related implications. The data for this study came from Weibo, a popular Chinese microblog. It was preprocessed to extract the most important and associated results elements, then converted to geographical information systems format, appraised, and finally displayed using graphs, tables, and heat maps. For data significance, a linear regression model was used, and, for spatial analysis, kernel density estimation was utilized. As per results of hours-to-day usage patterns, enjoyment activities and frequency distribution are produced. Our findings are based on the check-in behaviour of users at amusement locations, the density of check-ins, rush periods for visiting amusement locations, and gender differences. Our data provide light on different elements of human behaviour patterns, the importance of entertainment venues, and their impact in Shanghai. So it can be used in pattern recognition, endorsement structures, and additional multimedia content for these collections.

## 1. Introduction

In recent decades, academics have been more interested in mining location-based social network (LBSN) data for relevant outlines and awareness. A considerable quantity of data is created as a result of the vast number of LBSN-based apps available today, which is then analyzed to extract useable information, primarily from a practical standpoint, such as public transportation flows, disaster management, and collision avoidance [1]. These programmers' online capabilities enable users to contribute and share their opinions, habits, photographs, video files, and other content

with their network acquaintances, resulting in a large quantity of data that researchers may utilize to pinpoint visitors' actions and likings only over study. Internet services acquire and retain users' personal information as well as their current location.

The data are frequently augmented with information, multimedia, geolocations, and text, which may be utilized to do further study on various human behaviour features. Previous researches datasets were either physically collected data for populations in various classifications, such as leisure, or LBSNs data for the whole population without predefined implementations. If appropriately categorized,



the extensive elements of the LBSNs facts might demonstrate to be a valuable data source for analyzing human behaviour in various areas such as amusement, education, tourism, restaurants, and travel. As a consequence, we will cover the research gap of using LBSN data in article or substance in this study by determining which entertainment venues Shanghai residents want to visit. A variety of studies have been conducted to evaluate and recreate human activities using geodata. Recent studies, for example, use check-in data from internationally popular LBSNs like Twitter, Facebook, and Foursquare to uncover correlations and patterns across users like female and male, skilled or less skilled classes, and age groups [2, 3].

Unlike the widespread usage of Facebook, Twitter, and other LBSNs throughout the world, the majority of these LBSNs are outlawed or limited in China. As a result, Chinese residents prefer to utilize national microblog such as Weibo (Sina Weibo) [4, 5]. So, check-in data from Weibo may be acceptable for LBSNs statistical study in China. These outlines duplicate functional features inside the city and between cities and include activity behaviour, mobility, and density [6, 7]. The term “check-in” refers to a user using an LBSN application to confirm her/his location by participating in an activity or sharing her/his site with someone in a note [8, 9]. Weibo is well known not only among users but also among researchers, who execute a variety of topics to extract useful information from its geodata, such as the analysis of traffic accidents in Shanghai [10, 11], the analysis of tourism hotspot appeal features, the evaluations of the growth of Beijing’s urban boundaries [12], and spatiotemporal analysis by sex [13]. The majority of this research focuses on check-in data study for specific users or implementation details such as tourism, road accidents, determining urban borders, spring-festival rush, or sex [14]. There is a need to connect these spatiotemporal features to the locations where guests check in to get more details.

To the best of our knowledge, other researchers have not included this in the past. As a result, we concentrated on three distinct elements of analysis on Weibo’s check-in records from Shanghai city for two years, from July 2015 to June 2017, to discover spatiotemporal patterns and population estimates using entertainment venue categorization and density estimation.

As a result, the latest research highlights three main features of the analysis, our contribution to the field’s available research:

- (i) Time scales of an hour, a week, and a day.
- (ii) Data grouping and entertainment venue research.
- (iii) Modeling and abundance estimate using spatial analysis.

Tableau, a famous statistical tool among academics, was used to do temporal analysis to find many patterns from user data in “time,” verifying the data appropriateness for some further evaluation by presenting typical individual contacts. We deliver thorough clarifications of the findings in both statistical tables and graphical graphics. The geographical analysis was approved using kernel density estimation

(KDE) in ArcMap of ArcGIS Desktop 10.7.1 and map data from OpenStreetMap (OSM) to prove the variability of the check-ins.

Section 2 of this research includes pertinent work on big data, LBSNs, and their critical implications in a variety of fields, as well as pieces on Weibo, Shanghai, and China. Section 3 gives a summary of the dataset as well as the analytical technique. The findings and a summary are included in Section 4, and the study’s conclusion and recommendations are included in Section 5.

## 2. Related Work

Concerning other areas of computer science, research in big data analysis has advanced at an accelerating rate during the period, attracting enormous attention from numerous academic communities. Big data is becoming near, but potentially too near [15] for the greater advantage or the infringement of privacy. “Big data” is a phrase that should be used. Reference [16] provides the idea that only volumes are necessary; nevertheless, when defining “big data,” more factors must be considered, such as behaviour, difficulty, construction, tools, procedures, and technologies utilized to evaluate and handle the massive amounts of data [17]. Dumbill established the renowned three “V’s,” denoting dimensions of “big data,” meaning volume, variation, and velocity of its contents [18]. Mayer-Schönberger and Cukier [19] emphasized critical “big data” challenges such as association rather than interconnection, chaos rather than order, and populations rather than sample data.

Ovadia, on the other hand, showed and underlined the relevance of “big data” for academics and social scientists, stating that “big data” is too crucial to ignore because most social scientific research requires a large quantity of data and large datasets [20]. Many study areas, such as time and space geography, human mobility, user activity, and urban functions, began with statistical data derived from trip diaries, interviews, surveys, questioners, and other by-hand composed datasets [21]. These approaches, however, may not be sufficient to detect patterns in data since mobile phones, the Global Navigation Satellite System (GNSS), smart cards, and location-based Internet apps, including geoinformation, have lately disseminated efficient data sources for such scientific articles [22]. With the rapid advancement of mobile technology and the widespread usage of portable devices, tracking users’ whereabouts and activities has become easy. Gonzalez et al. [23]. Despite providing the estimated position near the mobile phone’s base transmitter where the calls are connected, the dataset exhibited success in predicting the placements of users with limited time, which was subsequently employed in predicting user movements [24]. Zhu discussed several components of GIS (geographic information system) and its role in pattern pulling out and urban studies by proving how to analyze and show the spatiotemporal components of recyclable waste, gathering, and restoration [25].

Researchers can organize quantitative analyses of human behaviours, trends, and relevant characteristics such as social contacts, personal preferences, and dwelling areas in the

current digitized environment [26, 27]. Fan et al divided their user behaviour research into three sections: location suggestion, trajectory mining, and location prediction [28]. Stressing the significance of understanding user patterns of behaviour and how they may help with applications such as traffic regulation, mobile advertising, disaster assistance, human health, and urbanism, “big data” can be processed, stored, and analyzed at several levels. Business intelligence (BI), which initially arose in the late 1990s [29], is an essential field of “big data” at the organizational level. BI helps in decision making by lowering doubt through forecasting, ad-hoc enquiries, and aggregation-based reporting, as well as handling structured and unstructured data and integrating “big data”-based systems [30, 31].

BI systems incorporate data warehouses for storing clean, accurate, and extensive data from various sources, as well as online analytical processing (OLAP) for real-time multidimensional assessment with operations such as grouping, filtering, roll-up, rotation, and drilling-down for specifics [32]. OLAP is one of the most well-known and renowned methodologies for “big data” research in BI systems [33]. However, BI, data warehouse, and OLAP are potent tools for dealing with large amounts of data and a wide range of activities, additionally posing a difficulty due to the high cost, storage, and processing resources required [34]. As it has been utilized and is developing rapidly in practically every area globally, online social networks have proven to be the most momentous source of “big data” to study individual’s behaviour. The LBSNs’ online services allow users to post and share their activities, interests, and whereabouts, resulting in vast volumes of data to perform various studies on various subjects. Papers [35, 36] go into great detail about the research on human behaviour analysis approaches.

Lindqvist [37] investigated the usage of LBSNs, which was led by other research publications, including empirical investigations and sociospatial features employing LBSNs [38] and a personalized geosocial suggestion based on a dataset from two independent LBSNs, namely Gowalla and Foursquare, by Zhang and Chow [39]. Colombo et al. [40] used similar check-in data from LBSN to improve recommendation algorithms in two UK cities by collecting frequent users at diverse venues. Li et al. [41] conducted a rigorous analysis that analyzed foursquare data from 2.4 million sites in 14 states to discover the factors influencing place reputation. The study’s outcomes revealed three primary criteria influencing a venue’s fame: venue profile, venue age, and venue nature. One other analysis on user behaviour at several venue classifications fixated on “food” in Riyadh, Saudi Arabia, discovered that customers are more open to sharing their practices when visiting meal venues. The check-ins of approximately 19,000 swarm (Foursquare) participants from three urban centers, namely San Francisco, New York, and Hong Kong, were used to debate relationships among distinct venues at varying periods of the day [42].

Several studies have been undertaken throughout the world to explore various characteristics of users and check-ins using LBSN data sources such as Foursquare and

Twitter. These characteristics have been applied in a diversity of domains, including mobility patterns, venue classification, and urban planning and expansion [43]. Weibo, a renowned Chinese LBSN, was employed and shown to be effective for this study. In research for Shenzhen, Gu and colleagues [11] used Weibo data to examine the appeal powers of visitor attractions. Another study on people’s movements and activity patterns which was undertaken in order to examine urban borders in Beijing [12] also used Weibo check-in. In a similar vein, Shi et al. [43], stemming from different details given by the LBSN, Weibo data were used to explore features of tourism destinations and took the analysis in conjunction with sentiments from user comments. Wu et al. [44] investigated spatiotemporal analysis based on the time of day and the variation in check-in patterns among weekdays and weekends. Wu et al. [45] also investigated check-in studies at 21 of Wuhan’s most renowned lakes.

### 3. Dataset and Methodology

**3.1. Study Area and Data Source.** The earlier study was based on data attained for Shanghai, a well-known Chinese metropolis located on the Yangtze River between 3040J–3153JN and 12052J–12212JE and spanning an area of 83592 km. It was allocated into a county and sixteen districts, which were named “Baoshan,” “Chongming,” “Fengxian,” “Hongkou,” “Area,” “Minhang,” “Putuo,” “Qingpu” and “Xuhui” “Huangpu,” “Songjiang,” “Changning,” “Jingan,” “Jiading,” “Jinshan,” “Pudong New”, and “Yangpu”. Shanghai is recognized as a financial powerhouse that connects China to the global economy, with a GDP of over 2.7 trillion Yuan and an average growth rate of 7.4 per cent during the past five years. Shanghai has a population density of 3854 persons per square kilometre in metropolitan areas. With an increase of 0.66 million people per year, it has exceeded Beijing as China’s most populated city. It has surpassed New York, the world’s fifth most populous metropolis. The massive influx of migrants, which accounted for nearly 39% of Shanghai’s total population in 2010 [46], is the major driver of population expansion. Figure 1 depicts the research area, which is based on Shanghai’s ten districts.

The information was collected from one of China’s most famous LBSNs, Weibo, which is a hybrid of Twitter and Facebook (the world’s two most popular LBSNs) and was founded on August 14, 2009. It is a popular micro blog where users can express themselves by writing articles, check-ins, and communication with friends and family by sharing their thoughts, favorites, activities, shots, audio/video messages, and locations.

Weibo provides a variety of geographic data, with real-time location sharing, sites referenced in posts, and user profile location being three of the most useful. By the end of 2018, the number of visitors had climbed to 500 million, with 462 million monthly active users and 200 million daily active users. This research is based on two years of social basis gathered spatiotemporal check-ins from Weibo in Shanghai, from July 2015 to June 2017.

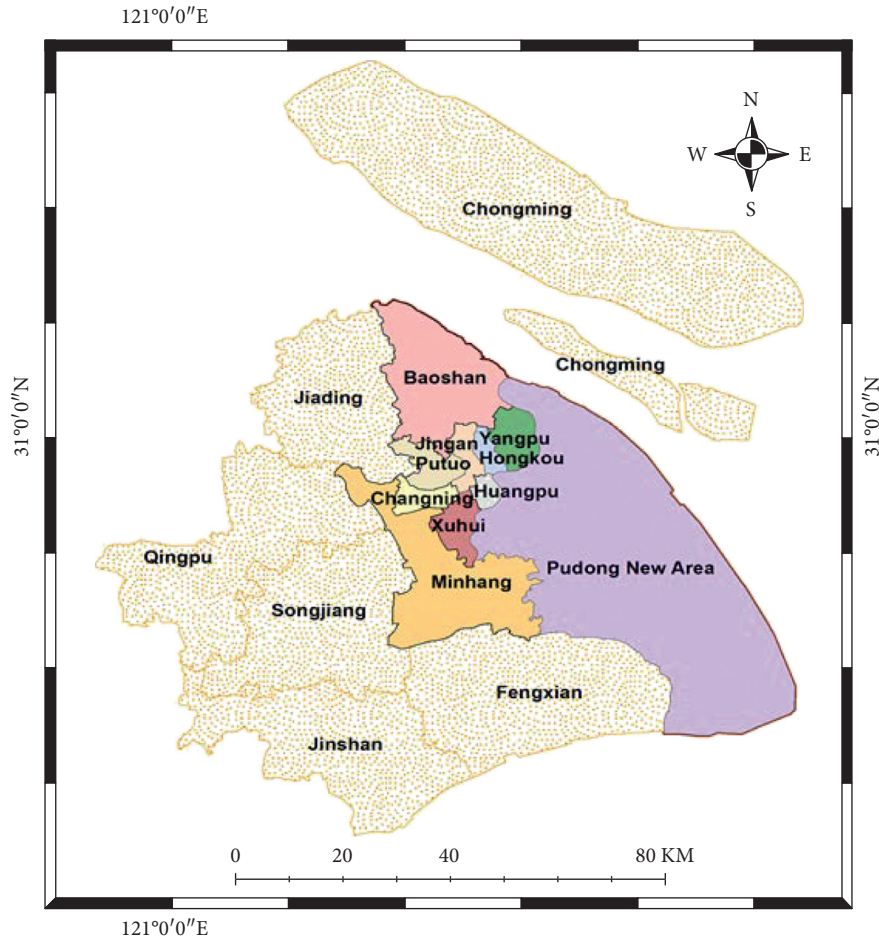


FIGURE 1: Study area.

The primary motivation for using LBSN is to share activities and remarks, which leads to the formation of a new intimate social companionship circle. This enables professionals to extrapolate a wide range of human behaviour and satisfaction from the geodata gathered by these LBSNs. The data for this article came from LBSN's Weibo account. To gather information from check-ins in Shanghai, we used the Weibo API (application programming interface) based on Python. It was gathered in 2017, with around 3.5 million cumulative check-ins from around two million individuals. The gathered data were translated from JavaScript Object Notation (JSON), the standard API Java programming language, to comma-separated values (CSV) using MongoDB for the present study. Figure 2 depicts the data processing path.

Anomalies, missing values, and irrelevant characteristics were removed from the dataset after being filtered for valuable data. Finally, the researcher evaluated the entertainment places with multiple check-ins for a more thorough study. This study employed a filtered dataset with 87480 check-ins from 20152 regular users. Table 1 shows a sample of the records found in the final dataset.

The data inquiry is divided into three parts: temporal analysis, statistical analysis using spatiotemporal analysis of leisure sites, and density estimate. One of the most

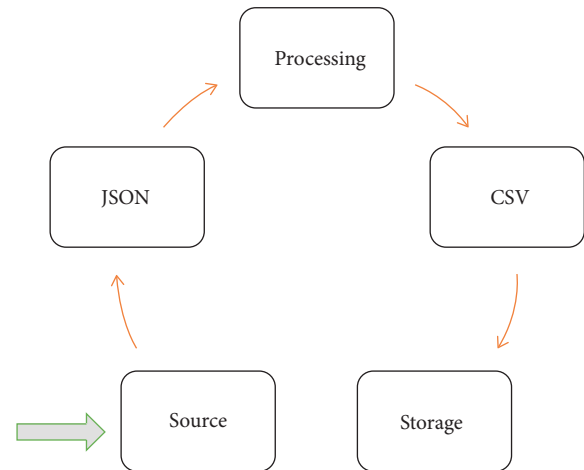


FIGURE 2: Process flow of data.

important goals of this type of research is to demonstrate the dataset's legitimacy by demonstrating some observable human behaviour, such as less LBSN utilize after midnight until early morning due to sleeping habits and much more check-ins after working hours and on weekends due to more social events during relaxation time. In addition, because both genders are represented in distinct colours in all

TABLE 1: The sample of attributes in the dataset.

User_id	Activity	Date	District	Lon	Lat	Gender	Time	Day
1.78 E + 09	Amusement	5/8/2017	Xuhui	121.4487	31.19813	M	2:20:12	Mon
3.06 E + 09	Amusement	6/8/2016	Yangpu	121.5208	31.29679	F	18:20:23	Thu
2.46 E + 09	Amusement	12/5/2015	Huangpu	121.4634	31.21838	M	7:25:40	Wed
1.78 E + 09	Amusement	8/24/207	Pudong	121.5592	31.24204	M	3:30:45	Mon

descriptive data, several fascinating patterns emerge for males and females. The check-ins collection criteria have been implemented, as shown in Figure 3.

The venues were classified by comparing physical locations inside the city to location names and location. The place names were decoded and retrieved from the Weibo dataset as the “location” property, as shown in Table 1, and categorized according to the functionalities of these various venues, such as those that were regularly frequented and well known in Shanghai. Every check-in was assigned to the class that most suited the type of the entertainment and amusement movement done at that place, such as “cinema, KTV entertainment hall, theatre, and Disney Park.” Figure 4 illustrates the flowchart of our technique.

**3.2. Statistical Analysis.** The study was conducted using SPSS (Version 17.0) and linear regression to see if the dependent variables are predictors of the independent variable. Table 2 shows the summary of the model.

$$\sum \text{Check in}_t = \beta_0 + \beta_1 \sum \text{District} + \beta_2 \sum \text{Days} + \beta_3 \sum \text{Gender} + \mu_t. \quad (1)$$

The models display  $R$  and  $R$  square values. The  $R$ -value (0.128) and the  $R$  square reflect a straightforward correlation (0.016). The value of  $R$  demonstrates that check-in can be predicted by 16 percent using characteristics such as days, gender, and districts.

Table 3 indicates that significance value of F-statistic in the model showed that the whole model is significant as  $F(3, 87476) = 482.358, p = 0.000$ .

As shown in Table 4, the independent variables are significant predictors for the dependent variable. The results show a statistically significant ( $P = 0.000$ ) and negative ( $-6325.933$ ) connection between gender and check-in. All other predictors, including days and districts, have a significant and positive relationship with the check-in having the  $P$  values 0.002 and 0.000, respectively.

**3.3. Spatial Analysis.** The KDE technique is a nonparametric way to estimate density from randomly selected evidence. KDE generates smooth distributions by removing some local noise, regarded as a nonprobability distribution with maximum bandwidth and lower error. KDE is a bulk study technique used to recognize numerous location-based features such as time and destination and is an imperative density approximation technique that has been widely studied for the analysis of unlike aspects of location-based social media data such as vital city limits, visitor’s mobility and activity patterns, recommendation for a position of

interest, and check-in manners. The KDE method has been used in a variety of applications, including medicine, marketing, and ecology for modeling spatial densities.

Let  $E$  be a set of historical data where  $e^j = \langle x, y \rangle$  is the geocoordinates of a location, and  $1 \leq j \leq n$ , for an individual  $i$ .  $h_j$  is the Euclidean distance to  $k$ th nearest neighbor  $e^j$  in the training data. The KDE is expressed as follows:

$$f_{\text{KD}}(e|E) = \frac{1}{n} \sum_{j=1}^n K_{h_j}(e, e^j), \quad (2)$$

$$K_h = \frac{1}{2\pi h} \exp\left(-\frac{1}{2}(e, e^i)^t \sum_h^{-1}(e, e^i)\right).$$

ArcGIS software has been used for spatial analysis and all the maps have been created through this software which is believed to be a significant geographic information systems software nowadays.

**3.4. Temporal Analysis.** Tableau software is used to do a temporal analysis for daily, weekly, and district-based check-ins.

## 4. Results and Discussion

Mobile technology, wireless connectivity, the Internet, and location-based services have evolved dramatically during the previous two decades. As a result, services based on these features, such as LBSN like Twitter, Weibo, and Facebook, are attracting an increasing number of academics to evaluate the vast amounts of data generated by these services. The study was incredibly helpful in identifying basic patterns concerning essential tasks like crisis and catastrophe management, urban planning, innovative city development, and other significant data-related sectors. This section looks at two different kinds of check-in results: temporal and spatial analysis.

We gathered check-ins based on entertainment purposes, and all of the check-ins from entertainment places are shown in Figure 5. The study area encompasses ten Shanghai districts.

The density hotspots were identified using kernel density estimation, and as shown in Figure 6, the enormous black dots represent a high density of visits. It is worth mentioning that Shanghai’s seven districts, together known as the city center, have the highest check-in density.

Figure 7 can see the temporal result of entertainment check-ins in districts, and all the district’s check-ins activity can be seen. Putuo and Pudong are two districts that have a higher number of amusement check-ins compared with others.



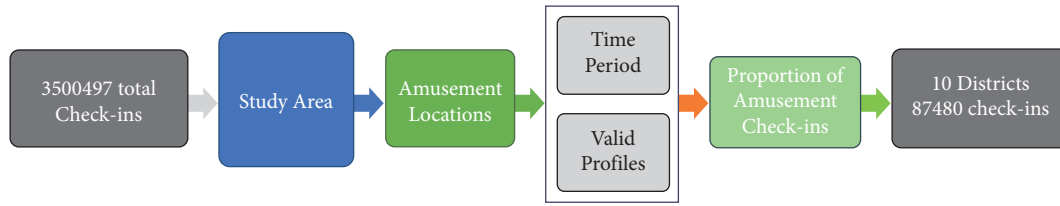


FIGURE 3: Criteria.

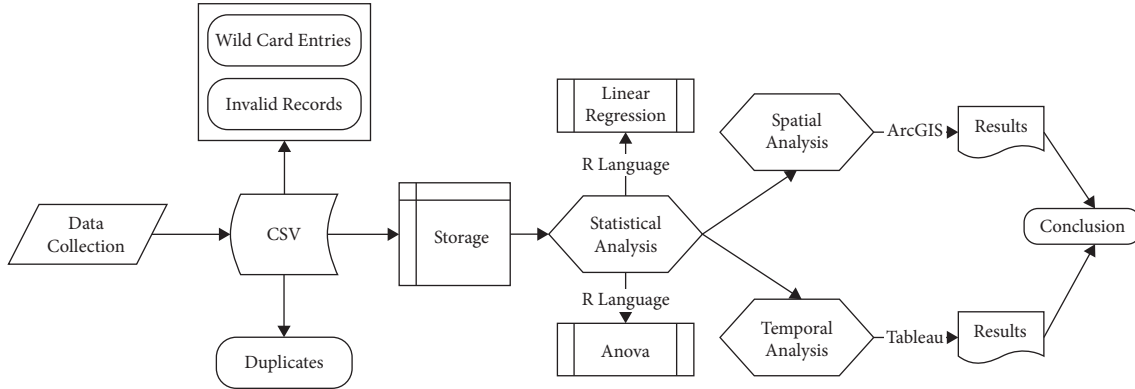


FIGURE 4: Methodology.

TABLE 2: Model summary.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.128 <sup>a</sup>	0.016	0.016	25047.553

a. Predictors: (constant), gender, districts, and days.

TABLE 3: ANOVA <sup>a</sup>.

Model		Sum of Squares	df	Mean Square	F	Sig. (b)
1	Regression	907864706534.297	3	302621568844.766	482.358	0.000
	Residual	54880685702175.710	87476	627379917.945		
	Total	55788550408710.010	87479			

a. Check in is a dependent variable. b. Predictors: gender, districts, (constant), and days.

TABLE 4: Coefficients.

Model		Unstandardized coefficients		Standardized coefficients		t	Sig.
		B	Std. Error	Beta			
1	(Constant)	51366.226	380.167			135.115	0.000
	Districts	333.889	32.151	0.035		10.385	0.000
	Days	127.114	40.212	0.011		3.161	0.002
	Gender	-6325.933	172.959	-0.123		-36.575	0.000

The weekly data indicate an odd phenomenon even after Saturday and Sunday being holidays. Saturday had more check-ins than Sundays. One reason is that Saturday is followed by another holiday (Sunday), allowing people to avoid getting up early and enjoy and amuse themselves until beyond late night every day. The weekly data indicate an odd phenomenon: while both Saturday and Sunday being holidays, Saturday had more check-ins than Sundays. Aside from that, check-in frequency was substantially lower and relatively consistent on all working days from Monday

through Thursday, increased dramatically on Fridays, and was followed by a significant number of check-ins on weekends. Figure 8 depicts the daily trend.

Figure 9 shows the hour-based check-ins of Weibo users, with the peak period of entertainment venue check-ins occurring between 8 and 10 p.m., and this pattern continued until midnight, with numbers declining after midnight.

In Shanghai, we looked at category (male and female) data to see how check-in frequency and mindset differed. Figure 10 depicts the gender check-in density in Shanghai. It

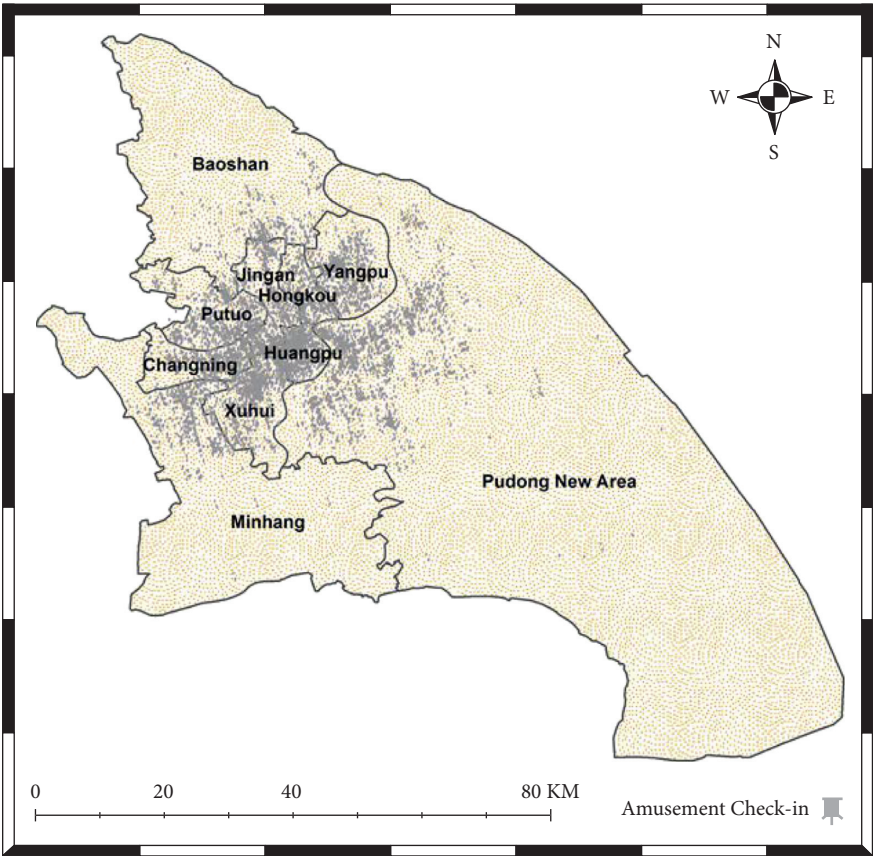


FIGURE 5: Amusement check-ins.

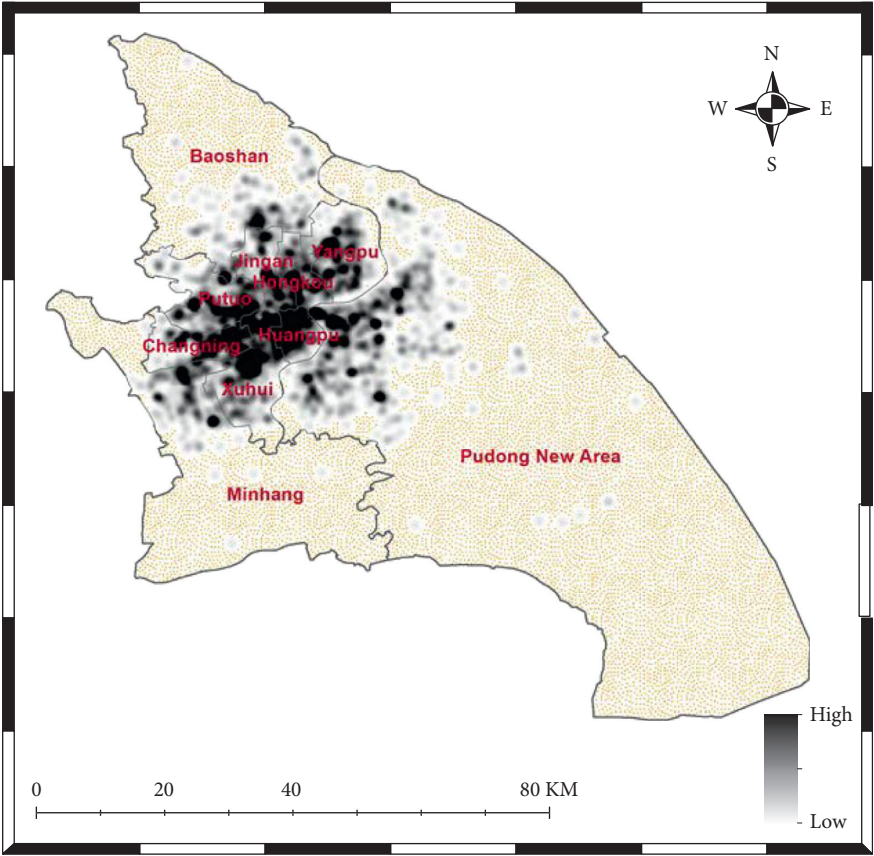


FIGURE 6: Check-ins density.



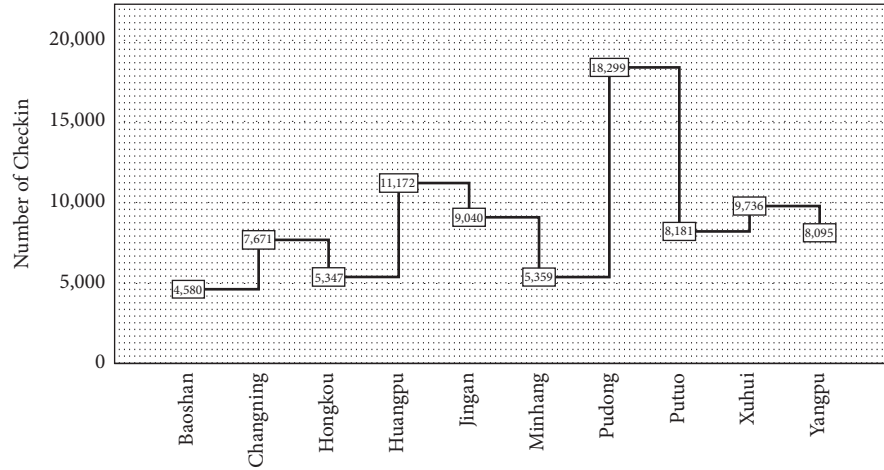


FIGURE 7: Amusement check-ins in districts.

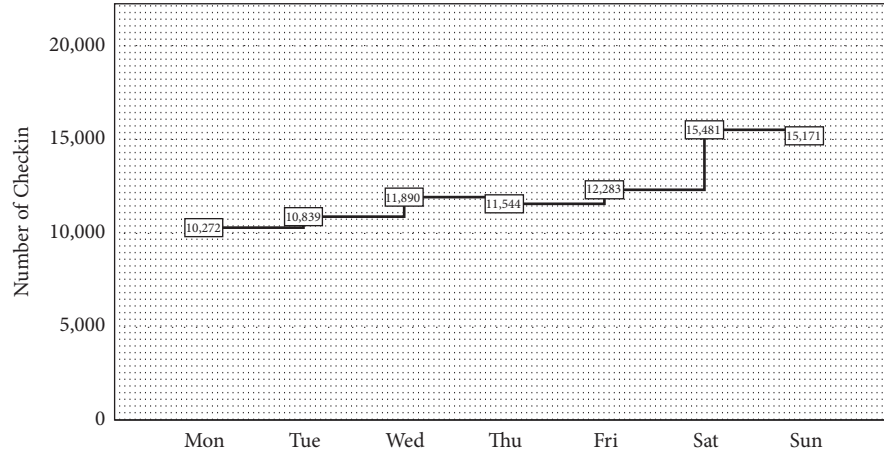


FIGURE 8: Check-ins pattern for days.

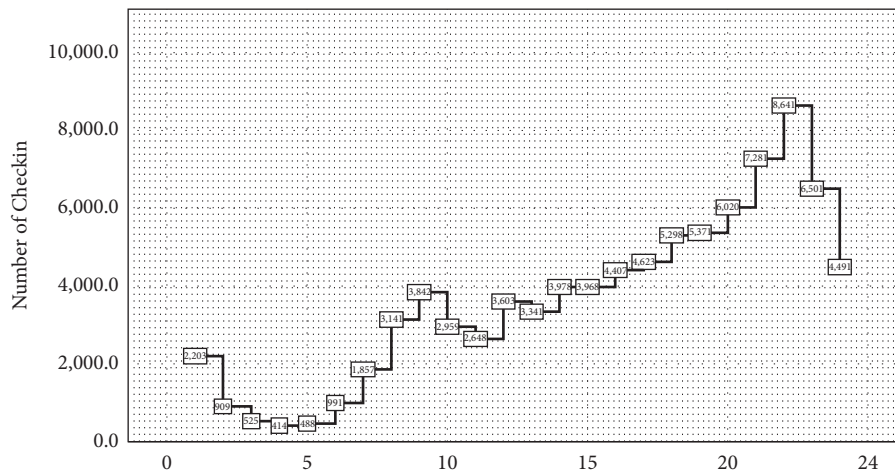


FIGURE 9: Hour-based check-ins.

has been observed that female visitors favor Weibo over male visitors. As a result, Figure 10 illustrates the results. This study showed the influence of each check-in entertainment venue through temporal and geographic

outcomes. However, the truth remains that, in comparison to suburban districts, the city center has a more focused and higher density. Aside from these diverse spatial and temporal trends, the findings demonstrate Weibo's potential as

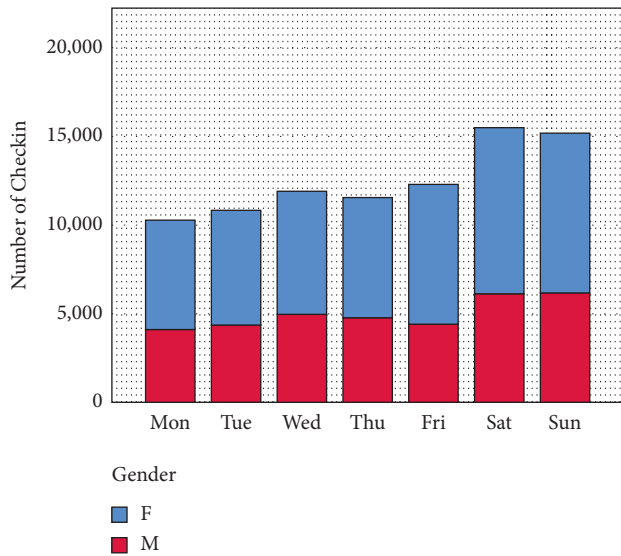


FIGURE 10: Gender difference.

an LBSN dataset by illustrating the critical involvement of every place type to the intensity and variety of Shanghai as a vibrant metropolitan center in terms of time and location. As long as the dataset is suitably classified into multiple groups, we may use LBSN data instead of human data collecting as a valuable source of big data analysis in numerous sectors.

## 5. Conclusion

We utilized the check-in data from Weibo for spatiotemporal analysis to investigate various trends in different activities linked to amusement in Shanghai during two years (July 2015 to June 2017). The study examines check-in behaviour over time (daily, weekly), as well as check-in data density predictions and the involvement of each check-in location to the strength. A temporal analysis revealed some noteworthy characteristics, including the low number of amusement events after midnight in a megacity like Shanghai and the most significant social activities on Saturday rather than Sunday. The findings of density estimates revealed that the city center performs the highest number of check-ins, as predicted, due to the greater availability of resources. In addition, females seem to be more likely to use social media when participating in entertainment. These conclusions are based on Weibo check-in data for Shanghai city, which has numerous qualities, portraying it as a chrono urban metropolis that is more reachable and friendly. The research might help create smart cities, recommendation systems, and LBSN studies in specific domains, including transportation, tourism, and entertainment. With the present research, there are various constraints to observe. Because Weibo was the sole source of data used, the collection was restricted and perhaps skewed. To acquire a more accurate sample, we may handle this problem by merging it with additional information sources such as WeChat, Trip Advisor, and other LBSNs.

## Data Availability

The dataset can be downloaded from <http://www.weibo.com>.

## Conflicts of Interest

The authors declare no conflicts of interest.

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## References

- [1] R. Singh, Y. Zhang, and H. Wang, "Exploring human mobility patterns in Melbourne using social media data," in *Australasian Database Conference* Springer, Berlin, Germany, 2018.
- [2] N. Alrumayyan, S. Bawazeer, R. AlJurayyad, and M. Al-Razgan, "Analyzing user behaviour s: a study of tips in Foursquare," in *Advances in Intelligent Systems and Computing* Springer, Berlin, Germany, 2018.
- [3] J. Preston and B. Stelter, *How government officials are using Twitter for Hurricane Sandy*, The New York Times, New York, NY, USA, 2012.
- [4] Weibo. [cited 2020 2 September]; Available from: <http://www.weibo.com>.
- [5] N. U. Khan, W. Wan, S. Yu, A. A. M. Muzahid, S. Khan, and L. Hou, "A study of user activity patterns and the effect of venue types on city dynamics using location-based social network data," *ISPRS International Journal of Geo-Information*, vol. 9, no. 12, p. 733, 2020.
- [6] B. Wang, F. Zhen, Z. Wei, S. Guo, and T. Chen, "A theoretical framework and methodology for urban activity spatial structure in e-society: empirical evidence for Nanjing City, China," *Chinese Geographical Science*, vol. 25, no. 6, pp. 672–683, 2015.
- [7] W. Bo, Z. Feng, and W. Zongcai, "The research on characteristics of urban activity space in Nanjing: an empirical analysis based on big data," *Human Geography*, vol. 29, no. 3, pp. 14–21, 2014.
- [8] A. W. Todd, A. L. Campbell, G. G. Meyer, and R. H. Horner, "The effects of a targeted intervention to reduce problem behaviors," *Journal of Positive Behaviour Interventions*, vol. 10, no. 1, pp. 46–55, 2008.
- [9] F. Zhen, Y. Cao, X. Qin, and B. Wang, "Delineation of an urban agglomeration boundary based on Sina Weibo microblog "check-in" data: a case study of the Yangtze River Delta," *Cities*, vol. 60, pp. 180–191, 2017.
- [10] B. P. Loo, S. Yao, and J. Wu, "Spatial point analysis of road crashes in Shanghai: a GIS-based network kernel density method," in *Proceedings of the 2011 19th International Conference on Geoinformatics*, June 2011.
- [11] Z. Gu, Y. Zhang, Y. Chen, and X. Chang, "Analysis of attraction features of tourism destinations in a mega-city based on check-in data mining-A case study of shenzhen, China," *ISPRS International Journal of Geo-Information*, vol. 5, no. 11, p. 210, 2016.

- [12] Y. Long, H. Han, Y. Tu, and X. Shu, "Evaluating the effectiveness of urban growth boundaries using human mobility and activity records," *Cities*, vol. 46, pp. 76–84, 2015.
- [13] C. Lei, A. Zhang, Q. Qi, H. Su, and J. Wang, "Spatial-temporal analysis of human dynamics on urban land use patterns using social media data by gender," *ISPRS International Journal of Geo-Information*, vol. 7, no. 9, p. 358, 2018.
- [14] D. Preoŕiuc-Pietro and T. Cohn, "Mining user behaviours: a study of check-in patterns in location based social networks," in *Proceedings of the 5th Annual ACM Web Science Conference*, New York, NY, USA, May 2013.
- [15] S. Lohr, *Big Data is Opening Doors, But Maybe Too Many*, New York Times, New York, NY, USA, 2013.
- [16] P. Chatterjee, "Big data: the greater good or invasion of privacy," *The Guardian*, vol. 12, 2013.
- [17] J. S. Ward and A. Barker, "Undefined by data: a survey of big data definitions," <https://arxiv.org/abs/1309.5821>.
- [18] E. Dumbill, "What is big data: an introduction to the big data landscape (article)," *Strata Oreilly*, vol. 11, 2012.
- [19] V. Mayer-Schönberger and K. Cukier, *Big Data: A Revolution that Will Transform How We Live, Work, and Think*, Houghton Mifflin Harcourt, Boston, MA, USA, 2013.
- [20] S. Ovadia, "The role of big data in the social sciences," *Behavioural & Social Sciences Librarian*, vol. 32, no. 2, pp. 130–134, 2013.
- [21] Y. Chai, Y. Shen, Z. Xiao, Y. Zhang, Y. Zhao, and N. Ta, "Review for space-time behaviour research: theory frontiers and application in the future," *Progress in Geography*, vol. 31, no. 6, pp. 667–675, 2012.
- [22] M. Graham and T. Shelton, "Geography and the future of big data, big data and the future of geography," *Dialogues in Human geography*, vol. 3, no. 3, pp. 255–261, 2013.
- [23] M. C. González, C. A. Hidalgo, and A.-L. Barabási, "Understanding individual human mobility patterns," *Nature*, vol. 453, no. 7196, pp. 779–782, 2008.
- [24] C. Song, Z. Qu, N. Blumm, and A.-L. Barabasi, "Limits of predictability in human mobility," *Science*, vol. 327, no. 5968, pp. 1018–1021, 2010.
- [25] X. Zhu, "GIS and urban mining," *Resources*, vol. 3, no. 1, pp. 235–247, 2014.
- [26] A. Wesolowski, T. Qureshi, M. F. Boni et al., "Impact of human mobility on the emergence of dengue epidemics in Pakistan," *Proceedings of the National Academy of Sciences*, vol. 112, no. 38, pp. 11887–11892, 2015.
- [27] L. Pappalardo, F. Simini, S. Rinzivillo, D. Pedreschi, F. Giannotti, and A. L. Barabási, "Returners and explorers dichotomy in human mobility," *Nature Communications*, vol. 6, no. 1, pp. 8166–8168, 2015.
- [28] C. Fan, Y. Liu, J. Huang, Z. Rong, and T. Zhou, "Correlation between social proximity and mobility similarity," *Scientific Reports*, vol. 7, no. 1, pp. 11975–11978, 2017.
- [29] B. Wixom and H. Watson, "The BI-based organization," *International Journal of Business Intelligence Research*, vol. 1, no. 1, pp. 13–28, 2010.
- [30] B. Wieder and M.-L. Ossimitz, "The impact of business intelligence on the quality of decision making - a mediation model," *Procedia Computer Science*, vol. 64, pp. 1163–1171, 2015.
- [31] T. Grublješić and J. Jaklić, "Conceptualization of the business intelligence extended use model," *Journal of Computer Information Systems*, vol. 55, no. 3, pp. 72–82, 2015.
- [32] S. Ahmad, S. Miskon, T. A. Alkanhal, and I. Tlili, "Modeling of business intelligence systems using the potential determinants and theories with the lens of individual, technological, organizational, and environmental contexts-a systematic literature review," *Applied Sciences*, vol. 10, no. 9, p. 3208, 2020.
- [33] Y. S. Singh, "Easy designing steps of a local data warehouse for possible analytical data processing," *ADB Journal of Engineering Technology*, vol. 8, 2019.
- [34] V. Santos, R. Silva, and O. Belo, "Towards a low cost ETL system," *International Journal of Database Management Systems*, vol. 6, no. 2, pp. 67–79, 2014.
- [35] E. Cho, S. A. Myers, and J. Leskovec, "Friendship and mobility: user movement in location-based social networks," in *Proceedings of the 17th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*, San Diego, CA, USA, August 2011.
- [36] H. Gao, J. Tang, and H. Liu, "Exploring social-historical ties on location-based social networks," in *Proceedings of the International AAAI Conference on Web and Social Media*, Palo Alto, CA, USA, 2012.
- [37] J. Lindqvist, "I'm the mayor of my house: examining why people use foursquare-a social-driven location sharing application," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, Vancouver, Canada, May 2011.
- [38] S. Scellato, "Socio-spatial properties of online location-based social networks," in *Proceedings of the International AAAI Conference on Web and Social Media*, Barcelona, Spain, July 2011.
- [39] J.-D. Zhang and C.-Y. Chow, "iGSLR: personalized geo-social location recommendation: a kernel density estimation approach," in *Proceedings of the 21st ACM SIGSPATIAL International Conference on Advances in Geographic Information Systems*, New York, NY, USA, November 2013.
- [40] G. B. Colombo, M. J. Chorley, M. J. Williams, S. M. Allen, and R. M. Whitaker, "You are where you eat: foursquare checkins as indicators of human mobility and behaviour," in *Proceedings of the 2012 IEEE International Conference on Pervasive Computing and Communications Workshops*, March 2012.
- [41] Y. Li, M. Steiner, L. Wang, Z.-L. Zhang, and J. Bao, "Exploring venue popularity in foursquare," in *Proceedings of the 2013 Proceeding IEEE INFOCOM*, April 2013.
- [42] S. Lin, R. Xie, Q. Xie, H. Zhao, and Y. Chen, "Understanding user activity patterns of the swarm app: a data-driven study," in *Proceedings of the 2017 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2017 ACM International Symposium on Wearable Computers*, Maui, HI, USA, September 2017.
- [43] B. Shi, J. Zhao, and P.-J. Chen, "Exploring urban tourism crowding in Shanghai via crowdsourcing geospatial data," *Current Issues in Tourism*, vol. 20, no. 11, pp. 1186–1209, 2017.
- [44] C. Wu, X. Ye, F. Ren, and Q. Du, "Check-in behaviour and spatiotemporal vibrancy: an exploratory analysis in Shenzhen, China," *Cities*, vol. 77, pp. 104–116, 2018.
- [45] J. Wu, J. Li, and Y. Ma, "A comparative study of spatial and temporal preferences for waterfronts in Wuhan based on gender differences in check-in behaviour," *ISPRS International Journal of Geo-Information*, vol. 8, no. 9, p. 413, 2019.
- [46] C. Y. Liu, J. Chen, and H. Li, "Linking migrant enclave residence to employment in urban China: the case of Shanghai," *Journal of Urban Affairs*, vol. 41, no. 2, pp. 189–205, 2019.

## Research Article

# Analyzing Drivers' Distractions due to Smartphone Usage: Evidence from AutoLog Dataset

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The usage of a smartphone while driving has been declared a global portent and has been admitted as a leading cause of crashes and accidents. Numerous solutions, such as Android Auto and CarPlay, are used to facilitate for the drivers by minimizing driver distractions. However, these solutions restrict smartphone usage, which is impractical in real driving scenarios. This research paper presents a comprehensive analysis of the available solutions to identify issues in smartphone activities. We have used empirical evaluation and dataset-based evaluation to investigate the issues in the existing smartphone user interfaces. The results show that using smartphones while driving can disrupt normal driving and may lead to change the steering wheel abruptly, focus off the road, and increases cognitive load, which could collectively result in a devastating situation. To justify the arguments, we have conducted an empirical study by collecting data using maxed mode survey, i.e., questionnaires and interviews from 98 drivers. The results show that existing smartphone-based solutions are least suitable due to numerous issues (e.g., complex and rich interfaces, redundant and time-consuming activities, requiring much visual and mental attention, and contextual constraints), making their effectiveness less viable for the drivers. Based on findings obtained from Ordinal Logistic Regression (OLR) models, it is recommended that the interactions between the drivers and smartphone could be minimized by developing context-aware adaptive user interfaces to overcome the chances of accidents.

## 1. Introduction

According to the world health organization, road accidents are the ninth leading cause of death and are expected to become seventh by 2030. [1]. Each year, more than one million deaths and 50 million damages are caused due to road crashes [1, 2]. The main reason for this depredation is the driver repeated engagements in nondriving activities [1, 3]. Driver engagements with nondriving or distracting activities caused 25% of crashes reported to the police [4]. These distractions disturb the normal driving activity and interrupt the drivers' attention, leading to accidents [4, 5]. There are different types of distracting activities, including interacting inside and outside objects, eating and drinking, operating the radio or music system, communicating with

commuters in the vehicle, and particularly operating smartphones [6].

The use of a smartphone while driving made driving activity more unsafe as performing concurrent activities requires fine-grained cognitive, physical, and mental skills [6, 7]. Various studies reveal that smartphone usage while driving is a global issue and the main source of accidents [8]. Despite the known calamities, drivers are still using their smartphones, which is evident from the fact that at a particular instant of time, about 0.66 million people are using their phones while driving [8, 9]. However, most countries have discouraged this activity and proposed high penalties [10]. According to the National Safety Council, it has been reported that 1.6 million accidents and 0.39 million deaths were caused by smartphone usage [11]. Along with other



smartphone activities, texting activity is very dangerous and has attracted public and media attention [12, 13]. Similarly, it has been investigated that novice drivers engaged with smartphones can spend more than 400% time not focusing on the road [14].

Reducing drivers' distractions is the researcher's prime interest and has tried different solutions, including Android Auto, CarPlay, and other infotainment systems, to combat the issue. The main objective of these solutions is to minimize the interaction between the vehicle and drivers for the secondary tasks. The available solutions are merely three basics concepts, i.e., blocking the smartphone's dangerous activities, changing interaction mode, and providing simplified interaction [8, 15]. Several solutions have been proposed to reduce drivers' interactions with smartphones [16] and suggest blocking smartphone features while driving [8, 15]. Blocking the smartphone features is found encouraging in some recent studies and has argued that it will significantly reduce the risks of crashes as many features of the phone will be stopped during driving. However, this approach is strongly discouraged by the people who have developed their habitual contact with their phones. Similarly, it has low adequacy among the drivers as the blocking approach is against the espousal of technology [17, 18]. Besides, no strong evidence has been found to investigate the effectiveness of this approach [8].

Another group of researchers has proposed changes in interaction with the smartphone using voice commands instead of visual interaction. Performing smartphone activities using voice commands will assist the drivers by minimizing physical and visual interactions [19]. Various solutions are using these voice-based interfaces for communication, including Do Not Disturb while Driving, CarPlay, Android Auto, and DriveSafe.ly [20]. This approach has shown comparatively more benefits over the visual interfaces [21, 22]. However, the researchers have claimed that drivers are still facing numerous issues as it is difficult to comprehend properly in noisy environments. Similarly, these still require interior glance time and higher cognitive overload. [8, 15, 23–25]. Technically, these solutions may reduce visual-manual interaction but increase cognitive overload [8, 26–28]. By considering the heap of limitations in the previous two approaches, the researchers have claimed that simplifying the smartphone functionalities will minimize the driver's distractions. [8, 15]. Following this idea, numerous applications have been designed that provides simplified interfaces in term of voice commands and shortcuts to the apps [2]. However, as discussed earlier, operating the smartphone through voice interfaces can increase cognitive overload, off-road visual engagements, and navigational complexities [29–31]. Certainly, the approach can be potentially advantageous and effective over the others, but empirically, no evidence is found supporting the applications in minimizing the risks of crashes [10]. The researcher's interests in this area are broader and have a high volume of success if proper attention is paid to come up with suitable solutions by recognizing the fact that driver status while driving is changed from his status while not driving. Therefore, the available solutions need to be redesigned

more intelligently so that most of the smartphone activities should be accomplished automatically. This paper is aimed to provide recommended interfaces to the drivers after analyzing (i.e., empirically and through AutoLog [32] dataset) the existing issues and challenges faced by the drivers. We have defined three research questions in this study:

- (1) Are the Smartphone Native Interfaces complex, time-consuming, require excessive visual, mental, and physical attention and lead to a change in vehicle dynamics (e.g., speed, acceleration, steering wheel) ?
- (2) Are the Voice Interfaces (i.e., performing smartphone activities via text-to-speech and speech-to-text) lead to increased cognitive overload and affect vehicle dynamics?
- (3) What type of recommended interfaces will be needed for drivers to overcome these issues and challenges?

The rest of the paper is organized as follows. Methods are presented in Section 2. Results are presented in Section 3, and their discussion is presented in Section 4. Finally, the conclusion is discussed in Section 5.

## 2. Materials and Methods

**2.1. Participants.** A total of 98 drivers participated in this study. Among these, 18.37% ( $n=18$ ) were female and 81.63% ( $n=80$ ) were male participants. The selection of the participants was based on the condition of having more than a year of driving experience with a valid driving license. Similarly, the participants were filtered with the condition of having a smartphone in use for the last three years. Ages ranged from 19 to 49 and above years. Participants have been categorized accordingly in four different age groups: 19–28 years ( $n=32$ ), 29–48 years ( $n=43$ ), 39–48 years ( $n=17$ ), and 49 and above ( $n=06$ ). The participants are normally habitual of performing common smartphone activities while driving using different metaphors, i.e., 79.6% ( $n=78$ ) are using native smartphone interfaces, 15.33% ( $n=15$ ) are using voice interfaces (e.g., Google Assistant, etc.), and 5.11% ( $n=5$ ) are using HUDs. The participant's frequency of travel daily was 34.69% ( $n=34$ ), and on a random or sometimes basis was 65.31% ( $n=64$ ). Normally, the traveling purpose was modeled as workplace mostly, business mostly, and shopping mostly. The number of participants who participated according to traveling type is: employee mostly ( $n=51$ ), business mostly ( $n=22$ ), and shopping mostly ( $n=25$ ).

**2.2. Procedure and Instrument.** A two-level methodology is proposed to investigate the drivers' distractions due to performing smartphone activities.

In the first level, our real-time Android app, namely "AutoLog," was installed on participants' smartphones (see Figure 1) [32]. As shown in Figure 1, the AutoLog is developed with the intention of a multimodal data acquisition platform to capture data related to the vehicle, drivers' smartphone activities, and environmental contextual data

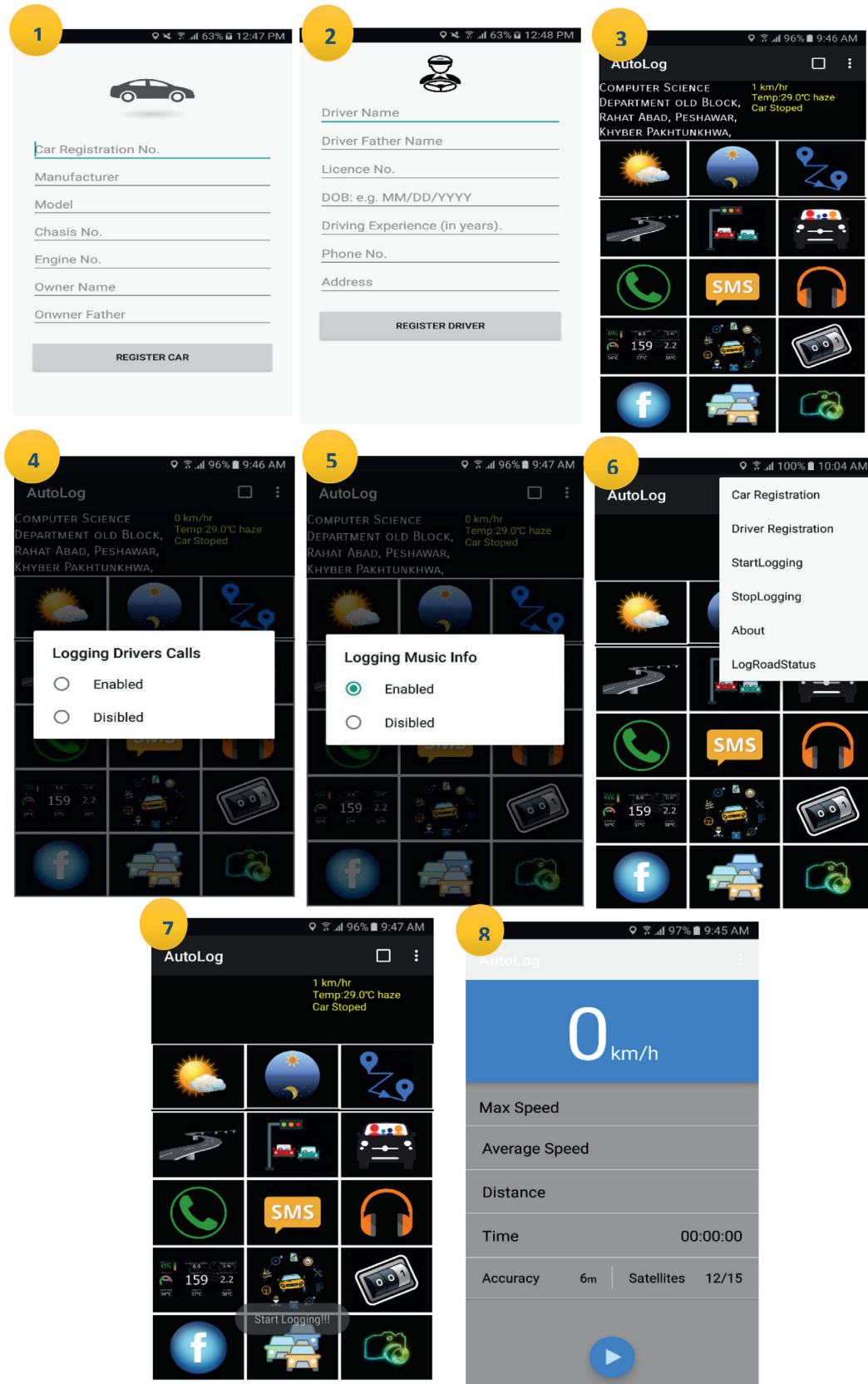


FIGURE 1: Screenshots of the autoLog application.



for finding latent distractions and their effects on driving performance. The participants are instructed that the application will be running in the background to log smartphone activities (i.e., keystrokes, missed touches, wrong touches, easiness, etc., are also captured to calculate perfect touch with less time), and their effect on vehicle dynamics irrespective of their privacy violation. The AutoLog uses built-in smartphone sensors and a simple plug-in-play module ELM327 to be inserted into the OBD2 port to obtain the required data. We have used built-in smartphone sensors (including accelerometer sensor, gyroscope sensor, location sensors, etc. [33, 34]) and OBD2 not to overburden and disturb the participant's drivers. The modalities captured and recorded by AutoLog are driver smartphone activities, location, weather information, and vehicle dynamics (engine RPM, brake status, accelerator status, and speed).

In the second level, to further strengthen our argument, a quantitative study was carried out to obtain data from different participants for the detailed investigation. The participants have completed an online questionnaire about their preferences and opinion regarding the usage of native smartphone interfaces, usage of voice interfaces, recommended interfaces, and their effect on vehicle dynamics. The average time for questionnaire completion was 20 minutes. The questionnaire contains different items, including driver demographics (i.e., age, gender, the purpose of traveling (mostly), travel frequency, etc.), usage of smartphone native interfaces (i.e., visual-manual interaction for texting, emailing, phone calls, and their effect on driving performance), usage of smartphone activities via voice interfaces (i.e., hands-free interaction including conversation and their effect on driving performance), and usage of recommended interfaces. Questions are organized in a way where participants will be asked to select an answer from a Likert-Scales, having Definitely to Definitely Not. We have informed the participants about the question's nature, purpose, the procedure of the data collection, and system evaluation.

To answer the first research question, participants were asked to answer 17 questions. For example, "Performing activities using native smartphone interfaces lead to change in speed/brake/accelerator/steering wheel variations?," "accessing and taping a specific area on smartphone screen and linking it with common tasks are time-consuming and difficult," and "is composing a text message and search for contact is time-consuming?" To answer the second research question, the participants were asked, "have you ever experienced an increase in cognitive overload when using a smartphone through voice commands?" "do you feel that performing smartphone activities via voice commands incurs extra burden for memorizing the commands?," "Are you satisfied and comfortable when doing basic smartphone activities via voice instructions?."

To answer the third question, participants were provided a list of recommended interfaces and were asked to select the options that they would prefer or feel comfortable. The functions were determined based on our future context-aware adaptive interfaces for drivers to minimize driver distraction. For example, the participants were asked, "do you agree to update the smartphone's existing User Interface

(UI) to be easy to use and driver-friendly?" "Will you agree to convert the interaction to an automatic mode where the interface will be changed to a simplified interface?" "Do you agree if the most frequent applications are to be placed on the main screen while driving," and "will you be happy to cancel unknown and lengthy messages while driving at higher speed?"

**2.3. Data Analysis.** We have performed numerous tests in this study and used STATA and Microsoft Excel to analyze the data statistically. For this reason, we have used descriptive tabulation to report frequencies and percentages of the variables. We have also performed the Cronbach alpha test to investigate the internal consistency and reliability of the measurement items. It is concluded that the items used in the study were found reliable and internally consistent. Further, to check multicollinearity, we have used Kendall's tau-b rank correlation matrix and found it satisfactory. Finally, for distraction-free recommended interfaces, four OLR models have been estimated.

### 3. Results

**3.1. Smartphone Use While Driving.** The responses of the participants have been compiled and showed descriptive statistics of frequencies and their percentages. Text messaging, phone calling, and emailing activities performed on Smartphone Native Interfaces (SNI) showed higher scales. This means that performing these activities while driving will lead to a change in vehicle dynamics, including variations in speed, lane deviation, and abrupt changes in braking. However, many participants have answered that variations are due to time-consuming, complex, rich interfaces. These applications have very low suitability for drivers as these are mainly designed with the perspective of ordinary smartphone users. Similarly, it has also been reported that operating smartphones via Voice Interfaces (VI) may increase cognitive overload. Furthermore, it has also been reported that sometimes performing smartphone activities using VIs is also not feasible in a noisy environment.

**3.2. Managing Text Messaging.** One of the most tedious and dangerous smartphone activities while driving is text messaging, which many researchers have been acknowledged as a major source of accidents. According to our analysis, maximum participants have selected higher scales 3, 4, and 5, which means that text messaging leads to speed variations, changes in lane variations, abrupt changes in braking, wrong tapping the screen, and particularly focusing off the road (see Figure 2). Similarly, some of the participants reported that texting is a difficult and time-consuming task.

**3.2.1. Managing Phone Calls.** It has been reported that managing phone calls while driving is complex and leads to vehicle dynamic variations due to changes in vehicle dynamics due to the intricate nature of searching phone numbers and dialing a number. Participants reported that

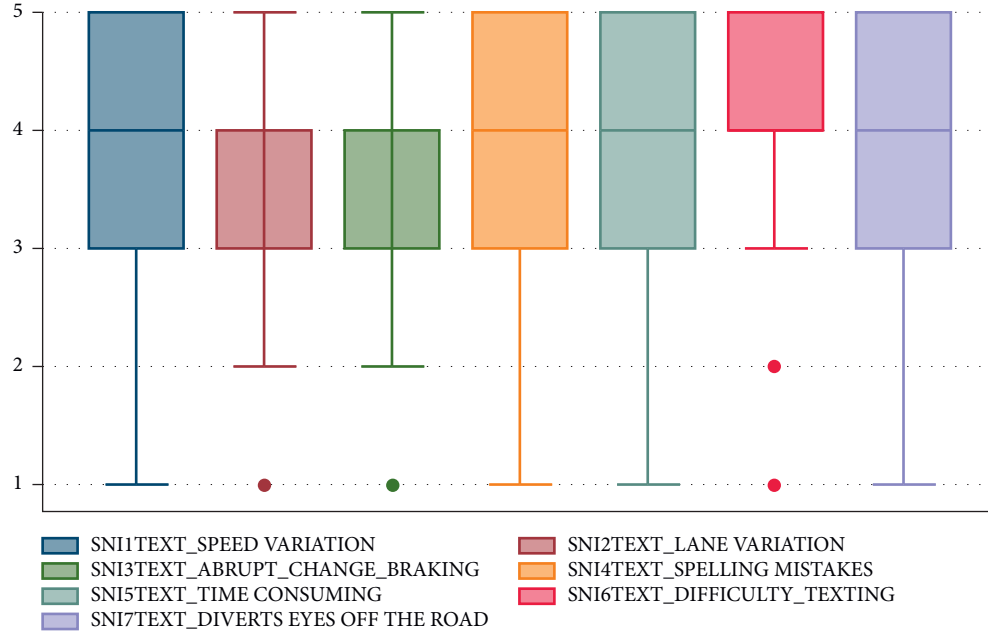


FIGURE 2: Issues in performing texting activities while driving.

the common reasons behind the complexity of making phone calls are small buttons, small interfaces, and complex navigational patterns. The results are summarized and depicted in Figure 3.

**3.2.2. Managing Emails.** Emails management while driving is not a much frequently used activity as compared to texting and calling. Performing emailing activity while driving is somewhat less usable as compared to texting and phone calling activities. Similarly, as per our analysis, the participants have stated that they usually ignore the emails while driving due to difficulties in reading and replying to emails. The participants also stated that in different varying contexts (i.e., variations in speed), complex interfaces, and smaller font size, they are ignoring the emails. Similarly, some of the participants have reported that they are ignoring emails while driving due to changes in vehicle dynamics, speed, lane variations, and abrupt changes in braking.

**3.2.3. Voice Interfaces.** Physical and visual engagement is not only enough for safe driving; minds need to be on-road as well. Mind engagement may increase while operating smartphones through voice interfaces. According to our statistics, performing smartphone activities while driving can overload the human brain as higher scales; i.e., Figures 4 and 5 show that cognitive overload will increase. The participants also reported that voice interfaces might disclose privacy to some extent. Similarly, some participants reported scales, i.e., 3 & 4, showing that they are not using voice interfaces due to noise, language barrier, and extra efforts. Some participants reported that they do not feel comfortable performing smartphones using voice interfaces (see Figure 5).

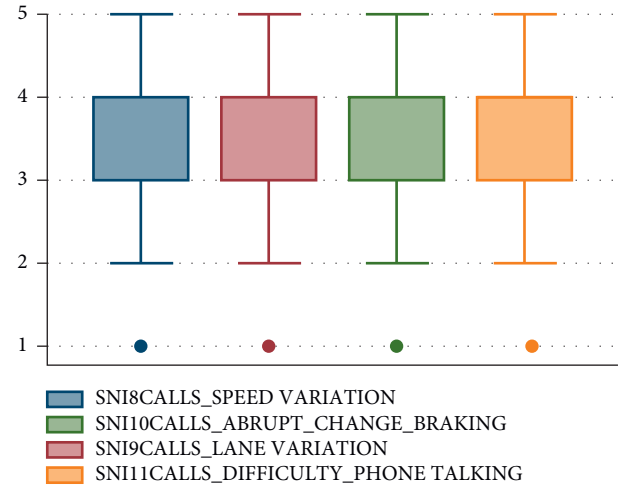


FIGURE 3: Participants responses for issues caused due to phone calls.

**3.3. Multicollinearity and Data Reliability Checking.** We have used Cronbach Alpha to check the reliability of the items. The scales are internally consistent and reliable (see Table 1). As shown in Table 2, we have also performed Kendall's correlation matrix to investigate the relationship between the independent variables. The values having an asterisk (\*) in Table 2 show that the correlation is significant. The results reflected that the correlation coefficient value is lower than 0.5, which means that there is no issue with multicollinearity.

**3.4. Distraction Analysis Using Dataset.** The dataset generated by the "AutoLog" application also contains valuable information, which could significantly add to the findings

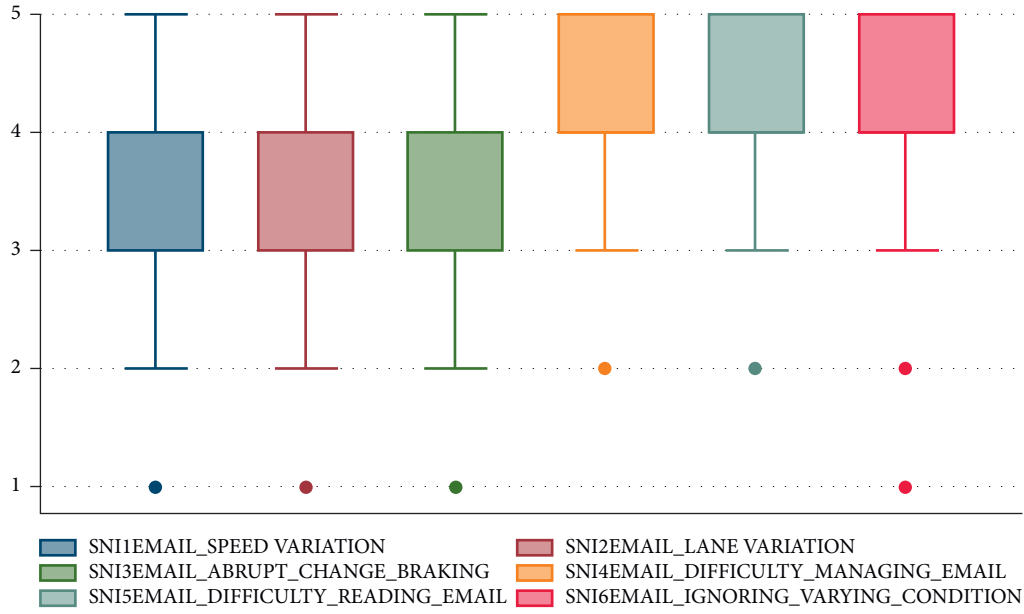


FIGURE 4: Participants responses for issues caused due to emailing.

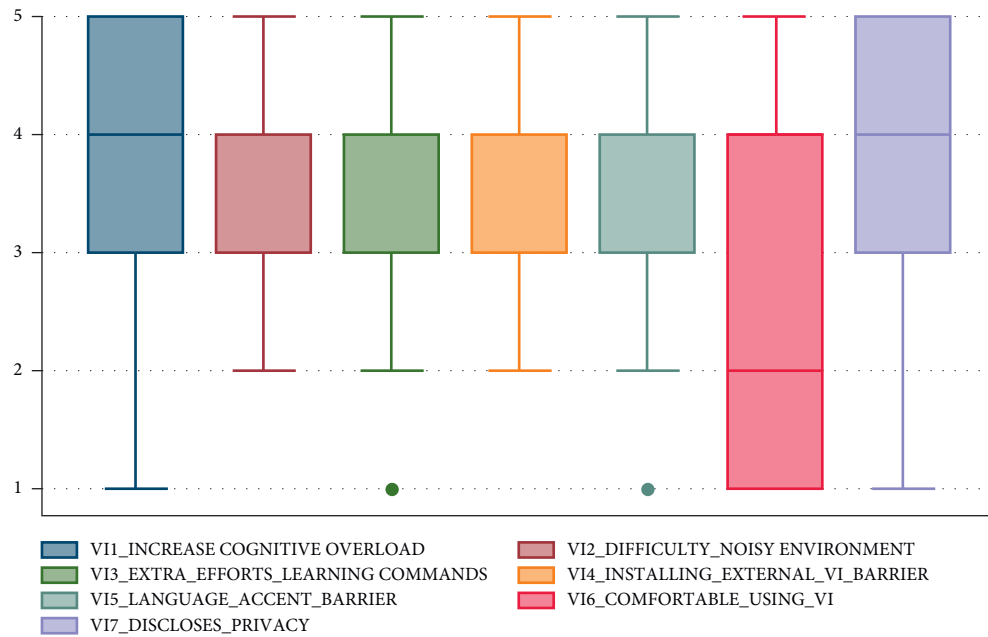


FIGURE 5: Operating smartphone using voice interfaces.

of distractions and issues discussed earlier. Analyzing the dataset will strengthen our recommendations and future directions for minimizing the drivers' distractions caused due to using a smartphone. Using a smartphone while driving could result in changes in vehicle dynamics, steering wheel movements, unwise usage of gas and brake pedals, and vehicle speed. The findings extracted from the dataset are discussed in the following sections.

**3.4.1. Speed Variations.** We have used the AutoLog application to capture and store the speed variations when performing common activities on smartphones while

driving. After analyzing the AutoLog dataset, we have noticed speed variables in different situations like attending the phone calls, reading the text messages, and replying to text messages. Speed variations can be seen in Figure 6 as it has been degraded from 80 km/h to 55 km/h while attending the phone call and 80 km/h to 30 km/h during texting activity while driving. These variations can lead to catastrophes of different kinds, such as on a highway, a vehicle following high speed may hit a vehicle ahead due to a sudden decrease in the speed. In Figure 6,  $X$ -axis shows the driving time, and  $Y$ -axis shows the speed of the vehicle.

TABLE 1: Measuring Data Reliability using Cronbach Alpha.

Measurement Items	Correlation			Cronbach alpha
	Item-test	Item-rest	Average inter-item	
SN1Txt	0.7424	0.7050	0.4235	0.9520
SN2Txt	0.7380	0.7008	0.4237	0.9520
SN3Txt	0.7303	0.7036	0.4235	0.9520
SN4Txt	0.6308	0.5449	0.4314	0.9535
SN5Txt	0.6915	0.6181	0.4278	0.9528
SN6Txt	0.6110	0.5550	0.4309	0.9534
SN7Txt	0.8327	0.7848	0.4196	0.9513
SN8PCall	0.7621	0.7482	0.4214	0.9516
SN9PCall	0.7911	0.7468	0.4214	0.9516
SN10PCall	0.7867	0.7697	0.4203	0.9526
SN11PCall	0.6652	0.6338	0.4270	0.9527
SN1Mail	0.6885	0.6588	0.4258	0.9524
SN2Mail	0.6655	0.6341	0.4270	0.9527
SN3Mail	0.7923	0.7710	0.4203	0.9514
SN4Mail	0.6033	0.5675	0.4304	0.9533
SN5Mail	0.5943	0.5579	0.4309	0.9534
SN6Mail	0.6130	0.5779	0.4299	0.9532
Visual interface-1	0.7235	0.6965	0.4239	0.9521
Visual interface-2	0.6476	0.6149	0.4280	0.9528
Visual interface-3	0.7051	0.6766	0.4249	0.9523
Visual interface-4	0.5465	0.5074	0.4333	0.9538
Visual interface-5	0.5481	0.5091	0.4333	0.9538
Visual interface-6	0.3752	0.3280	0.4425	0.9554
Visual interface-7	0.6682	0.6368	0.4267	0.9526
Recommended Interface-1	0.6295	0.5956	0.4287	0.9530
Recommended Interface-2	0.7643	0.7406	0.4216	0.9516
Recommended Interface-3	0.7153	0.6875	0.4242	0.9521
Recommended Interface-4	0.6273	0.5931	0.4289	0.9530
Observations 98	Test scale		0.4268	0.9542

TABLE 2: Kendal Tau-b rank correlation matrix.

	SNI1T	SNI2T	SNI3T	SNI4T	SNI5C	SNI6C	SNI1E	SNI2E	SNI3E	VI1	VI2	VI3	VI4	VI5
SNI1T	1.0000													
SNI2T	0.3501*	1.0000												
SNI3T	0.4386*	0.5290*	1.0000											
SNI4T	0.3956*	0.4349*	0.5118*	1.0000										
SNI5C	0.5183	0.4127*	0.5341*	0.3505*	1.0000									
SNI6C	0.2839*	0.5696*	0.4138*	0.2847*	0.5572*	1.0000								
SNI1E	0.4878*	0.2081*	0.3005*	0.2633*	0.3624*	0.3008*	1.0000							
SNI2E	0.4014*	0.3571*	0.1667	0.1968*	0.2611*	0.3348*	0.4766*	1.0000						
SNI3E	0.3717*	0.5319*	0.4527*	0.3996*	0.3882*	0.4163*	0.3867*	0.5926*	1.0000					
VI1	0.2278*	0.2679*	0.4597*	0.4357*	0.4577*	0.4080*	0.1532	0.0794	0.2507*	1.0000				
VI2	0.2534*	0.5066*	0.2630*	0.2329*	0.3167*	0.5460*	0.3480*	0.3423*	0.3530*	0.3599*	1.0000			
VI3	.2057*	0.5176*	0.3639*	0.2660*	0.4725*	0.6667*	0.2046*	0.2003*	0.4032*	0.4699*	0.5957*	1.0000		
VI4	0.2482*	0.1605	0.1004	0.0324	0.1572	0.1746*	0.1513	0.1918*	0.1894*	0.1244	0.2156*	0.2075*	1.0000	
VI5	0.3433*	0.5159*	0.3754*	0.2973*	0.3067*	0.4052*	0.2051*	0.3385*	0.4048*	0.3754*	0.4935*	0.4378*	0.073	1.0000

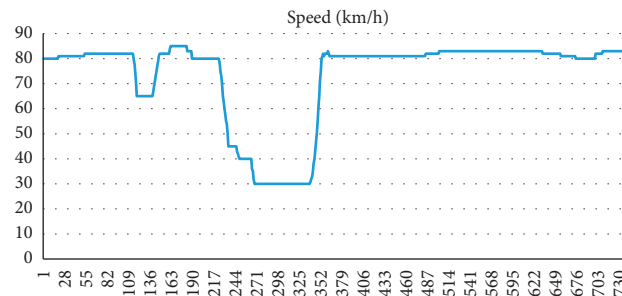


FIGURE 6: Speed variations during call and SMS [1].

**3.4.2. Variations in Steering Wheel.** Apart from speed data, the dataset also captured steering wheel information from the drivers. The control on the steering wheel w.r.t. speed shows the driving performance of a driver. Like speed, analyzing the dataset showed clear variations on the steering wheel control of the drivers, especially while attending phone calls, as shown in Figure 7. The variations in the steering wheel angle regarding speed are noticeable, and a significant variation is from 106 degrees to 121 degrees as the speed is decreased.

This shows a significantly large and consistent angle shift with a sudden decrease in the speed due to attending a call on a smartphone. Therefore, requiring drivers to be sharper in steering when attending phone calls while driving compared to other conditions. These abrupt changes in the steering wheel could be catastrophic and could result in lane deviation and an accident.

**3.4.3. Distraction Analysis Using Dataset.** To come up with optimum solution, data is collected from participant's drivers for recommended solutions. As shown in Figure 8, the categorized tabulation for the four dependent variables has been constructed for Recommended Interfaces. Participants selected higher scales responses that show that the existing interfaces' changes would be viable and fruitful. Cross-tabulation of the four dependent variables, i.e., Recommended Interfaces (RI) have been performed whereas RI1 shows Automatic and Contextual Mode of Interaction, RI2: Change the existing Interface, RI3: Automatically avoiding lengthy messages, and RI4: Priorities the Activities) as shown in Table 3. These variables have been analyzed concerning driver's demographics, i.e., age, experience, and traveling mode.

The young participants (65%) and educated participants (i.e., 80%) have provided their positive back (i.e., mostly agree) about changing the existing smartphone user interfaces to most driver-friendly interfaces. The new driver-friendly interfaces will automatically change the driving mode and will prioritize the communication activities. Similarly, drivers with driving inner city and outer city were also having a positive attitude for new proposes driver-friendly interfaces. In addition, the participants who are driving for business purposes, work purposes, or shopping purposes also wanted new driver-friendly interfaces.

**3.5. Regression Analysis.** Logistic regression models have been estimated (see Tables 4–7) to investigate the effect and cause of the four variables of “Recommended Interfaces.” The independent variables for all models are the same, including drivers' demographics, i.e., age, experience, traveling and driving mode, and perception about the existing interfaces. A correlation test has been conducted and found satisfied to check the multicollinearity problem between the independent variables.

## 4. Discussion

Minimizing smartphone distracted driving has been identified as a fundamental issue for the 2018–2020 National Road Safety Action Plane [2]. This study makes an effective

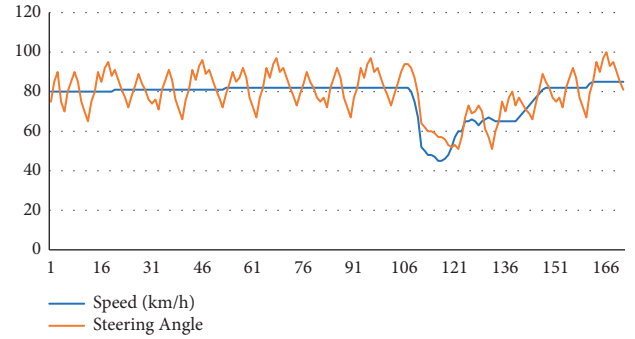


FIGURE 7: Steering wheel angle and speed variations during receiving calls.

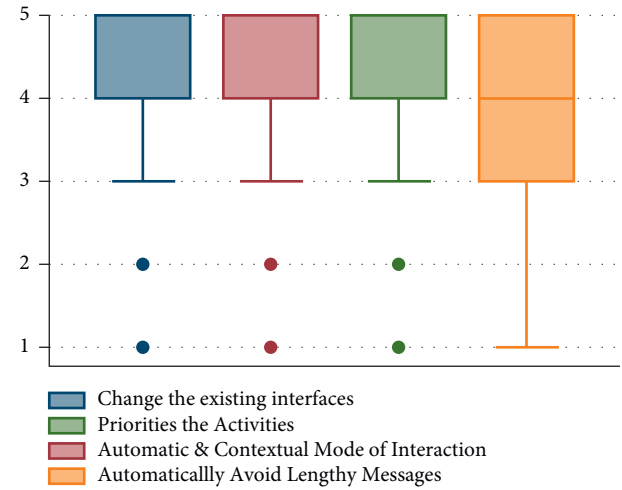


FIGURE 8: Recommendations for changing the existing interfaces.

contribution to investigate the issues in smartphone technology and recommended a driver-friendly solution for the development of countermeasures.

In this study, we have identified that 80% of the sample uses smartphone native interfaces, 15% sample are using supportive voice interfaces (e.g., Google Assistant), and only 5% are using Head-Up-Display (HUDs). This means that the drivers are habitual of using smartphone native interfaces. The current smartphone native interfaces require much visual, manual, and mental attention. It has been concluded that smartphone activities either on smartphone native interfaces or other infotainment systems could create serious driving distractions. It has been investigated that usage of smartphones while driving could distract drivers both physically and visually. For example, performing a textual activity for 2 sec can increase accidents 24 times [3].

Our results revealed that smartphone activities while driving lead to abrupt variations in speed, braking, lane position, wrong touches, and spelling mistakes, and diverting focus off the road. These issues are due to the small interface size, containing small icons with small font sizes. For example, the small size of a button most often leads to the wrong button/widget and requires much visual and mental attention. According to our results, using smartphone native interfaces for performing activities is difficult

TABLE 3: Cross-tabulation.

Variable Label	Variable category	Definitely Not				Possibly				Probably				Very Probably				Definitely			
		RI1	RI2	RI3	RI4	RI1	RI2	RI3	RI4	RI1	RI2	RI3	RI4	RI1	RI2	RI3	RI4	RI1	RI2	RI3	RI4
Age	19–28 years	06	06	06	01	02	01	00	07	04	01	03	00	04	08	09	10	15	16	14	14
	29–38 years	00	00	00	00	02	02	01	02	01	05	06	16	18	14	15	13	22	22	21	12
	39–48 years	00	00	00	00	00	00	00	00	00	00	00	02	04	06	09	06	13	11	08	09
	49 and above	00	00	00	00	00	00	00	01	00	02	00	01	05	02	04	04	01	02	02	00
Education level	Literate	00	00	00	00	00	00	00	00	01	01	01	07	07	10	12	09	10	07	05	02
	Educated	06	06	06	01	04	03	01	10	04	07	09	12	24	20	25	27	41	44	44	30
Drive mode	Inner city	01	00	00	01	00	01	00	03	01	01	02	06	09	09	12	07	13	14	11	08
	Long drive	00	00	00	00	00	00	00	00	01	01	01	01	01	01	00	01	00	00	01	00
Travel frequency	Both	05	06	06	00	04	02	01	07	03	06	06	12	21	20	25	28	38	37	33	24
	Random	06	06	06	00	04	02	00	08	02	03	05	07	10	09	13	09	11	14	10	10
Travel purpose	Daily	00	00	00	01	00	01	01	02	03	05	04	12	21	21	24	27	40	37	35	22
	Business	00	00	00	00	01	01	00	00	02	01	02	04	07	11	14	13	12	09	06	05
Travel purpose	Employee	00	00	00	01	02	02	01	03	03	07	06	10	16	12	14	17	30	30	30	20
	Shopping	06	06	06	00	01	00	00	07	00	00	01	05	08	07	09	06	09	12	09	07

TABLE 4: Ordinal Logistic Regression Model for the perception about changing the smartphone interactions to an automatic contextual interface.

Automatic and contextual mode of interaction	Coefficient	Standard error	Z-Value	$P >  z $
Exp	−0.949624	0.3103208	−3.06	0.002
Sex	12.3117	5.185264	2.57	0.010
Age	3.11290	1.955462	1.08	0.280
Qualification	5.54612	4.530418	1.00	0.316
Driving-mode	−3.83377	2.334614	−2.07	0.038
Traveling mode	19.5984	9.046204	2.39	0.017
Purpose of travel	4.57517	2.315121	1.54	0.123
Valid license	−2.75837	1.960209	−0.90	0.370
SN1Txt	5.67337	3.337954	2.00	0.046
SN2Txt	4.59828	2.382641	2.77	0.006
SN3Txt	−4.37022	2.185859	−1.54	0.123
SN4Txt	6.46458	3.378782	2.21	0.027
SN5Txt	−12.24350	4.894838	−2.28	0.023
SN6Txt	5.386821	1.979122	2.27	0.023
SN7Txt	5.860908	3.351189	2.08	0.038
SN8PCall	−13.53108	5.295263	−3.10	0.002
SN9PCall	−6.506811	2.111559	−2.18	0.029
SN10PCall	14.71013	6.223496	2.70	0.007
SN11PCall	−4.453164	1.480809	−2.27	0.023
SN1Mail	−10.44832	4.444549	−2.60	0.009
SN2Mail	8.524289	3.6931	2.55	0.011
SN3Mail	4.654765	4.396298	0.85	0.393
SN4Mail	−4.82445	4.444212	−0.89	0.376
SN5Mail	4.610155	2.380717	1.56	0.119
SN6Mail	13.546052	3.431265	3.34	0.001
Visual interface-1	1.15801	1.823014	1.12	0.261
Visual interface-2	4.33807	3.231024	1.00	0.316
Visual interface-3	7.233364	2.518425	3.23	0.001
Visual interface-4	−7.513761	3.553192	−2.42	0.015
Visual interface-5	2.850426	2.449121	0.80	0.423
Visual interface-6	−5.291706	2.012937	−2.63	0.009
Visual interface-7	−1.172993	1.066752	−1.10	0.272
/cut1	125.2839	39.44332		
/cut2	152.8744	48.8225		
/cut3	170.321	53.83508		
No of observations = 59				
Wald $\chi^2(32) = 57.29$				
$P \leq 0.001$				
Pseudo $R^2 = 0.6730$				
Log pseudolikelihood = −19.236206				



TABLE 5: Ordinal Logistic Regression Model for the perception about changing the existing interfaces.

Change the existing interfaces	Coefficient	Standard error	Z-Value	$P >  z $
Exp	-18.4540	2.501872	-8.22	0.001
Sex	140.753	17.5606	8.42	0.001
Age	-189.627	23.15696	-8.41	0.001
Qualification	350.8052	41.60189	8.24	0.001
Driving-mode	49.33828	6.043952	8.51	0.001
Traveling mode	439.1332	54.95374	8.08	0.001
Purpose of travel	-149.5421	18.40198	-8.45	0.001
Valid license	-529.6207	62.55927	-8.55	0.001
SN1Txt	-29.5140	6.452717	-5.52	0.001
SN2Txt	-59.1540	7.291356	-8.68	0.001
SN3Txt	-321.28643965	37.88391	-8.38	0.001
SN4Txt	171.4605	20.69075	8.04	0.001
SN5Txt	-481.4669	56.75089	-8.40	0.001
SN6Txt	409.5528	49.32636	8.33	0.001
SN7Txt	79.18007	10.35985	7.83	0.001
SN8PCall	-281.5654	34.61485	-7.99	0.001
SN9PCall	211.8213	25.08761	8.33	0.001
SN10PCall	274.8012	33.12115	8.30	0.001
SN11PCall	-295.5953	35.57816	-8.31	0.001
SN1Mail	-802.6423	96.33161	-8.33	0.001
SN2Mail	-72.61328	8.316154	-8.73	0.001
SN3Mail	761.8761	90.95409	8.38	0.001
SN4Mail	-64.51524	12.22568	-5.28	0.001
SN5Mail	222.3784	26.50356	8.39	0.001
SN6Mail	173.682	21.2409	8.18	0.001
Visual interface-1	-620.495	74.42446	-8.34	0.001
Visual interface-2	607.7279	71.93654	8.45	0.001
Visual interface-3	239.8945	29.78239	8.05	0.001
Visual interface-4	-83.16526	10.5197	-7.91	0.001
Visual interface-5	248.1227	31.36583	7.91	0.001
Visual interface-6	-156.7105	19.25008	-8.14	0.001
Visual interface-7	180.2639	21.36577	8.44	0.001
/cut1	1527.27	188.7543		
/cut2	1531.154	189.2725		
/cut3	2242.325	274.1231		
No of observations = 59				
Wald $\chi^2(32) = 235.44$				
$P \leq 0.001$				
Pseudo $R^2 = 0.9149$				
Log pseudolikelihood = -4.8564726				

as it requires much time, effort, and concentration; even passengers cannot manage properly in a moving vehicle. It has been investigated that accessing a particular area on a smartphone screen for touching or tapping is time-consuming and difficult for drivers. Unfortunately, drivers are familiar with the smartphone native interfaces as they use the same in their normal routine life. These results further highlighted that the drivers are uncomfortable using supportive voice interfaces for many reasons, including privacy issues, language barriers, and noise.

We have estimated OLR models for the four different variables representing recommended interfaces. Model 1 represents the question about updating the existing UIs to more easy-to-use UIs. Model 2 is about knowing the driver perception regarding switching to an automatic mode of interaction. Model 3 is about prioritizing the applications in a way to looks less distractive and more efficient. Similarly, model 4 is about the perception of automatically

ignoring and canceling lengthy messages. According to our results, the models are significant statistically as the  $p$ -value is less than 0.05, values of all coefficients are equal to zero, and the  $\chi^2$  value is greater than 2.0. Hence, therefore, the null hypothesis has been rejected. It has been concluded that all the models are significant. RI2 values represent the percentage (%) variations with values 0.721, 0.673, 0.573, and 0.925 as elucidated by the independent variables for the four models in the dependent variables. The estimated probability value is less than 0.05, and the  $z$ -statistics value is greater than 2, which seems that the coefficients of independent variables are significant. The variables that hold negative coefficients will reduce the probability (log odds) while positive coefficients increase the log odds.

In conclusion, 82% of participants have selected the scale “Definitely” and “Very Probably” that the existing mode of interaction between driver and smartphone needs to be

TABLE 6: Ordinal Logistic Regression Model for the perception about avoiding lengthy messages automatically.

Avoiding lengthy messages	Coefficient	Standard error	Z-value	$P >  z $
Exp	0.0450562	0.1648833	0.95	0.344
Sex	-2.720471	1.855887	-0.99	0.324
Age	-.858536	1.097658	-0.78	0.434
Qualification	2.16993	1.426154	1.52	0.128
Driving-mode	0.1544981	.9879131	0.16	0.876
Traveling mode	5.649868	2.11949	2.67	0.008
Purpose of travel	2.612008	.9911119	2.64	0.008
Valid license	-9.216121	3.564899	-2.59	0.010
SN1Txt	1.230921	1.199268	1.03	0.305
SN2Txt	-0.8629046	.7964669	-1.08	0.279
SN3Txt	-0.1809369	.8859942	-0.20	0.838
SN4Txt	-2.107618	1.672393	-1.26	0.208
SN5Txt	0.0972826	1.644342	0.06	0.953
SN6Txt	0.4282987	1.053603	0.41	0.684
SN7Txt	3.022207	1.158804	2.61	0.009
SN8PCall	0.0371694	1.116448	0.03	0.973
SN9PCall	1.053618	0.9636646	1.09	0.274
SN10PCall	-2.579661	1.381452	-1.87	0.062
SN11PCall	2.130834	0.9951324	2.14	0.032
SN1Mail	-0.3561978	1.167004	-0.31	0.760
SN2Mail	-0.1387213	1.004044	-0.14	0.890
SN3Mail	0.6601901	1.316659	0.50	0.616
SN4Mail	0.478997	1.206689	0.40	0.691
SN5Mail	1.257184	.7716569	1.63	0.103
SN6Mail	2.536931	.9134279	2.78	0.005
Visual interface-1	3.161218	1.353173	2.34	0.019
Visual interface-2	-3.132817	1.248298	-2.51	0.012
Visual interface-3	0.5081588	1.088503	0.47	0.641
Visual interface-4	0.7872293	1.161302	0.68	0.498
Visual interface-5	0.6762423	1.361247	0.50	0.619
Visual interface-6	-0.5132211	0.4750714	-1.08	0.280
Visual interface-7	1.142862	0.9429931	1.21	0.226
/cut1	35.82099	10.84208		
/cut2	40.25627	10.84055		
/cut3	47.22419	11.72782		
No of observations = 59				
Wald $\chi^2(32) = 102.30$				
$P \leq 0.001$				
Pseudo $R^2 = 0.5730$				
Log pseudolikelihood = -26.674877				

TABLE 7: Ordinal Logistic Regression Model for the perception about prioritizing the activities.

Prioritizing the activities	Coefficient	Standard Error	Z-Value	$P >  z $
Exp	-0.1707440	0.2771559	-1.02	0.309
Sex	4.718558	2.275798	2.55	0.011
Age	3.153012	3.05413	0.68	0.499
Qualification	2.512767	1.262127	1.29	0.198
Driving-mode	4.540853	1.918299	1.90	0.057
Traveling mode	5.018110	5.80873	1.06	0.291
Purpose of travel	0.04787	1.637832	2.54	0.011
Valid license	-26.44864	6.38875	-4.31	0.001
SN1Txt	-1.23716	3.183147	-0.74	0.461
SN2Txt	3.726827	1.077125	2.63	0.008
SN3Txt	-0.1621387	1.191217	-0.21	0.832
SN4Txt	5.560123	3.639498	2.11	0.035
SN5Txt	-2.977216	1.827565	-1.63	0.103
SN6Txt	-1.143575	1.831291	-0.62	0.532
SN7Txt	4.834982	1.776108	2.72	0.006

TABLE 7: Continued.

Prioritizing the activities	Coefficient	Standard Error	Z-Value	$P >  z $
SN8PCall	-2.064167	1.490176	-1.39	0.166
SN9PCall	1.947548	1.866658	1.04	0.297
SN10PCall	3.446161	2.5194	1.37	0.171
SN11PCall	-.0341503	.8400654	-0.04	0.968
SN1Mail	-2.567933	1.660064	-1.55	0.122
SN2Mail	-0.7192782	1.000074	-0.72	0.472
SN3Mail	6.967619	2.517348	2.77	0.006
SN4Mail	-6.613736	2.012419	-3.29	0.001
SN5Mail	3.321731	1.112994	2.98	0.003
SN6Mail	6.209074	1.705888	3.64	0.001
Visual interface-1	-0.2021435	1.745629	-0.12	0.908
Visual interface-2	0.4624554	1.873938	0.25	0.805
Visual interface-3	-3.252232	0.8262406	-3.94	0.001
Visual interface-4	3.591892	1.214865	2.96	0.003
Visual interface-5	-4.300956	1.502282	-2.86	0.004
Visual interface-6	0.3914871	0.5097102	0.77	0.442
Visual interface-7	3.478623	1.882344	1.85	0.065
/cut1	71.77695			
/cut2	87.23475			
/cut3	100.2217			
No of observations = 59				
Wald $\chi^2$ (32) = 62.16				
$P \leq 0.001$				
Pseudo $R^2 = 0.7205$				
Log pseudolikelihood = -20.036181				

changed to more simplified and easy-to-use interfaces. In terms of “Switching to automatic interactions,” 80% of participants selected the scale “Definitely” and “Very Probably.” Similarly, more than 75% of participants reported prioritizing the activities to more relevant and less distractive interfaces. However, avoiding lengthy and unknown messages automatically while driving was reported by about 60% of participants.

There are several methodological limitations noted in this study. Firstly, although diverse recruitment strategies were adopted, still limited participants’ drivers participated in this study. Similarly, it observed that certain groups of people might have been less likely to participate due to the online nature of this study (e.g., lack of Internet accessibility, lack of education, remote areas, etc.). Secondly, due to some privacy issues about self-reported data, it is possible that participants may have been influenced by biases and recorded incorrect responses. Thirdly, most participants who participated in this study were teenagers; the reason may be that the number of drivers that use a smartphone while driving belongs to the younger population. Future research should consider some more methods to investigate the activities that may increase risky driving behaviors. In the current study, all the participants’ drivers were healthy, and future studies could examine the drivers, the low vision drivers, or those affected due to ocular pathologies issues. Furthermore, in the future, we intend to develop a solution that will use different sensors to identify the context and generate user interfaces in real-time for driver’s smartphone users. It is expected that the context-aware adaptive solution will improve driver safety by minimizing physical, mental, and visual distractions.

## 5. Conclusion

Smartphone usage while driving has got considerable attention globally as it requires full attention, enough physical engagements, and high psychological skills to perform concurrent activities. Using smartphones while driving is a dangerous activity and was found to be a significant source of crashes and accidents. In ordinary daily life, a person is free to operate a smartphone despite concurrent activities. However, a person while driving has certain issues due to his physical limitations, visual limitations, and psychological limitations. The current smartphone technologies and their rich and complex nature are designed for ordinary users who might not be efficient for the drivers to be used while driving. However, researchers have developed some solutions to cope with the issues and facilitate drivers with easy-to-use interfaces to minimizing distractions and issues. However, there is no empirical evidence found regarding the minimization of distractions and accidents crashes. Therefore, the existing solutions are not viable for the drivers. This paper investigated the existing issues in the state of the art smartphone and their interfaces and proposed the recommended mode of interaction and interfaces for the drivers to minimize distractions. Based on our analysis and investigation, it has been concluded that a context-aware adaptive solution could be an optimal solution to reduce the driver’s limitations.

## Data Availability

The data that support the findings of this study are available upon request from the corresponding author.

## Conflicts of Interest

The authors declare that they have no conflicts of interest.

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## References

- [1] A. Fernández, R. Usamentiaga, J. Carús, and R. Casado, "Driver distraction using visual-based sensors and algorithms," *Sensors*, vol. 16, no. 11, p. 1805, 2016.
- [2] World Health Organization, *Mobile phone Use: A Growing problem of Driver Distraction*, World Health Organization, Geneva, Switzerland, 2011.
- [3] O. Oviedo-Trespalcacios, M. M. Haque, M. King, and S. Demmel, "Driving behaviour while self-regulating mobile phone interactions: a human-machine system approach," *Accident Analysis & Prevention*, vol. 118, pp. 253–262, 2018.
- [4] J. C. Stutts, D. W. Reinfurt, L. Staplin, and E. A. Rodgman, *The Role of Driver Distraction in Traffic Crashes*, AAA Foundation for Traffic Safety, Washington, DC, 2001.
- [5] I. Khan, S. Khusro, and I. Alam, "Smartphone distractions and its effect on driving performance using vehicular lifelog dataset," in *Proceedings of the 2019 International Conference on Electrical, Communication, and Computer Engineering (ICECCE)*, pp. 1–6, Swat, Pakistan, June 2019.
- [6] K. Young, M. Regan, and M. Hammer, "Driver distraction: a review of the literature," *Distacted Driving*, vol. 2007, pp. 379–405, 2007.
- [7] I. Khan and S. Khusro, "Towards the design of context-aware adaptive user interfaces to minimize drivers' distractions," *Mobile Information Systems*, vol. 2020, Article ID 8858886, 23 pages, 2020.
- [8] G. Albert, O. Musicant, I. Oppenheim, and T. Lotan, "Which smartphone's apps may contribute to road safety? An AHP model to evaluate experts' opinions," *Transport Policy*, vol. 50, pp. 54–62, 2016.
- [9] Y. Wang, J. Yang, H. Liu, Y. Chen, and M. Gruteser, "Sensing vehicle dynamics for determining driver phone use," in *Proceeding of the 11th Annual International Conference on Mobile Systems, Applications, and Services*, pp. 41–54, Taipei Taiwan, June 2013.
- [10] S. P. Walsh, K. M. White, M. K. Hyde, and B. Watson, "Dialling and driving: factors influencing intentions to use a mobile phone while driving," *Accident Analysis & Prevention*, vol. 40, no. 6, pp. 1893–1900, 2008.
- [11] G. Rumschlag, T. Palumbo, A. Martin, D. Head, R. George, and R. L. Commissaris, "The effects of texting on driving performance in a driving simulator: the influence of driver age," *Accident Analysis & Prevention*, vol. 74, pp. 145–149, 2015.
- [12] F. A. Wilson and J. P. Stimpson, "Trends in fatalities from distracted driving in the United States, 1999 to 2008," *American Journal of Public Health*, vol. 100, no. 11, pp. 2213–2219, 2010.
- [13] J. K. Caird, K. A. Johnston, C. R. Willness, M. Asbridge, and P. Steel, "A meta-analysis of the effects of texting on driving," *Accident Analysis & Prevention*, vol. 71, pp. 311–318, 2014.
- [14] S. G. Hosking, K. L. Young, and M. A. Regan, "The effects of text messaging on young drivers," *Human Factors: The Journal of the Human Factors and Ergonomics Society*, vol. 51, no. 4, pp. 582–592, 2009.
- [15] O. Oviedo-Trespalcacios, M. King, A. Vaezipour, and V. Truelove, "Can our phones keep us safe? A content analysis of smartphone applications to prevent mobile phone distracted driving," *Transportation Research Part F: Traffic Psychology and Behaviour*, vol. 60, pp. 657–668, 2019.
- [16] S. Siuhi and J. Mwakalonge, "Opportunities and challenges of smart mobile applications in transportation," *Journal of Traffic and Transportation Engineering*, vol. 3, no. 6, pp. 582–592, 2016.
- [17] D. P. Chiang, A. M. Brooks, and D. H. Weir, "Comparison of visual-manual and voice interaction with contemporary navigation system HMIs," *SAE Transactions*, vol. 104, pp. 436–443, 2005.
- [18] J. Shutko, K. Mayer, E. Laansoo, and L. Tijerina, "Driver workload effects of cell phone, music player, and text messaging tasks with the Ford SYNC voice interface versus handheld visual-manual interfaces," pp. 0148–7191, SAE Technical, 2009.
- [19] M. C. McGinn, "Predicting factors for use of texting and driving applications and the effect on changing behaviors," M. S. Thesis, Southern Illinois University at Edwardsville, Edwardsville, IL, USA, 2014.
- [20] J. M. Cooper, H. Ingebretsen, and D. L. Strayer, *Mental Workload Of Common Voice-Based Vehicle Interactions Across Six Different Vehicle Systems*, Foundation of Traffic Safety, Washington, DC, USA, 2014.
- [21] Y. Fukatsu, B. Shizuki, and J. Tanaka, "No-look flick: single-handed and eyes-free Japanese text input system on touch screens of mobile devices," in *Proceedings of the 15th International Conference on Human-Computer Interaction with Mobile Devices and Services*, pp. 161–170, Munich, Germany, August 2013.
- [22] T. C. Lansdown and A. N. Stephens, "Couples, contentious conversations, mobile telephone use and driving," *Accident Analysis & Prevention*, vol. 50, pp. 416–422, 2013.
- [23] N. S. Council, "Understanding the distracted brain: why driving while using hands-free cell phones is risky behavior," 2012.
- [24] P. Tchankue, J. Wesson, and D. Vogts, "Are mobile in-car communication systems feasible?: a usability study," in *Proceedings of the South African Institute for Computer Scientists and Information Technologists Conference*, pp. 262–269, Pretoria, South Africa, June 2012.
- [25] Z. Yang, H. Li, S. Ali, Y. Ao, and S. Guo, "Lane detection by combining trajectory clustering and curve complexity computing in urban environments," in *Proceedings of the 2017 13th International Conference on Semantics, Knowledge and Grids (SKG)*, pp. 240–246, Beijing, China, August 2017.
- [26] J. Hindy, *Best Driving Apps*, Ridester, 2018.
- [27] B. Adipat and D. Zhang, "Interface design for mobile applications," in *Proceedings of the AMCIS 2005*, p. 494, Omaha, NE, USA, August 2005.
- [28] F. Liu, B. Lv, and J. Huang, "Edge user allocation in overlap areas for mobile edge computing," *Mobile Networks and Applications*, vol. 116, 2021.

- [29] M. Regan, "Driver distraction: reflections on the past, present and future," *Distracted Driving*, pp. 29–73, Australasian College of Road Safety, Sydney, Australia, 2007.
- [30] I. Khan, M. A. Khan, S. Khusro, and M. Naeem, "Vehicular lifelogging: issues, challenges, and research opportunities," *Journal of Information Communication Technologies and Robotics Applications*, vol. 8, pp. 30–37, 2017.
- [31] Z. Ali, G. Qi, K. Muhammad, P. Kefalas, and S. Khusro, "Global citation recommendation employing generative adversarial network," *Expert Systems with Applications*, vol. 180, Article ID 114888, 2021.
- [32] I. Khan, S. Khusro, N. Ullah, and S. Ali, "AutoLog: toward the design of a vehicular lifelogging framework for capturing, storing, and visualizing LifeBits," *IEEE Access*, vol. 8, pp. 136546–136559, 2020.
- [33] I. Khan, S. Ali, and S. Khusro, "Smartphone-based lifelogging: an investigation of data volume generation strength of smartphone sensors," *Simulation Tools and Techniques*, vol. 8, pp. 63–73, 2019.
- [34] I. Khan, S. Khusro, S. Ali, and J. Ahmad, "Sensors are power hungry: an investigation of smartphone sensors impact on battery power from lifelogging perspective," *Bahria University Journal of Information & Communication Technologies (BUJICT)*, vol. 9, no. 2, 2016.

## Research Article

# Selection of Devices Based on Multicriteria for Mobile Data in Internet of Things Environment

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Internet of Things (IoT) is a computing term which describes universal Internet connectivity, transforming everyday objects into connected devices. Many smart devices are interconnected to sense their surroundings, send, and process the sensed data. The IoT connects the real world with the global world by interconnecting edge devices. The main goal of the IoT is to attain high operating performance, improve throughput, and control the assets and processes of the industry. Many heterogeneous devices in IoT settings are linked with each other to transfer huge amount of information for operations of organizational efficiency. The appropriate and proper device may hinder the main goals of the IoT which seems difficult to achieve. However, not a single research study is focused on the selection of devices based on multicriteria properties. For solving the dilemma of the IoT device selection, “Properties Based Device Selection Using Ant Colony Optimization (PBDS-ACO)” is implemented in this paper which selects a device based on multicriteria properties. By exploiting the suggested model, the effectiveness and efficiency of the IoT are shown.

## 1. Introduction

IoT paradigm is a blend of three “visions,” namely, “things,” “Internet,” and “semantic-oriented.” IoT is a network of heterogeneous devices that are linked and addressed via shared communications protocol, either from things oriented or via Internet point of view [1]. IoT connects the real world with the global world by interconnecting edge devices [2]. The “Internet of Things” terminology is for the explosion of network communication and computing power to various devices, objects, sensors, and other noncomputer-like devices. These “smart objects” create, share, and consume data with little human interaction, and they often provide access to analyzing, collecting, and controlling distant. The IoT devices are linked in industrial setting for consumer, national, and commercial use [3]. Devices, computers, and people can communicate and connect with each other more efficiently and effectively due to the Internet of Things [4].

IoT provides universal Internet connectivity, by transforming ordinary objects into connected devices. The IoT concept is based on the deployment of many smart devices that are interconnected to sense their surroundings, send, and process the sensed data. Connecting unusual objects to the Internet would enhance industry and society’s sustainability and protection, as well as aid efficient communication between the digital and real world, referred to as a cyber-physical system (CPS). The IoT concept is also viewed as a revolutionary technology capable of addressing many of today’s societal challenges, including smart cities, intelligent transportation, radiation emissions, and allied healthcare [5].

Industrial IoT is being developed as a result of the introduction of new technological developments and implementations of the IoT in Industrial Internet of Things (IIoT). IIoT is an industrial concept that automates intelligent objects for the detection, storage, processing, and transmission of events in industrial real-time networks



environment. IIoT seeks to achieve high operating efficiency, higher productivity, and appropriate planning of industrial assets and processes by customizing products, by integrating intelligent applications for manufacturing and mechanical health services, and by maintaining industrial preventive machinery [6]. People and companies now connect and conduct business electronically thanks to the Internet. As a result, the new concept the “Industrial Internet of Things” encompasses a variety of devices, software, and services that link the virtual and physical worlds [7]. In the industrial environment, different sensors and wireless devices have become widely implemented because of the fast-developing requirements for industrial production/service for protection, efficiency, and reliability. The IIoT, a subset of the IoT developed for industrial applications, is being built on this basis. The IIoT gathers massive quantities of data regularly [8].

Various devices properties were extracted from the literature with the intention of using them for selecting appropriate devices in IoT settings. According to our analysis, the proposed “PBDS-ACO” is a novel approach since no prior research has used the ant colony approach for addressing the dilemma of device selection in IoT settings. The efficacy and reliability of IoT would significantly be improved if this technique was used as it selects appropriate devices based on multicriteria properties.

The structure of the current paper is as follows. The literature review is briefly shown in Section 2. The methodology of the proposed research along with details is presented in Section 3. The results and discussions are comprehensively presented in Section 4. Conclusion of the paper is given in Section 5.

## 2. Literature Review

The practice of combining computers and networks to track and manage devices is known as “Internet of Things.” Several technological and business developments are combining to make it possible to attach more and smaller devices cheaply and easily. The IoT is the result of the integration of many computing and networking technologies. At this time, a wide variety of industries, including automotive, healthcare, engineering, home and consumer electronics, and many others, are exploring how IoT technology can be integrated into their products, services, and operations [9]. Millions of sensor-equipped devices are interconnected to gather and share data. The Internet of Things is considered as the daily object phenomena, which are linked by an interconnected system. These sensors create a mass of data simultaneously and constantly, often known as big data, from a broad range of appliances or products. If we reduce time, energy, and processing capacity, this large data volume and various variants pose critical issues. Therefore, for data acquired by IoT, big data analytics are more complex. IoT big data issues were identified and managed with respect to data management, data analysis, unstructured data analysis, data visualization, interoperability, data semantic, scalability, data fusion, data integration, data quality, and information discovery [10]. In today’s IoT environment, policymakers,

entrepreneurs, the academia sector, and even the general public are highlighting the connection between technology-driven (data), copyrights, privacy law, and competitive legislation. For instance, business people can build resources; analysts can readily gather, evaluate, and share information; and now everyone recognizes that collecting and distributing personal data might lead to data privacy issues [11].

The industry 4.0 aims to increase the efficiency, adaptability, and digitization of core operations that integrate value chains so that companies may plan and interact with available data from various technologies. This makes it difficult for firms to comprehend how the technology of industry 4.0 may be used to improve the available processes by providing the current and new users a more compelling value proposition [12].

The IoT keeps spreading in previously inaccessible sectors. These areas may present specific limitations that make IoT systems challenging to create and execute. For instance, the lack of specific protocols, restricting the information that may be accessed, and the necessity to facilitate the public and monitor the communications operations are some of these restrictions. Fast and efficient implementation of these initiatives is crucial if such restrictions are to be collected, evaluated, and exploited [13]. Connectivity is one word, which summarizes the transformation of industry 4.0. Due to the increased globalization and industry 4.0, the relevance of IoT and Industrial IoT (IIoT) has increased substantially. With global increase in upcoming opportunities, data protection and data security have become crucial features of IIoT. Considerable significance is devoted to the identification of industrial networks (IIoT). For instance, it is a vital component for the safe running of intelligent grid systems and for safeguarding the privacy of the client. Data transmission is also a feasible method for transferring cloud research into the fog for industrial networks, providing quick intrusion detection and time to prevent networks attack [14].

The notion is very engaging for most industrial sectors due to increased operational effectiveness in production processes, smart item identity methods, and intelligent control applicability. It reduces employee intervention in hazardous industrial circles. The IIoT phenomenon is built on the IoT (Internet of Things) technologies, which presently guarantee effective working performance in many domains, both in the sector and business and commercial sectors [15]. Enhanced sensing, data collecting, and communication technologies lead to an enormous expansion of the IIoT in recent years, which intensifies the transformation in the monitoring and management of electronic asset values. An open environment is an essential necessity so that users may connect freely on user terminals via web or mobile apps with power devices and servers, thereby improving IIoT flexibility. The fundamental open ecosystem technology for the future IIoT includes strong sensor technologies, broad-based ways for communication, a big data services platform, data processing algorithms, and intelligent maintenance. In the management of wind farms, the potential IIoT ecosystem should be addressed. Wind farm

quality and efficiency are demonstrated through enabling an open future ecology IIoT which provides an advanced insight into electrical assets control and maintenance with high dependability [16].

The fundamental open technological platform for the future IIoT includes strong sensor technologies, broad-based ways for communication, a big data services platform, data processing algorithms, and intelligent maintenance. In the management of wind farms, the potential IIoT ecosystem should be addressed. Wind farm quality and efficiency are demonstrated through enabling an open future ecology IIoT which provides an advanced insight into electrical assets control and maintenance with high dependability. The adaptive transmission architecture is proposed by SDN and EC for IIoT. The dominance Internet of Things is a ground-grained algorithm that satisfies time restrictions in the short-term context (IoT). The path difference degree (PDD), taking into consideration the time limit, traffic load balances, and energy consumption additive, has been used for an optimum scheduling route. A well-designed strategy is introduced in a tight time to establish a powerful transmission channel using a low latency adaptive power approach when the gross grain technology is beyond the scope. Finally, the simulation assesses the plan's success. Results demonstrate that the system suggested exceeds the average time, commodities, output, PDD, and download time for the corresponding techniques. The approach described provides an improved way to manage IIoT data [17].

### 3. Methodology

In the Internet of Things ecosystem, heterogeneous devices are linked to form a network. The selection of the appropriate device is a daunting activity. The selection of devices will be based on multicriteria properties. These properties were discovered by analyzing the literature. As heterogeneous devices combine to form the IoT ecosystem, the properties set of these devices will be broad and there may exist redundancy which influences the proper selection. To eliminate complexity and redundancy, these were filtered out.

**3.1. Selection Based on Device Properties.** Feeding a large number of device properties into a detection system not only makes computation more difficult but also causes the dimensionality curse. A broad and complex dataset is reduced, and suitable properties are sorted out using properties based filtering. The properties based selection technique is used to pick a subset of the original set while maintaining the original set's accuracy. The effectiveness and scalability of a system can be enhanced by eliminating unnecessary and redundant device properties. When working with a large number of device properties datasets, it is important to choose the right device based on its specific properties. Properties based selection is needed in real-world problems owing to the proliferation of noisy, unnecessary, or misleading properties. The IoT ecosystem is

made up of a wide range of heterogeneous devices, each with its own set of characteristics. The properties of devices are gathered from previous research studies. It was important to identify these properties in order to differentiate between appropriate and inappropriate devices. The inconsistency and complexity are then removed by filtering these properties. As a result of reviewing the literature, a set containing multiproperties shown in Table 1 was formed. Our proposed method would pick different types of devices that will be used in an IoT environment based on these multicriteria properties.

**3.2. Properties Based Device Selection Using Ant Colony Optimization (PBDS-ACO).** Dorigo and Blum in year 1990 presented ant colony optimization as a technique related to swarm intelligence [27]. After inspiring from a vast utilization mechanism, the ant follows strategies and techniques which are well recognized for optimizing purposes, and the applications of ant colony optimization are widely used. Ant colony optimization (ACO) is a conceptual focusing mechanism based on various ant species scavenging. If the ants migrate from one place to the next, they lay the pheromones on the planet to indicate encouraging indications in the colony for other ants (members). Ant optimization utilizes a similar method to address problems of optimization [28]. Heuristic information and the frequency of pheromones are two factors that ants use to solve problems. The mutual communication among artificial ants can result in high-quality outcomes. Pheromone trail values are obtained by indirect communication (sensed the pheromone) of various ants. Ants do not change themselves; instead, they adapt how other ants represent and perceive the dilemma [28]. ACOs may be used to solve a variety of issues in the industrial sector.

In the IoT ecosystem, the ACO method can be used to solve the device selection dilemma. The proposed system "Properties Based Device Selection Using Ant Colony Optimization (PBDS-ACO)" depicts the various steps involved in implementing the ACO algorithm for device selection optimization (see Figure 1). The approach presented will handle the problem of device selection. The selection procedure starts with the creation of ants that go through numerous pathways (ranges) and choose devices depending on the edged pheromone information. If the crossover of ants does not satisfy the stop criterion, the pheromone levels are altered and the cycle is reinitiated.

Devices present in the IoT ecosystem possess unique properties that are identified from the existing literature in Table 1. A device set (D) is formed by combining the positive and alternative properties shown in Table 2. The properties based device selection technique will reduce the original set in Table 2 by eliminating inappropriate devices. The higher degree of precision in the depiction of the entire set, however, will be preserved. As a result, only a portion of the devices is selected. The previous device attached to a node has no influence on the subsequent device selection.

TABLE 1: Properties of heterogeneous devices in IoT environment.

S. no	Properties of IoT devices	Citations
1	Flexibility	[5, 8, 18]
2	Scalability	[5, 6, 18, 19]
3	Efficiency	[3, 5, 8, 19–21]
4	Reliability	[4–6, 20]
5	Security	[3–5, 19, 22, 23]
6	Privacy	[5, 6, 22, 24]
7	Interoperability	[5, 7]
8	Real time	[3, 5, 25]
9	Intelligent	[3, 6, 8, 18, 21]
10	High sensing	[3, 4, 8]
11	Availability	[5, 18, 19]
12	Cost effective	[8, 25]
13	Increase throughput	[5]
14	Compatibility	[26]
15	Adaptability	[18]

TABLE 2: IoT devices set.

Devices	Multiproperties of IoT devices
D1	Flexible, interoperable, cost effective
D2	Nonflexible, noncompatible, expensive
D3	Insecure, decrease throughput, low sensing
D4	Security, increase throughput, high sensing
D5	Intelligent, reliable, compatible
D6	Nonintelligent, nonreliable, noncompatible
D7	No privacy, inefficient, nonadaptable
D8	Privacy, efficiency, adaptable
D9	Available, scalable, real time
D10	Unavailability, nonscalable, asynchronous

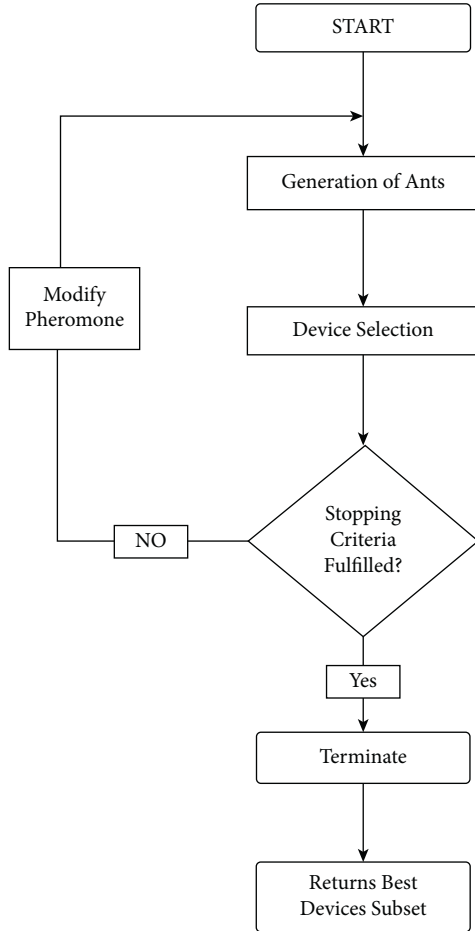


FIGURE 1: Properties based device selection using ant colony optimization (PBDS-ACO).

The device selection dilemma is mapped using the steps as follows:

- (i) Graphical illustration method
- (ii) The heuristic desirability and pheromone intensity
- (iii) Modifying the pheromone value
- (iv) Results

(1) *Graphical Illustration Method.* Ant colony optimization usually represents a problem in graphical structure, as shown in Figure 2. The nodes represent different devices, and the edges indicate the appropriate selection of the device. The nodes are connected to make it possible to pick any IoT device. When an ant navigates the graph or visits different nodes, an ideal collection of devices is picked. The traversal of ants must satisfy the terminating requirements (i.e., select optimal devices). In Figure 2, the ants 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 are allowed to leave their nest and begin moving to various nodes such as D1 or D2 and then to D3, D4, D5, D6, D7, D8, D9, and D10.

(2) During the traversal process, these ants leave pheromones as shown in Figure 3, a chemical material, on various edges. The traveling of ants depends on the probabilistic values of pheromone intensity on distinct paths (if the levels of the pheromones are high, then the ant will only choose those edges (bold lines) and only those specific nodes). The ants from the nest will choose node D1 and then D4 using the transition law. It then selects D5, D8, and D9.

When the ant traversal reaches D9, it meets the stopping criterion and stops, providing a partial solution to the original device set “D,” which consists of devices D1, D4, D5, D8, and D9 shown in Figure 4. As a result, high degree of precision is achieved. The device subset is then used as a nominee in IoT settings.

(3) *The Heuristic Desirability and Pheromone Intensity.* Devices are evaluated on the basis of optimal properties. The initial selection of device substitutes is made using a simple multi-state local search process. In the ACO algorithm, the  $(\eta_i)$  heuristic function is utilized in accumulation with the pheromone score, to make a correct transition. Evaluating the pheromone and heuristic meaning yields the best devices subset. A device selection occurs if the value of pheromone on connected edge is higher. Inappropriate devices, on the other

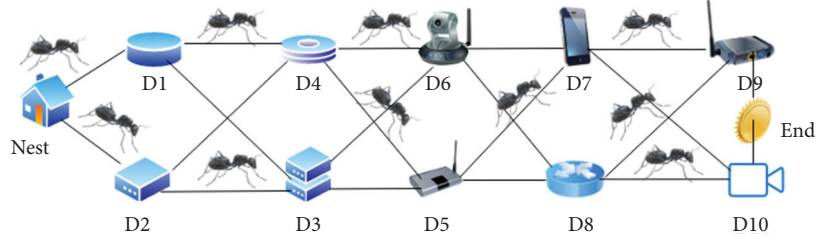


FIGURE 2: Ant's traversal on edges.

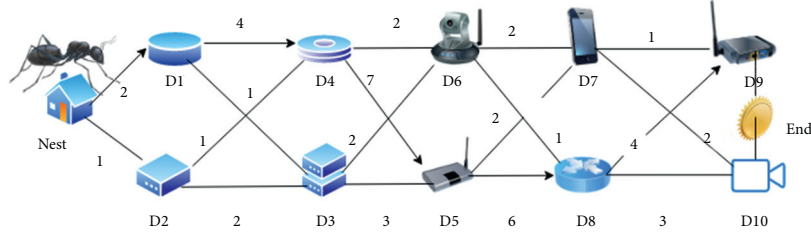


FIGURE 3: Pheromones secretion by ants on paths.

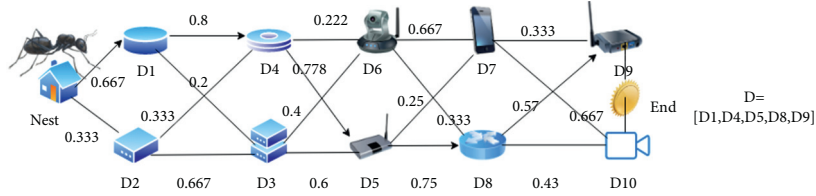


FIGURE 4: Probability of pheromones on edges.

hand, are rejected based on the pheromone score in addition to the respective path, which is lower. An ant in D1 decides whether D3 should be picked or not, and the decision is based on the likelihood of the highest value of pheromones on its path. The probability of pheromones on path can be calculated using the following equation:

$$P(\text{edge}) = \frac{P(\text{pheromones}(Xi)\eta_i)}{\sum (P(\text{pheromones}(Xi))\eta_i)} \quad (1)$$

Equation (1) is used for evaluating ant's probability for selecting a node, probability is represented by  $P$ , edges or path are represented by  $Xi$ , and the heuristic intensity is represented by  $\eta_i$ . If an edge is to be chosen, the  $\eta_i$  value should be held higher; otherwise, it should be lower. The pheromone value has an effect on node traversal and selection (i.e., device). The ant will follow the path having highest value of pheromone.

- (4) *Modifying the Pheromone Value.* In a case where terminating requirement for ant traversal is not met, the value of pheromone is modified, new ants are initialized, and the cycle continues further. The pheromone is modified using the following equation:

$$\tau_i(\tau + 1) = (1 - \rho)\tau_i(\tau) + \rho\Delta\tau_i(\tau), \quad (2)$$

where  $\rho$  is considered as pheromone decay coefficient and the cost assigned to it ranging from 0 to 1,  $\tau_i$  is considered as pheromone limit that still resides on specific path, and  $\Delta\tau_i$  is considered as pheromone increment for updated iteration process. Best ants leave more pheromones on optimal solution nodes, and as outcomes, optimal properties of devices are revealed

- (5) *Results.* The PBDS-ACO procedure starts with the formation of a specific number of simulated ants that are positioned on the graph with an equal number of connected devices. The traversal of each ant starts the process of constructing a graph from a specific (device) node. Ant moves in a probabilistic fashion from a starting point, crossing different nodes while following strategic criteria which are fulfilled. The resulting device set is collected and evaluated for an ideal subset. The experiment ends when the best devices are identified, and the results are revealed in Figure 4. When the terminating requirements are not fulfilled, the pheromone are updated and new ACO is generated, and then the iteration of device selecting process initiates.



TABLE 3: Probability-wise nodes selection.

Devices	Selected devices	Ants	Pheromone quantity paths	Paths selection probability	Path selection	Probability
D1, D2 D3, D4, D5, D6, D7, D8, D9, D10	D1, D4, D5, D8, D9	1	2, 4, 7, 6, 4	0.667, 0.8, 0.778, 0.75, 0.57	3.565	0.143
	D2, D3, D5, D8, D9	2	1, 2, 3, 6, 4	0.333, 0.667, 0.6, 0.75, 0.57	2.92	0.117
	D1, D3, D6, D7, D10	3	2, 1, 2, 2, 2	0.667, 0.2, 0.4, 0.667, 0.667	2.601	0.104
	D2, D3, D6, D8, D9	4	1, 2, 2, 1, 4	0.333, 0.667, 0.4, 0.333, 0.57	2.303	0.092
	D2, D3, D6, D7, D9	5	1, 2, 2, 2, 1	0.333, 0.667, 0.4, 0.667, 0.333	2.4	0.096
	D1, D4, D6, D8, D10	6	2, 4, 2, 1, 3	0.667, 0.8, 0.222, 0.333, 0.43	2.452	0.098
	D2, D4, D6, D8, D10	7	1, 1, 2, 1, 3	0.333, 0.333, 0.222, 0.333, 0.43	1.651	0.066
	D1, D3, D5, D7, D9	8	2, 1, 3, 2, 1	0.667, 0.2, 0.6, 0.25, 0.333	2.05	0.082
	D1, D4, D5, D7, D9	9	2, 4, 7, 2, 1	0.667, 0.8, 0.778, 0.25, 0.333	2.828	0.113
	D2, D3, D6, D8, D10	10	1, 1, 2, 1, 3	0.333, 0.667, 0.4, 0.333, 0.43	2.163	0.087
						$\Sigma = 24.932$

#### 4. Results and Discussion

Attention must be given when choosing appropriate devices for the IoT as the quality of operation improves with the selection of suitable devices. A device set (10 devices “D1, D2, D3, D4, D5, D6, D7, D8, D9, and D10”) with multiple properties (appropriate and inappropriate) is positioned in a graphical structure in our framework of device selection based on properties. The devices are represented as a sequence of nodes linked by edges; an equal number of ants are generated to navigate along multiple edges and select devices, resulting in a partial solution of the device collection. If a partial solution fulfills the stop criteria, the ants will finish exploring and generate the optimal device subset with several properties (i.e., it selects the appropriate devices subset D). If the ant’s traversal does not meet the stopping criterion, the pheromones are updated and the process restarts. The pheromone value at each edge is considered as the decision system for the selection and rejection of devices; if the value is greater, nodes are picked and the best devices subset is formed in the ant’s process of path discovery; if the value is lower, edges and device connected to nodes are rejected. Table 3 shows the ants and their preferred direction. The probability of pheromones is determined to identify the optimum navigational path so that only appropriate IoT devices are selected. For the proposed device selection, the device subsets D1, D4, D5, D8, and D9 are selected by ant 1 route discovery mechanism because the likelihood of the pheromone values at their appropriate node (device) edges has been greater than that of other node edges (devices).

#### 5. Conclusion

The IoT is a universal Internet connectivity phenomenon where smart objects are associated and linked to sense their

surroundings, transmit, and process the data. Both the cyber and physical world are connected by IoT. The main goal of IoT is to attain high operating performance and improved throughput and to control the assets and processes in industry. Various research articles have been published. However, our research focusses on the device’s selection problem in IoT setting. Properties Based Device Selection Using Ant Colony Optimization for the device selection problem in IoT settings was proposed that selects appropriate devices. Our study makes a significant contribution by assisting in the selection of the suitable device based on multicriteria properties. The performance and effectiveness of IoT will be improved by identifying the suitable device. The method is theoretically discussed in this article with fewer devices. We will utilize the method in the future since the system is effective (i.e., it selects devices based on multicriteria properties) and will play a crucial role in the device selection process in IoT environments.

#### Data Availability

No data were used to support this study.

#### Conflicts of Interest

The authors declare that there are no conflicts of interest.

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## References

- [1] J. Chanchaichujit, A. Tan, F. Meng, and S. Eaimkhong, "Internet of Things (IoT) and big data analytics in healthcare," in *Healthcare 4.0*, pp. 17–36, Springer, Berlin, Germany, 2019.
- [2] W. Li and P. Wang, "Two-factor authentication in industrial Internet-of-Things: attacks, evaluation and new construction," *Future Generation Computer Systems*, vol. 101, pp. 694–708, 2019.
- [3] H. Boyes, B. Hallaq, J. Cunningham, and T. Watson, "The industrial internet of things (IIoT): an analysis framework," *Computers in Industry*, vol. 101, pp. 1–12, 2018.
- [4] H. Ezz El-Din and D. H. Manjaiah, "Internet of nano things and industrial internet of things," in *Internet of Things: Novel Advances and Envisioned Applications*, pp. 109–123, Springer, Berlin, Germany, 2017.
- [5] E. Sisinni, A. Saifullah, S. Han, U. Jennehag, and M. Gidlund, "Industrial internet of things: challenges, opportunities, and directions," *IEEE Transactions on Industrial Informatics*, vol. 14, no. 11, pp. 4724–4734, 2018.
- [6] W. Z. Khan, M. H. Rehman, H. M. Zangoti, M. K. Afzal, N. Armi, and K. Salah, "Industrial internet of things: recent advances, enabling technologies and open challenges," *Computers & Electrical Engineering*, vol. 81, Article ID 106522, 2020.
- [7] A.-H. Muna, N. Moustafa, and E. Sitnikova, "Identification of malicious activities in industrial internet of things based on deep learning models," *Journal of information security and applications*, vol. 41, pp. 1–11, 2018.
- [8] Y. Chen, G. Lee, L. Shu, and N. Crespi, "Industrial internet of things-based collaborative sensing intelligence: framework and research challenges," *Sensors*, vol. 16, no. 2, p. 215, 2016.
- [9] K. Rose, S. Eldridge, and L. Chapin, "The internet of things: an overview," *The Internet Society (ISOC)*, vol. 80, pp. 1–50, 2015.
- [10] P. Wongthongtham, J. Kaur, V. Potdar, and A. Das, "Big data challenges for the internet of things (IoT) paradigm," in *Connected Environments for the Internet of Things. Computer Communications and Networks*, Z. Mahmood, Ed., Springer, Cham, Switzerland, 2017.
- [11] B. Lundqvist, "Big data, open data, privacy regulations, intellectual property and competition law in an internet-of-things world: the issue of accessing data," in *Personal Data in Competition, Consumer Protection and Intellectual Property Law*, M. Bakhoum, B. Conde Gallego, M. O. Mackenrodt, and G. Surblytė-Namavičienė, Eds., vol. 28, Springer, Berlin, Heidelberg, 2018.
- [12] M. Flores, D. Maklin, M. Golob, A. Al-Ashaab, and C. Tucci, "Awareness towards industry 4.0: key enablers and applications for internet of things and big data," in *Collaborative Networks of Cognitive Systems. PRO-VE 2018. IFIP Advances in Information and Communication Technology*, L. Camarinha-Matos, H. Afsarmanesh, and Y. Rezgui, Eds., vol. 534, Springer, Cham, Switzerland, 2018.
- [13] T. M. Ethan, K. Matthew, D. M. John, and M. Laine, "Designing for reuse in an industrial internet of things monitoring application," in *Proceedings of the 2nd Workshop on Social, Human, and Economic Aspects of Software*, Salvador, Brazil, May 2017.
- [14] A. Sari, A. Lekidis, and I. Butun, "Industrial networks and IIoT: now and future trends," in *Industrial IoT*, I. Butun, Ed., Springer, Cham, Switzerland, 2020.
- [15] S. Madakam and T. Uchiya, "Industrial internet of things (IIoT): principles, processes and protocols," in *The Internet of Things in the Industrial Sector*, Z. Mahmood, Ed., Springer, Cham, Switzerland, 2019.
- [16] P. Zhang, Y. Wu, and H. Zhu, "Open ecosystem for future industrial Internet of things (IIoT): architecture and application," *CSEE Journal of Power and Energy Systems*, vol. 6, no. 1, pp. 1–11, 2020.
- [17] X. Li, D. Li, J. Wan, C. Liu, and M. Imran, "Adaptive transmission optimization in SDN-based industrial internet of things with edge computing," *IEEE Internet of Things Journal*, vol. 5, no. 3, pp. 1351–1360, 2018.
- [18] N. Muthukumar, S. Srinivasan, K. Ramkumar, D. Pal, J. Vain, and S. Ramaswamy, "A model-based approach for design and verification of Industrial Internet of Things," *Future Generation Computer Systems*, vol. 95, pp. 354–363, 2019.
- [19] J. H. Park, *Advances in Future Internet and the Industrial Internet of Things*, Multidisciplinary Digital Publishing Institute, Basel, Switzerland, 2019.
- [20] A. Liu, Q. Zhang, Z. Li, Y.-j. Choi, J. Li, and N. Komuro, "A green and reliable communication modeling for industrial internet of things," *Computers & Electrical Engineering*, vol. 58, pp. 364–381, 2017.
- [21] H. Xu, W. Yu, D. Griffith, and N. Golmie, "A survey on industrial Internet of Things: a cyber-physical systems perspective," *IEEE Access*, vol. 6, pp. 78238–78259, 2018.
- [22] H. Mouratidis and V. Diamantopoulou, "A security analysis method for industrial Internet of Things," *IEEE Transactions on Industrial Informatics*, vol. 14, no. 9, pp. 4093–4100, 2018.
- [23] Q. Yan, W. Huang, X. Luo, Q. Gong, and F. R. Yu, "A multi-level DDoS mitigation framework for the industrial Internet of Things," *IEEE Communications Magazine*, vol. 56, no. 2, pp. 30–36, 2018.
- [24] C. Yin, J. Xi, R. Sun, and J. Wang, "Location privacy protection based on differential privacy strategy for big data in industrial internet of things," *IEEE Transactions on Industrial Informatics*, vol. 14, no. 8, pp. 3628–3636, 2017.
- [25] W. Chen, "Intelligent manufacturing production line data monitoring system for industrial internet of things," *Computer Communications*, vol. 151, pp. 31–41, 2020.
- [26] V. Kulik and R. Kirichek, "The heterogeneous gateways in the industrial internet of things," in *Proceedings of 2018 10th International Congress on Ultra Modern Telecommunications and Control Systems and Workshops (ICUMT)*, pp. 1–5, IEEE, Moscow, Russia, November 2018.
- [27] M. Dorigo and C. Blum, "Ant colony optimization theory: a survey," *Theoretical Computer Science*, vol. 344, no. 2–3, pp. 243–278, 2005.
- [28] M. Dorigo, M. Birattari, and T. Stutzle, "Ant colony optimization," *IEEE Computational Intelligence Magazine*, vol. 1, no. 4, pp. 28–39, 2006.