

## *Retraction*

# **Retracted: A Novel Strategy for Waste Prediction Using Machine Learning Algorithm with IoT Based Intelligent Waste Management System**

### **Wireless Communications and Mobile Computing**

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This article has been retracted by Hindawi, as publisher, following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of systematic manipulation of the publication and peer-review process. We cannot, therefore, vouch for the reliability or integrity of this article.

Please note that this notice is intended solely to alert readers that the peer-review process of this article has been compromised.

Wiley and Hindawi regret that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

### **References**

- [1] G. Uganya, D. Rajalakshmi, Y. Teekaraman, R. Kuppasamy, and A. Radhakrishnan, "A Novel Strategy for Waste Prediction Using Machine Learning Algorithm with IoT Based Intelligent Waste Management System," *Wireless Communications and Mobile Computing*, vol. 2022, Article ID 2063372, 15 pages, 2022.

## Research Article

# A Novel Strategy for Waste Prediction Using Machine Learning Algorithm with IoT Based Intelligent Waste Management System

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Internet of Things (IoT) has now become an embryonic technology to elevate the whole sphere into canny cities. Hasty enlargement of smart cities and industries leads to the proliferation of waste generation. Waste can be pigeon-holed as materials-based waste, hazard potential based waste, and origin-based waste. These waste categories must be coped thoroughly to make certain of the ecological finest run-throughs irrespective of the origin or hazard potential or content. Waste management should be incorporated into ecological preparation since it is a grave piece of natural cleanliness. The most important goalmouth of waste management is to maintain the pecuniary growth and snootier excellence of life by plummeting and exterminating adversative repercussions of waste materials on environment and human health. Disposing of unused things is a significant issue, and this ought to be done in the best manner by deflecting waste development and keeping hold of cost, and it involves countless human resources to deal with the waste. These current techniques predominantly focus on cost-effective monitoring of waste management, and results are not imprecise, so that it could not be developed in real time or practically applications such as in educational organizations, hospitals, and smart cities. Internet of things-based waste management system provides a real-time monitoring system for collecting the garbage waste, and it does not control the dispersion of overspill and blowout gases with poor odor. Consequently, it leads to the emission of radiation and toxic gases and affects the environment and social well-being and induces global warming. Motivated by these points, in this research work, we proposed an automatic method to achieve an effective and intelligent waste management system using Internet of things by predicting the possibility of waste things. The wastage capacity, gas level, and metal level can be monitored continuously using IoT based dustbins, which can be placed everywhere in city. Then, our proposed method can be tested by machine learning classification techniques such as linear regression, logistic regression, support vector machine, decision tree, and random forest algorithm. The proposed method is investigated with machine learning classification techniques in terms of accuracy and time analysis. Random forest algorithm gives the accuracy of 92.15% and time consumption of 0.2 milli seconds. From this analysis, our proposed method with random forest algorithm is significantly better compared to other classification techniques.

## 1. Introduction

IoT is the latest developing technology for connecting various things, which will communicate with each other by using sensors and embedded and wireless technologies. The

wireless technologies may be mobile or wireless fidelity networks. This technology makes our live and habits easy and automatic. Some examples of IoT devices are automatically driving cars and smart wearable devices and machines. It does not need social interaction and computer

to human communication. The usage of IoT devices in industries and cities is speedily increasing due to its special features like rapid decision-making skills and efficient service. It has special key characteristics including connectivity, intelligence, enormous scaling, sensing, dynamic nature, and heterogeneity structure [1]. It can be used in enormous number of applications. These are smart household, wearables, grid, connected healthcare, traffic management, smart farming, connected vehicles, industrial Internet, and smart city.

The IoT structure can be developed in three layers. These are device, access, and platform layer. These layers are accessed by the steps of sensing, acquisition, edge information technology, and cloud storage. It can be shown in Figure 1. In the first stage, the information will be continuously collected from the environment. This unreadable information is converted to useable knowledge by using acquisition in second stage [2]. Then, this useable knowledge is transferred to information technology world in third stage. In the last stage, the collected data are stored in cloud.

Nowadays, smart city applications are developing by using Internet of things. Because this technology used to make the cities more intelligent by integrating the various approaches of transference, it is used for effective urban area furniture management, and smart efficiency enhancement. IoT can be used in many application areas like traffic and vehicle parking management, street lighting, safety management, and waste management system to achieve an efficient and intelligent smart city.

The intelligent smart city should have the features like sufficient water resource, guarantee electrical supply, urban flexibility, reasonably priced housing, digitalization, worthy governance, education, health, and sanitation of wastages. Due to this rapid development of smart city, the waste things also increased. Discarding unusable wastages is a major challenge in IoT based smart cities. It is a regular duty to get clean city, but it needs large human resources and energy. Figure 2 shows the features of IoT to develop the smart city. These are scalability, activity, security, connectivity control, data analytics, and management of IoT devices. The scalability feature considers the number of buildings, organization, and devices being used. The activity-based feature reflects the heterogeneity of the various devices and its development schemes. The connectivity feature manages the latency and movement of things. The data analytics feature considers the size and data collection in city [3]. Then, these data are continuously monitored and collected by the management ability of IoT devices. The feature of security is divided into object and data level security. It considers the cryptanalyses techniques and advanced attacks and tools. Here, the calculations are performed, in view of heuristic models or diagram hypothesis, from which we can track down ways of limiting the distance of waste assortment. The basic role is to lessen the all cost of transport, move, save work, and diminish the reliance on utilized vehicles, while expanding administration quality, just as working on broad personal satisfaction.

IoT with machine learning algorithm provides effective result in waste management system to develop the smart

city. Mainly, the following machine learning algorithms are used in waste management system. These are linear regression, logistics regression, support vector machine, and decision tree. These algorithms are used in collection and prediction of waste in smart city. But still, it has many issues and challenges to collect and dispose waste in accurate manner. This work is to introduce the intelligent waste management system with machine learning algorithms to classify the waste prediction.

The major contribution of the paper is summarized as follows:

- (i) Review on the smart city IoT applications and its key factors.
- (ii) A detailed explanation of existing waste management solutions and its drawbacks.
- (iii) A classification of different machine learning algorithms in smart city waste management system and its countermeasures.
- (iv) We present intelligent based waste management system with machine learning algorithm to collect and predict the waste accurately.
- (v) The proposed method can be analyzed with different machine learning algorithm in terms of accuracy and time consumption.

The paper is organized as follows: Section 2 discusses the overview of smart city in IoT including key elements and application area of smart city. Section 3 summarizes the related works in waste management system. In section 4, materials and methods of proposed method with machine learning algorithms and its issues are discussed. Section 5 presents the proposed method results and performance analysis of classification algorithms. Finally, section 7 concludes the paper.

## 2. Overview of Smart City IoT Applications

*2.1. Definition of Smart City.* Smart city is developing community to enhance the sustainability, livability, and achievability by using the key factor of IoT technology. Washburn et al. proposed SC architecture that has the domains like city organization, medical services, real estate, social safety, learning, and traffic management [4]. Giffinger et al. proposed an intelligent based smart city that has been defined in terms of features including economical social, human being, authority, movement of things, environment, and lifestyle [5]. Similarly, Neuroti et al. discussed the smart city in the major domain of hardware and software. The hardware domain provides the resource management and safety to enhance the sustainability. The software domain considers the learning and authority process [6]. Liu et al. proposed smart cities into three major areas. These are rich lifestyle, which considers the education, living place, and medical services, social management, which includes safety on food, society, and traffic, and resource management, which includes the water service, electricity service, and farming [7]. Similarly, many authors discussed the definition of smart cities with descriptions. But still it has many issues

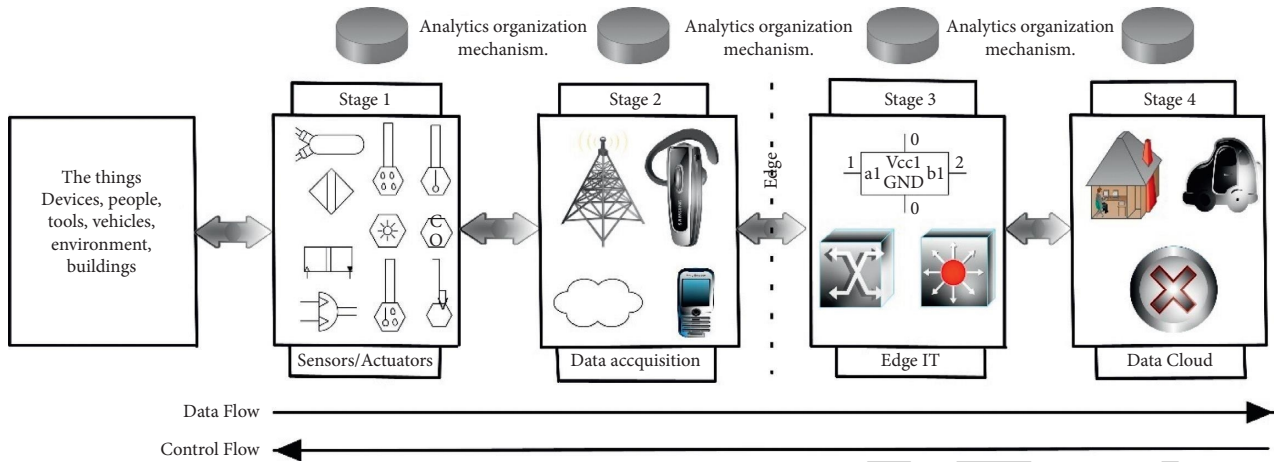


FIGURE 1: The four stages of IoT Architecture.

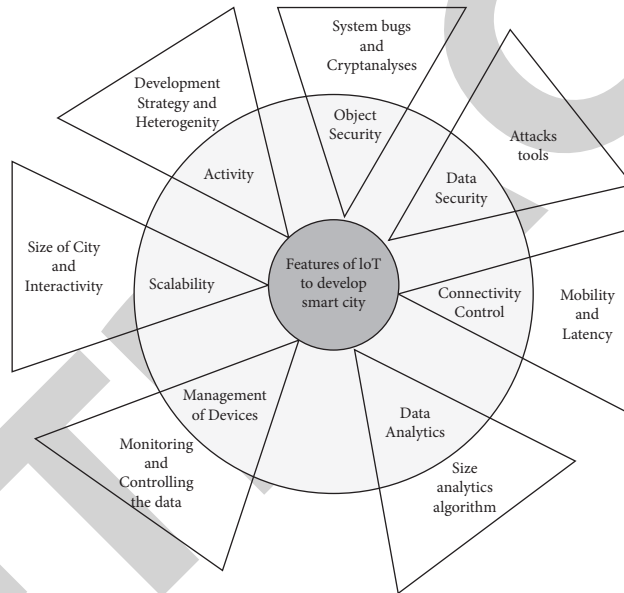


FIGURE 2: Features of IoT to develop the Smart City.

to develop the smartness and intelligent with security based smart city. However, the smart city is a developing technology in world. Figure 3 shows the Indian cities with most web searches for smart city, and Figure 4 shows the number of hits of smart city web searches between 2010 and 2020 from the source of Google trends explore. From this graph, we understand that the development of SC has been increased across the world like China, India, and UAE.

**2.2. Key Elements of Smart City.** Numerous authors discussed the key elements to enhance the smart city in IoT applications. Figure 5 shows the key elements of smart city. These key elements are security, medical services, smart learning, structure, mobility, environment, lifestyle, economical services, society, governance, and waste management. Table 1 shows the different key elements of smart city

analysis for various structures. Nam et al. discussed the SC, but it does not provide smart medical care, education, and waste management [8]. Similarly, Chourabi et al. discussed the smart city but did not consider the medical, education, security, and waste management system [9]. Dameri et al. discussed the SC with well-defined architecture and production of energy [10]. Neirrotti et al. proposed the technique and mainly focused on smart social with human resources [6]. From this analysis, we understand that many frameworks are developed to obtain the smart city, but the researcher wants to concentrate more on waste management system.

**2.3. Application Scenarios for Smart Cities with IoT.** Smart city with IoT scenarios uses numerous areas to achieve a healthy atmosphere, to enhance the safety and traffic, to

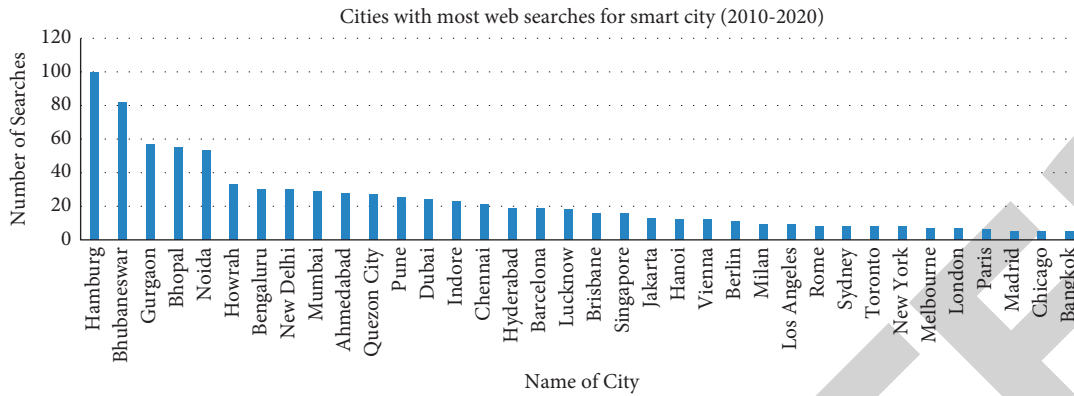


FIGURE 3: Cities with most Web Searches for Smart City from 2010 to 2020.

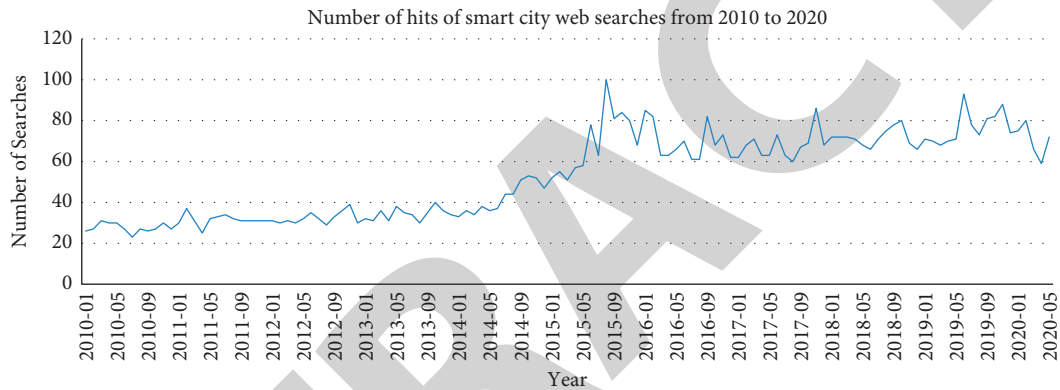


FIGURE 4: Number of hits of Smart City Web searches from 2010 to 2020.

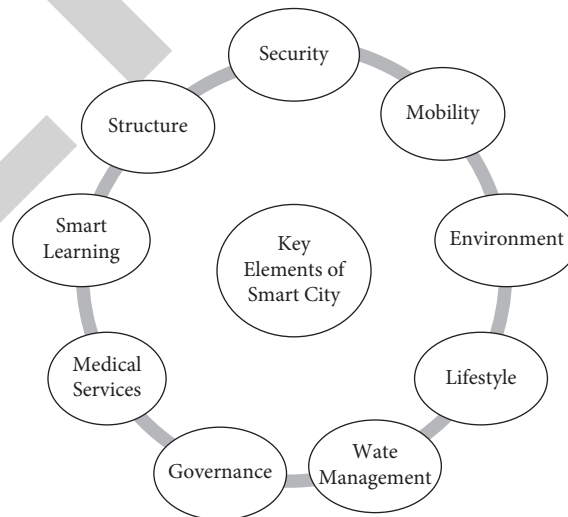


FIGURE 5: Key elements of Smart City.

improve the street lighting, and to manage the waste. Some applications of smart cities with IoT are traffic management, smart parking, transportation, home utilities, street lighting, environment safety, and waste management.

2.3.1. *Traffic Management.* It can be widely used in intelligent traffic management by the way of controlling the vehicles and extrapolation systems. It is used to enhance the security by collecting and investigating the actual data from



social. Nellore and Hancke proposed a technique to investigate the blockage in street traffic by controlling the lights in traffic signals [14]. Traffic jam is the main issue in traffic management system. It can be discussed by Knorr et al. There are many technologies developed to improve the traffic management [15]. These are analyzing the information from videos, usage of IR sensor, and remote sensor system. But these techniques have the limitations of time and cost. So, RFID based traffic organization techniques are developed by Miz et al. This technique is mainly recommended for traffic blockages with less time and less expenses [16]. Arbabi and Weigle proposed Dynamic Traffic Monitoring System (DTMon), which continuously gathers time and speed information [17]. Similarly, Mazloumi et al. proposed automobile tracing system based on global positioning system to minimize the distance limitations [18]. Chao et al. discussed the intelligent traffic management system based on RFID, which is used to control the minimize the accidents and regulate the traffic flow [19].

**2.3.2. Smart Parking.** IoT based smart parking management system is used to minimize the parking space and enhance the efficiency. Mainly, IoT based parking applications are used many sensors, which have the features including detection of speed, multilane, invasive, count, and climate sensitive. Table 2 shows comparison of various sensors used in smart parking system.

It can be categorized as booking system, direction system, crowdsourcing system, and agent-based system. Booking system is used to provide the spacing for vehicles automatically. But some methods are used to reserve the slots and not for place. Drivers can choose the place by using IoT techniques that are costlier and difficulty. And the verification of position is difficult in parking system. Pham et al. addressed this issue in parking management system [20]. Similarly, Zhang et al. proposed the technique of reservation payment system based on fog computing. In this technique, the driver can book the parking place by paying money [21].

In direction systems, the parking slots and positions can be chosen with the help of guide, whose purpose is to reduce the time for searching for free places. Geng et al. proposed smart parking with efficient resource allocation. It can be developed mainly for street or city parking in smart way [22]. It has the benefits of exact data with correct time and more decision-making choices. Crowdsourcing is mainly combined with cell phones to get exact real time data from parking place. Chen and Liu. proposed smart parking system with continuous monitoring system by using mobile. In this technique, smart parkers are used to send the information to the user in the way of answering the questions [23]. In agent-based system, software modules are used as agent. But these methods are costly and have scalability issues.

**2.3.3. Street Lighting.** Normally, we use the physical system to operate the street lights. But it needs more energy and human source. Street lighting is a major area to obtain smart city. It limits the usage of man power and wastage of

electricity. And it has been mainly developed to detect the crimes, reduce the preservation cost, and enhance the safety. Dheena et al. proposed smart street light system to save the power and minimize the human manual work [24]. But this system has high maintenance cost. Arkade et al. proposed the same energy in domestic and industrial applications. But it consumes more energy to develop this technique [25]. Parkash and Rajendra proposed the intelligent based smart lighting system, but it takes more initial cost [26]. Patil et al. discussed smart lighting system by using pollution detecting sensors to enhance the efficiency and to minimize the cost. But it will be work in independent way [27]. Similarly, Kokilavani et al. discussed the IoT based smart lighting system by using the LDR sensor, which has covered a small distance [28].

**2.3.4. Waste Management System.** The wastage can be generated by various environment as different characteristics. Based on this characteristic it can be collected and recycled to convert into useable things. IoT based waste management system concentrates on classification techniques and development of special containers. Table 3 shows the different types of waste and its definition.

Waste management system is the recent growing technology to develop IoT based smart cities. But still, it has many issues in collecting and disposing waste. Because it is daily routine process and needs more human source to complete the process. Many researches are already proposed for waste management system. Its related works can be discussed in next section.

### 3. Related Works

IoT with machine learning-based waste management system mainly focuses on dispersion of waste and enhances the environment to healthier. The collection and decomposition of waste things in intelligent way are the major issue in smart city application. Because rapid development of smart city and population increases the wastages in every day, in a traditional way, the decomposition of waste requires more human resources and more time. And it spoils the environment, social life, and atmosphere. Abdullah et al. and Talari et al. discussed the review of waste management system based on Internet of things [37, 38]. Monika et al. proposed the smart dustbin system to collect the waste with Arduino UNO board with GSM module. But it has limitations like difficult to maintenance, and more time to collect [39]. Similarly, Kumar et al. proposed dustbin by using ultrasonic sensor to continuously monitor the garbage level. And it ensures immediate disposal of waste after reaching the certain level of waste in dustbin [40]. In India, Shyam et al. proposed the intelligent based dustbin in Pune by using IoT prototype [41]. It analyzes the IoT-based waste administration, for example, the closest neighbor search, province advancement, hereditary calculation, and molecule swarm enhancement strategies.

Pardini et al. proposed the solid waste management system to collect the waste information from other

TABLE 2: Comparison of various sensors used in smart parking system.

| Sensor Types   | Detection of Speed | Detection of Multilane | Invasive | Count | Climate Sensitive |
|----------------|--------------------|------------------------|----------|-------|-------------------|
| Acoustic       | ×                  | ×                      | —        | ×     | ×                 |
| LDR            | —                  | —                      | —        | ×     | ×                 |
| RFID           | —                  | —                      | —        | —     | —                 |
| CCTV           | ×                  | ×                      | —        | ×     | ×                 |
| Microwave      | ×                  | ×                      | —        | ×     | —                 |
| WIM            | —                  | ×                      | ×        | —     | —                 |
| Pneumatic tube | ×                  | —                      | ×        | ×     | —                 |
| Piezoelectric  | ×                  | —                      | ×        | ×     | ×                 |
| Magnetometer   | ×                  | —                      | ×        | ×     | —                 |
| Inductive loop | ×                  | —                      | ×        | ×     | ×                 |
| Ultrasonic     | —                  | —                      | —        | ×     | ×                 |
| Active IR      | ×                  | ×                      | ×        | ×     | —                 |
| Passive IR     | —                  | —                      | —        | ×     | ×                 |

TABLE 3: Different types of waste and its definition.

| Type of waste | Reference | Definition   |
|---------------|-----------|--|
| Organic       | [29]      | It can be produced by restaurants, and areas related to work with food. And it is separated from other waste and used in landfills |
| Decomposable  | [30]      | It can be generated by companies or industries. This type of waste can be transformed to other forms through recycling process     |
| Industrial    | [31]      | It can be produced by industries in the form of solid. This waste reused by the same industries                                    |
| Medical       | [32]      | It can be produced by hospitals or clinics. But it is dangerous compared to other waste. Because it transfers the disease          |
| Commercial    | [33]      | It can be generated by textiles, toy companies. These wastes are recycled easily   |
| Green         | [34]      | These wastes are produced by trees which fall in street. But it can be used for organic purpose                                    |
| Electronics   | [35]      | This type of waste produced by electronic companies. It can be transferred to recycling process without any cautions               |
| Nuclear       | [36]      | It is radioactive elements produced by nuclear plants. As well as it is very dangerous to be treated carefully                     |

companies. This existing work only focused on collection of data [42]. Similarly, Bueno-Delgado et al. proposed waste collection system using optimization in smart cities. It is mainly used to improve the rural areas. But it does not provide clarity results [43]. Lozano et al. discussed the linear regression and genetic algorithm-based waste management system to collect the waste and check the status of bins. But it has limitation to change the waste from bins to other devices. So, it is difficult to achieve waste transformation system [44]. Hannan et al. proposed garbage waste management system by using line following robot to collect the waste, but it is not developed for optimization of waste [45].

Popa et al. discussed the method to collect the food waste by using RFID technology and transferred through wireless networks. But this method is not suitable for huge distance area to obtain smart city. And practically, it cannot be applied for real time applications [46]. Cerchecci et al. discussed the sensor-based waste management system. But this work can be tested only in board but not in real time applications for waste management system [47].

Existing methods mainly focused on to predict the solid and nonhazardous waste. But these techniques do not concentrate on hazardous waste control that overspill and blowout gases with poor odor. And it leads to the emission of radiation and toxic gases and affects the environment. The main aim of this work is to introduce the intelligent waste management system in Internet of things to predict the

hazardous waste that produces toxic gases. Then, our proposed method can be tested by different machine learning classification algorithms for better waste prediction.

## 4. Materials and Methods

*4.1. Intelligent Waste Management System.* This section introduces the intelligent waste management system that contains combinations of Internet of things and machine learning. Internet of things can be used for real time monitoring and collecting the waste. The waste can be collected by placing sensor-based dustbins in different places. Arduino and microcontroller-based dustbins can collect the waste within small area, and it cannot be classified based on its characteristics. So, IoT based waste management system can be selected for continuously collecting and monitoring the waste. But existing systems did not give concentration on hazardous waste that produces poor odor and poisonous gas. So, intelligent based waste management system can be proposed to monitor the hazardous waste and nonhazardous waste. Sensor based dustbins can be placed in different places that contain sensors like ultrasonic sensor, MQ4 sensor, HX711 sensor, and metal oxide sensor. The collected information from sensors and actuators can be stored in cloud, which is used to process the data and stored as database. Machine Learning can be utilized to simply decide and research the enormous measure of data from



sensor IoT gadgets. It is a fundamental device to choose activities relying upon the information assortment.

Sensor based dustbins can be designed by raspberry pi and Wi-Fi module with sensors. Nonhazardous waste like metal and wood can be monitored by ultrasonic sensors from lower part of the dustbins. When the dustbin filled above 60%, the alert message can be sent to central waste management cloud center. MQ4 sensor can be used to monitor the methane asphyxiates gas that are produced in rainy seasons and cause the displacement of oxygen level in blood. It can be used to detect the methane gas in the range of 300 ppm to 10000 ppm. HX711 sensor is used as weight sensor that monitors the load in dustbins; once it reached above 60%, it sends an alert message to the central server. QS-01 can be used as an odor sensor to detect toxic gases, and metal oxide sensor can be used to sense the various gases with changes of metal oxide by absorbing the gases. Based on this sensor information, the waste can be classified in CSV file. Figure 6 represents the intelligent waste management system with sensor-based dustbin.

The database can be created by classification and prediction of waste in the file of comma separated file. The CSV file is used to collect and store large amount of information and transfer this information from machine to machine. Python based application can be used for classification and prediction of waste using machine learning algorithms. In our proposed method, the waste can be classified as organic, hazardous, and nonhazardous waste, and it can be predicted by machine learning algorithms. Finally, it analyzes the linear regression, logistic regression, support vector machine, decision tree, and random forest algorithm in terms of accuracy and time consumption.

**4.2. Machine Learning Algorithms.** IoT with machine learning algorithm can be used in waste management system to develop the smart city in effective manner. The waste can be classified depending on its characteristics by using ML classifier algorithm. ML algorithm can be classified into three major types. These are supervised learning, unsupervised learning, and reinforcement algorithm, which are shown in Figure 7.

Mainly, supervised learning algorithm is used for waste collection and management to develop the efficient smart city. Because it provides better output and to solve classification and regression challenge. So, this work mainly focuses on supervised learning-based waste management system. Applications of Machine learning algorithms send the monitored data through an android application, and these kinds of android application are well suited for deep learning approach, and they collect the real time data with the help of Bluetooth technologies.

The supervised learning is divided into linear regression, logistics regression, decision tree, support vector machine, and random forest algorithm.

**4.2.1. Linear Regression.** It is the numerical model that investigates the dependent variable with given independent variable. The data will be continuously predicted and

increased to get constant slope. This algorithm mainly concentrates on prediction of data and not the classification of data. If the dependent and given variables are positive, it can be called as positive relationship [48]. Otherwise, it can be called as negative relationship. The simple linear regression can be written as

$$A = nB + C, \quad (1)$$

where  $A$ -Predicted output,  $B$ & $C$ -Variables, and  $n$ -Given Input data.

Similarly, multivariable regression equation can be written as

$$F(a, b, c) = X_1a + X_2b + X_3c + e, \quad (2)$$

where  $X_1, X_2, X_3$  represent the weights or coefficients of the model,  $a, b, c$  represent the characteristics of the model, and  $e$  represents the error present in the data. The data can be predicted by using the considerations including multiple collinearities, auto connection, and variable relationship. In linear regression algorithm, there is no multiple collinearity and auto connection in data and its information. And the data response and its characteristics must have feature of linear.

**4.2.2. Logistics Regression.** Logistic regression is mainly focused on classification and prediction of data depending on its characteristics. Here, the dependent variable is denoted as binary forms. It can be classified into binomial, multinomial, and ordinal. Figure 8 shows the types of logistics regression. In binomial regression, the two types of dependent variables are possible, for example, pass and fail, win and loss, etc. In multinomial regression, the dependent variable must have the three or more possible values in unordered manner [49].

In ordinal regression, the dependent variable must have three or more possible values in ordered manner. The following assumptions are considered in logistics regression. These are binomial regressions representing the target values in terms of binary values. It does not have multiple collinearity, which means that the variables are independent of each other. These variables must have proper meaning. It can be used in huge model. Here, the input is linear function, and it can be related with another function  $G$ . The relationship can be written as

$$H\theta(y) = G(\theta^t y), \quad (3)$$

where  $H_\theta(y)$  can be denoted as binomial logistics regression, and it has the values between 0 and 1. Then, the performance of the algorithm can be found by loss function. It can be written by

$$H = G(y\theta). \quad (4)$$

**4.2.3. Support Vector Machine.** Support vector machines can be used in both regression and classification of data. But mainly, it can be used in data classification issues. This

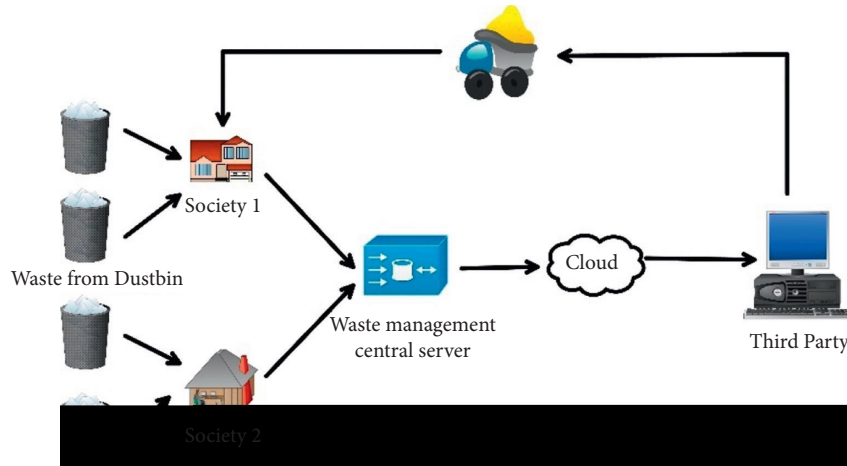


FIGURE 6: Intelligent waste management system.

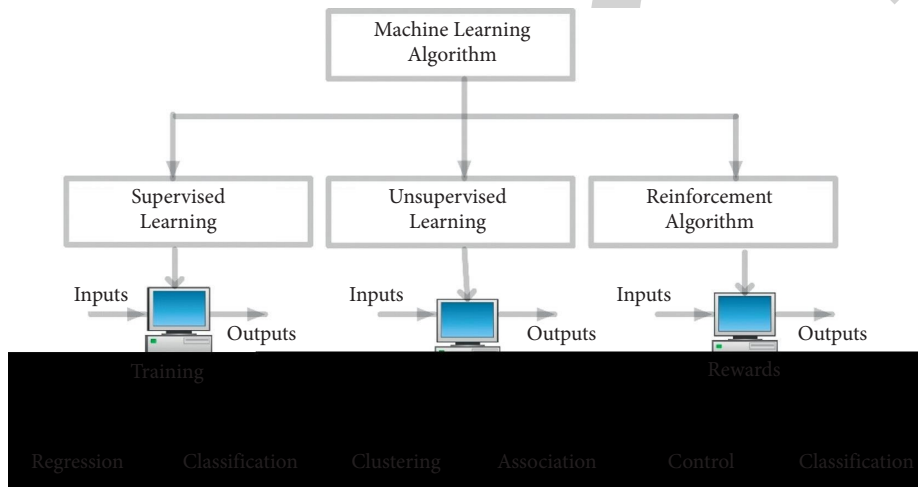


FIGURE 7: Types of machine learning algorithm.

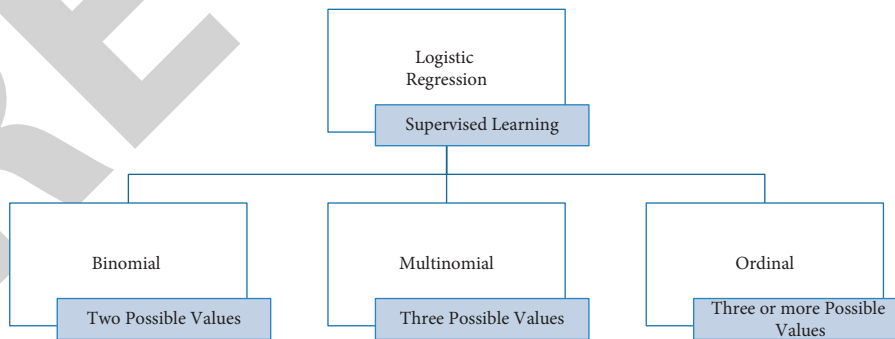


FIGURE 8: Types of logistics regression.

algorithm is very famous due to its capability to handle the multiple and continuous variables. The main of the SVM is to classify the data based on characteristics and to enhance the marginal hyperplane. It uses the models of hyperplane, margins, and support vectors. Hyperplane is a method of space that can be divided between objects and different

classes. Some data points are nearer to hyperplane, which are called as support vectors [50]. Margins are denoted by gap of two lines that is nearer to data points. And it can be measured by perpendicular distance to the support vector. The good margin has the large size, and the bad margin has small size.

Practically, it can be implemented with kernel, which is used to transfer the input space to essential form. This kernel makes the SVM more accurate and flexible by converting the nonseparable higher space into lower and separable data space. It can be classified into linear, polynomial, and RBF kernel that is shown in Figure 9.

Linear kernel is obtained by product of any two observations, and it can be written as two vectors by using the following equation:

$$K(x, y) = \text{sum}(x * y). \quad (5)$$

Polynomial kernel is distinguishing curve input space, and it can be written as

$$K(x, y) = 1 + \text{sum}(x * y)^{d_e}, \quad (6)$$

where  $d_e$  is polynomial degree, which is used to identify the learning algorithm.

Radial basis function can be used to map the input space the unspecified space, and it can be used by following equation:

$$K(x, y) = \exp(-\text{gamma} * \text{sum}((x - y)^2)), \quad (7)$$

where the gamma ranges from 0 to 1, and it can be separable data as linear.

**4.2.4. Decision Tree.** Decision tree is an algorithm to predict the values and to classify the data based on its features. So, it can be used for both regression and classification. It has the two main entities including data split and data leave. It can be classified into regression and classification decision tree. In classification decision tree, the decision variable is definite. In regression decision tree, the decision variable is continuous. A tree consists of root node and terminal node. First, the root node was created; then, the remaining nodes were formed by the following steps including creation of terminal node and recursive splitting [51]. The creation of terminal node is done by concentrated depth of tree and slightest records of the node. The prediction of data using decision tree is considering the following assumptions. The training data can be considered as root node. Then, the data feature values will be definite and recursively dispersed.

Many existing methods are based on machine learning algorithm including linear, logistic, decision tree, and support vector machine algorithm. But still, it has many issues in collecting of data. Existing methods are not effectively collecting the data in accurate manner [52]. Still, it needs efficient method to collect the waste in waste management system to develop smart city. The related works of waste management system are discussed in the next section.

**4.2.5. Random Forest Algorithm.** This work is to introduce the novel method of random forest algorithm to collect and predict the waste information depending on its features. It is a combination of huge number of decision tree and created from training dataset. It can be developed by using the constructions including the construction of discrete tree, generation of altered data set, and prediction of discrete tree.

Figure 10 shows the flowchart of random forest algorithm. It is used to create the forest by different way randomly. It gives the more accurate result compared with other classification algorithm by the relationship of number of trees and its results because randomly it finds the root node and split the feature of data. It has the following benefits compared to other algorithms. These are suitable for both classification and regression, fitting with model, handling the missed values, and definite data modelling.

In random forest algorithm, the certain features can be selected from total features. From those features, the root node can be calculating by using of split point. Similarly, the calculated node is divided into daughter nodes. The process was repeated until the specific tree number is obtained. Then, repeat the process until obtaining the  $n$  number of trees. In this way, the random forest classifier algorithm is developed. In data prediction, the test features can be processed to predict the target. Then, the votes are calculated by using predicted result. It creates the multiple trees and combines them together to enhance accuracy and to obtain an established prediction. In this algorithm, hyperparameters are used to enhance the speed and predictive power. These hyperparameters are  $n$ -number of estimators, maximized features, minimized leaf,  $n$ -number of jobs, random states, and sampling. First, three parameters are used to increase the predictive power. The last three parameters are used to increase the speed. This work is mainly focused on collecting and predicting of waste data based on its characteristics. This work is to enhance the security with less time compared with other algorithms.

## 5. Results and Discussions

The intelligent based waste management system provides accurate waste collection and prediction compared with another classifier algorithm. Figure 11 shows the waste collection and prediction using intelligent waste management system. It collects the data for each month and compares with other classifier algorithm. It collects the waste based on its characteristics like rubbish, organics, and recycling waste. The increasing strength of tree leads to reducing of forest error. This method is more efficient and robust due to its less error. In random forest algorithm, two parameters are considered as important. These are number of trees and random variables in forest. Based on these parameters, the classification and regression of waste data are developed. So, it does not have the problem of over fitting.

Figure 12 shows the proposed method regression and its heat map. The proposed work with random forest relies on good accuracy compared with other classifier algorithm including linear regression, logistics regression, support vector machine, and decision tree algorithm. In the next subsection, the performance analysis of various classifier algorithm was discussed.

**5.1. Performance Analysis.** Table 4 shows the performance analysis of various machine learning classifier algorithm. The performance of each and every algorithm is verified in terms

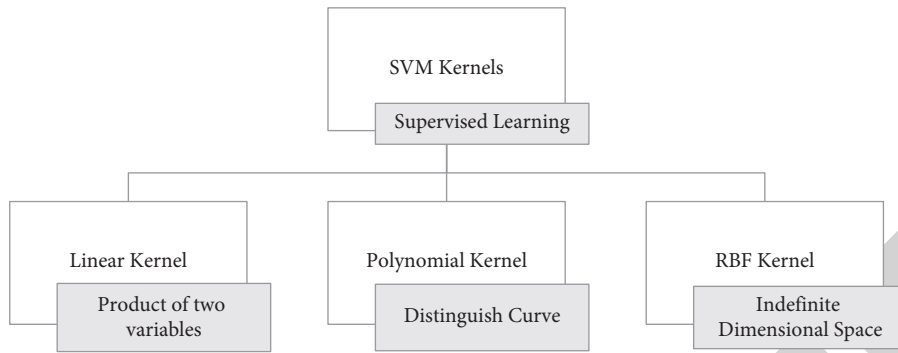


FIGURE 9: Types of SVM kernels.

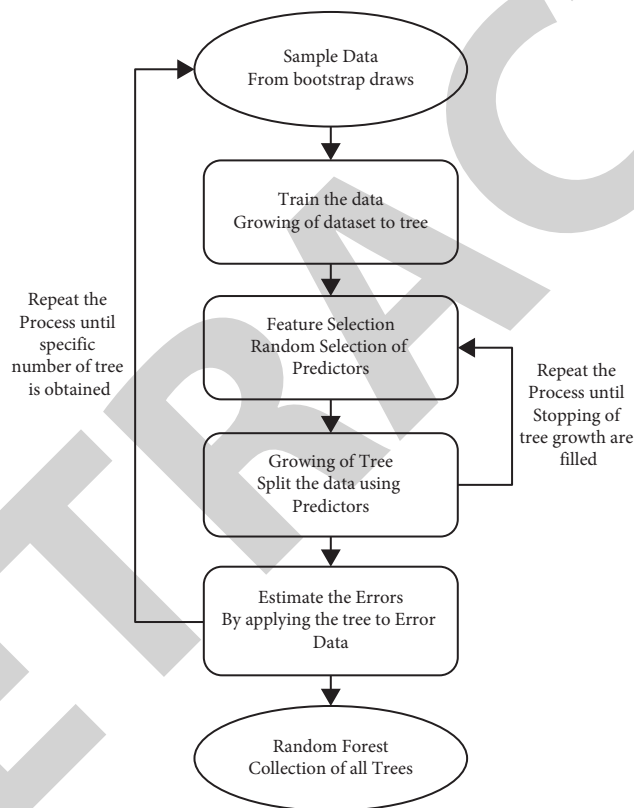


FIGURE 10: Flowchart of random forest algorithm.

of accuracy and time consumption to collect and predict the waste. In this work, accuracy can be measured by calculating predicted value and total predictions. It is the representation of correct prediction in testing the data, which can be denoted in percentage. It can be written as

$$\text{Accuracy} = \frac{\text{correct predictions}}{\text{All predictions}} \quad (8)$$

The average accuracy is obtained by calculating the waste collection from every month. In this work, time represents the period for testing and classification of data. Figure 12 represents the performance analysis various machine learning algorithm based on accuracy and time analysis.

From Figure 13 we understand that the random forest algorithm (RFA) provides good accuracy of 92.15% compared with another classifier algorithm. Similarly, decision tree provides the accuracy of 89.43%, and it is near the random forest algorithm, because the RFA escapes from overfitting. From that work, it is clear that our proposed work with RFA algorithm gives better accuracy with less time consumption compared with other algorithm. It has accuracy of 92.15% and time consumption of 0.2 milliseconds.

From above analysis, random forest algorithm has significantly higher accuracy, taking less time for classification of waste. The reason is that random forest algorithm is avoiding the overfitting data. It performs well by applying random split of waste in the form of possible best waste

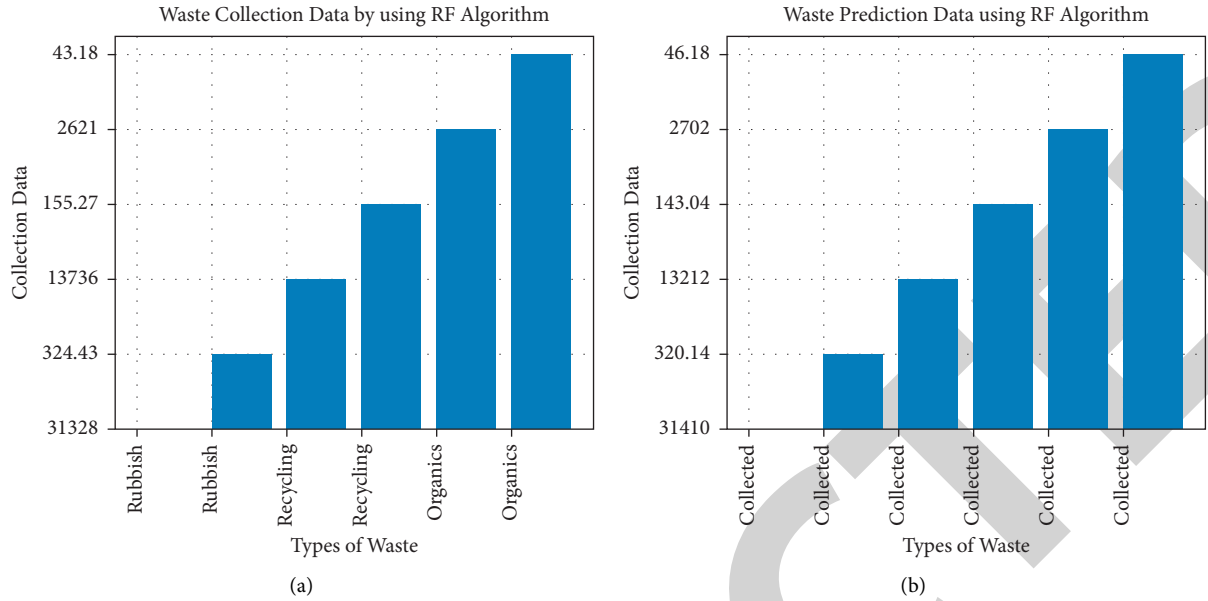


FIGURE 11: Proposed method. (a) Waste Collection. (b) Waste Prediction.

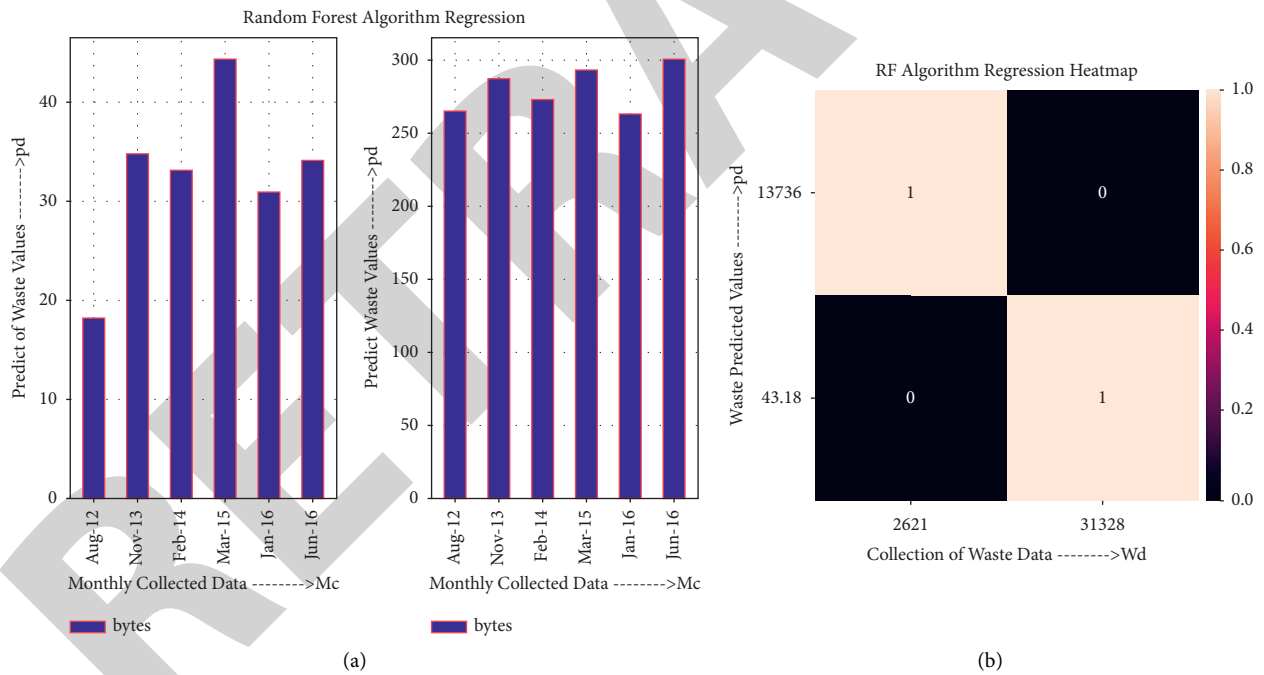


FIGURE 12: Proposed method. (a) Regression. (b) Regression Heat map.

TABLE 4: Performance analysis of machine learning algorithm.

| Algorithm              | Accuracy (%) | Time (ms) |
|------------------------|--------------|-----------|
| Linear regression      | 73.12        | 2.5 ms    |
| Logistics regression   | 78.38        | 1.4 ms    |
| Support vector machine | 85.27        | 0.7 ms    |
| Decision tree          | 89.43        | 0.4 ms    |
| Proposed work with RFA | 92.15        | 0.2 ms    |

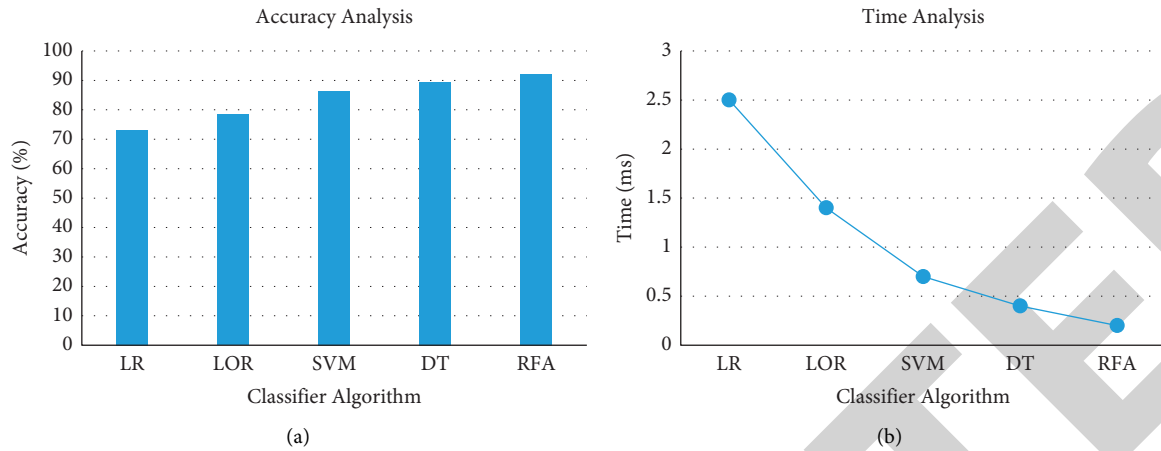


FIGURE 13: Performance analysis of machine learning algorithm: (a) accuracy analysis; (b) time analysis.

classification. And it has been done by random selection of subset of features for growing each tree.

## 6. Conclusion

IoT with machine learning is an emergent technology to upgrade the entire world into smart cities. Due to these rapid developments of smart cities and industries, the generation of waste is also increasing. Discarding unused things is a major issue in IoT. It is a regular and traditional duty in cities, but it requires a huge number of human resources to manage the waste. And it spoils nature, social characteristics, and efficient growth. In related works, many methods will be discussed about the waste management system for the disposal of unusable things. These existing methods mainly focused on giving the cost-effective monitoring of wastage. It provides a real-time monitoring system for collecting the garbage waste, but it does not control the dispersion of overspill and blowout gases with poor odor. So, in this work, we propose an intelligent waste management system by predicting the possibility of waste things in Internet of things. This work can be proposed to monitor hazardous and nonhazardous waste by sensor-based dustbins. Then, this work can be tested by classification algorithms like linear regression, logistic regression, support vector machine, decision tree, and random forest algorithm with normal parameters. From this analysis, random forest algorithm has an accuracy of 92.15% with less time of 0.2 milliseconds. When compared to existing approaches, our proposed method is working well with RF algorithm to effectively collect and predict the waste. In future, it can be extended to classify the waste based on its image and analyze it with various machine learning algorithms.

## 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 they have no conflicts of interest.

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