Review Article

A Genetic Predictive Model Approach for Smart Traffic Prediction and Congestion Avoidance for Urban Transportation

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Abstract

Traffic congestion is a persistent problem worldwide. With the growth of population and urbanization, traffic congestion has become a major issue in many cities, especially in metropolitan areas. Intelligent transportation systems (ITS) play a crucial role in managing traffic congestion by providing real-time information and predictive analytics. This paper proposes a Smart Traffic Prediction and Congestion Avoidance System (s-TPCA) that utilizes Poisson distribution for predicting vehicle arrivals and integrates a fuel consumption model to optimize energy efficiency. The system integrates Poisson distribution for prediction of vehicle arrivals from recurring size. The framework comprises traffic identification, prediction, and congestion avoidance phases. The system checks for the fitness function to determine the traffic intensity and further uses predictive analytics to determine the traffic level in future. This also integrates fuel consumption model to save time and energy. The proposed s-TPCA system outperforms the conventional systems in terms of delay and proves to conserve energy. The fuel conservation is observed to be 20% higher than the other existing systems.

1. Introduction

Road traffic congestion is a persistent problem worldwide. With huge growth of population, numbers of vehicles are increasing at a larger rate. This results in a congested traffic, which is a major issue in urban transportation [1]. This problem is extremely faced in almost all major cities of India. In this paper, Indian traffic system is considered, and the proposed work is appropriate to Indian cities. This can also be employed at cities in other nations. Since Indian traffic system is chaotic and nonlane-based, this is different from western traffic. The problem is felt in all major cities, since there is a great increase in population, and the number of vehicles, space, cost, and infrastructure is a major problem that leads to heavy traffic congestion. In many of the nations, intelligent transportation system (ITS) helps in avoiding congestion and to make the traffic system to be efficient [2]. These kinds of technologies cannot be used as it is in India. Our Indian traffic system scenario is different from other countries. This has to be altered and should make suitable for characteristics of Indian roads. Due to the development of building infrastructure, metro rails, and road enlargement, traffic congestion is getting huge in all metropolitan cities. Few of the Indian cities had their surprising growth in IT sector; it also has an abrupt growth in population. Bangalore, Delhi-NCR, Hyderabad, and Pune are some
of the cities where traffic congestion issues are rising every day. Providing a solution to resolve traffic issues needs infrastructure growth also. Space and cost are the primary constraints in improving the traffic scenarios.

There are many different solutions to reduce the traffic congestion, such as construct new roads, enhancing road pricing policies, promoting public transportation, avoiding using own car for individuals, etc. Indian traffic system needs an efficient traffic management system (ETMS), to predict and manage traffic flows in metropolitan cities. Traffic prediction helps to avoid traffic before congestion occurs. This is the idea behind smart traffic management system (STMS). Intelligent traffic system is an interdisciplinary research area. Many researchers proposed a huge number of solutions and methodologies; most of the solutions are not well suitable for our Indian traffic system. Our traffic system is different from other countries. Traffic is one of the reasons for accidents. Most of the travelers are not strict to the rules and rash driving, which leads to accidents. This also affects the environment and causes many health-related diseases. Improving the traffic flow and making commuters more knowledgeable about traffic condition can decrease the negative impact of congestion, though cannot solve it on the whole. Building road sensors need embedded systems background; this also helps in avoiding the traffic congestion. With the development of technology mobile phones, sensors are widely used to analyze the traffic condition. Machine learning algorithms and big data analytics techniques are used in controlling and predicting the traffic congestion [3]. Big data analytics is crucial in the study of intelligent traffic management systems. Data analytics helps us to predict traffic before congestion, and the occurrence of traffic can be avoided. This is an active research area across every part of the telecom ecosystem. Making data valuable is becoming more difficult and important to solve with real-time applications. To process huge amount of data, Map Reduce is utilized. There are several big data analytics models such as Hadoop and Sailfish.

Data collection, data extraction, and analysis are most important in the prediction of traffic. In this paper, the proposed system predicts the traffic congestion using the time arrivals of vehicle. The Poisson distribution is used in the prediction technique on low and moderate traffic volumes to represent the predicted traffic frequency.

The rest of this paper is organized as follows: Section 2 reviews the studies on road traffic prediction and congestion avoidance. Section 3 presents the s-TPCA framework with its preliminaries and algorithms. Section 4 discusses the results of the proposed work with a case study. Concluding remarks are described in Section 5.

2. Literature Review

Reducing the traffic congestion and providing uninterrupted traffic flow is the major goal behind smart traffic management system. In India, many of the metropolitan cities are facing difficulties in managing the traffic. Since, we are not strict with the rules and few of our traffic system rules are not coordinated with our present scenario. This paper focuses on providing a smart traffic system suitable for Asian continents. Prediction of traffic flow to avoid traffic congestion is one of the complicated problems in transportation planning and car navigation systems. A huge number of researches are focused on traffic prediction, and most models focus on short-term traffic prediction. Approaches are normally categorized as parametric and nonparametric [4, 5]. These approaches majorly focus on the structure of the model and real-time traffic scenarios. To improve the accuracy of prediction, ARIMA [6] and STARIMA [7] were proposed. Several nonparametric approaches are proposed with various advantages, these approaches encompass Kalman filters [8, 9], SVM [10–12], NNs [13–16], and hybrid methods [17, 18]. Few statistical methods are used to analyze and predict traffic occurrence duration time. These models are linear or nonparametric regression [19–21].

Several data mining–machine learning methods are employed in predicting the traffic. These approaches are classification trees model (CTM) [22, 23], decision trees (DT) artificial neural networks (ANN) [24–27], genetic algorithm (GA) [28], and support/relevance vector machine (SVM/RVM) [11]. Many researchers have developed a hybrid method [29] for prediction. Short-term traffic prediction [17] may apply for numerous applications when compared with no prediction techniques or inaccurate prediction techniques. Short-term prediction can be better applied on free-flow traffic in urban areas. This prediction technique reduces traffic congestion. The problem to be solved is whether the traffic can be predicted in flow ahead of time.

Intelligent transportation system (ITS) is indispensable in proposing solutions to these types of problems. However, the abrupt quantity of vehicles in urban transportation forces the necessitate for big data analytics to process and utilize the traffic system in an optimized way [5]. Regression techniques are proposed to model the vehicle arrivals based on real-time data [30, 31]. In this paper, they introduced a new model for controlling the behavior of traffic system. High-end software systems are required for real-time traffic planning which is a challenge. The need for the integration of the proposed form with the other traffic simulation techniques has to be addressed. Intelligent transportation system provides the techniques for traffic prediction [32], which needs precisément traffic flow information. This is the most significant in deploying the intelligent transportation systems. The significance of intelligent vehicles using Lidar sensors was discussed [33]. Traffic data have been enlarging and increasing from the past decade. We are in the era of big data analytics for transportation management and control. To study the features of generic traffic flow, a stacked autoencoder model is used. They employed a traffic prediction model, which considers the spatial and temporal correlations essentially. The prediction layer in the proposed system uses logistic regression. There is a need for the sophisticated deep learning algorithm to effectively route the traffic in the city.
In paper [34], real world big traffic data was used to examine in the construction of traffic simulation. They used data to generate model for arrival of vehicles, turning behavior, and traffic flow. They built a microscopic traffic simulation based upon real world data. Strengths and weakness of various simulation optimization methods are addressed. The key motivation of this paper is to acquire better effectiveness, safety, and price of road systems as this is a crucial social problem that must be solved. A traffic flow prediction algorithm was proposed with LWL (locally weighted learning), based on local models, and this uses local linear/non-linear models to fit the nearest points and then uses their values to compute the values of the query points for prediction. This method uses the historical data values. The precise short-term traffic flow prediction was deployed within freeway networks. They propose the traffic flow structure pattern. This technique was especially suitable in abnormal traffic flow states.

Accurate traffic prediction [35] is proposed as a traffic estimation method that makes use of road network correlation and sparse traffic sampling. This research was examined in the Shanghai City of China. The findings demonstrated that the proposed method uncovers the hidden structure of traffic correlations. In resolving the destination prediction on location-based services, a novel model T-DesP [36] is proposed. An algorithm for short-term traffic flow forecasting technique is proposed [1]. This algorithm uses traffic correlation model and presents coefficients optimization algorithm. To reduce the traffic accidents and to save life, a method for predicting future accidents in advance was required [37]. This will reduce the accidents and saves life on roads. The proposed work used Hadoop framework in processing and analyzing huge traffic data efficiently.

Genetic algorithm has its role in various domains. It plays a vital role in providing a system for traffic prediction and supports in avoiding traffic congestion. A genetic algorithm is necessary to determine the global minimum in the search area. This is a heuristic method. John Holland was the first to develop mathematical form of GAs [38]. GA is capable of resolving problems by directing the search using “the string” fitness. This is the most important advantage of GAs when comparing with other search methods. This does not necessitate any specific knowledge of the search space. It operates on population and requires only a specific measure of flow. This compares an entity to the other entity. In predicting the traffic flow, a deep belief network-based model is proposed [39]. This model employs genetic algorithm to find the optimal hyperparameters. For short-term traffic flow prediction, an advanced time delay neural network (TDNN) model based on a genetic algorithm (GA) is proposed. This model shows that the proposed model is greater to well-known neural work models. [40] A multilayered structural optimization strategy based on genetic algorithm is used for appropriate depiction of traffic flow data with spatial and temporal characteristics [41]. GACE [42] is a hybrid method proposed with the integration of genetic algorithm (GA) and the cross-entropy (CE). The results proved that the proposed hybrid method is efficient in predicting short-term traffic congestion. For a very short traffic prediction for the interval of 5 minutes, a hybrid lane-based genetic algorithm is proposed [43]. To represent the actual travel patterns of considerable amount of vehicles in a city, an approach based on genetic algorithm was developed. This finds an optimal origin-destination matrix and provides opportunity to plan and analyze the traffic scenario [44]. A novel real-time estimation of vehicle counts using vehicle probe data is proposed and evaluated [45]. Smart grids should be explored throughout improving energy efficiency in smart cities [46]. This is also capable of meeting today’s problems and requirements. A genetic algorithm method has been proposed to find the best OD matrix by analyzing the actual travel patterns of a number of vehicles within the city.

Adaptive genetic algorithm [47] is based on the population size, which helps in deciding mutation probability as well as crossover probability. These values are dependent on the fitness value, based on the population cover. The systems with fairly high fitness function values are found to perform better than that with less fitness value. The probability value decreases when the population is in outer space and increases as the population moves towards the local minima.

Feature representation [48] is very important for creating any models on machine learning. It reveals the usage of any genetic programming technique for the feature space transformation. Fitness function is very important because it helps in determining the feature space. The various functions are compared, and a framework is proposed to automate the process.

The path optimization is targeted by the genetic algorithm [49], which helps in feasible path with less hindrance. The proposed algorithm predicts the traffic flow during the holidays; this work comprises discrete Fourier transform (DFT) with support vector regression (SVR). An urban traffic flow forecasting model is proposed based on genetic algorithm (GA) [50]. The proposed model is built with backpropagation (BP) neural network.

Most of the researchers have used neural networks, support vector machine, and genetic algorithms in predicting traffic during abnormal circumstances. The existing methods have certain limitations, which have to be conquered. In this paper, we propose a fitness function that takes into account various measures such as energy, distance, and safety to aid in the algorithm’s convergence for better results. To address the traffic congestion issues, a smart transportation system is proposed which can handle traffic issues efficiently and avoids traffic congestion. The first section presents the traffic identification and prediction system, and the latter section offers the avoidance scheme. The evaluation shows the effectiveness of the proposed system in terms of energy and time. The major contributions of the paper are (1) providing an efficient traffic identification and prediction system, (2) traffic congestion avoidance system, (3) integrating rerouting and fuel consumption model, and (4) case study of our proposed system with simulation results.
3. Smart Traffic Prediction and Congestion Avoidance System

3.1. Preliminaries. Probability and statistics applications are increasing at a wider rate in providing solutions to solve engineering problems; an intelligent transportation system is an interdisciplinary area, which uses different mathematical models and data analytics to predict the traffic congestion and avoidance. Most of the probability techniques are useful in vehicular traffic. The Poisson distribution is a mathematical model used to determine the randomness of a given set of data and to predict certain phenomena based on basic data. Traffic engineers can apply this distribution technique in analyzing the arrival rates of a vehicle at given point of time. We use Poisson distribution for prediction of arrivals from recurring size. In finding the number of vehicles arrival and modeling the random process at a given time period, Poisson distribution is used conventionally. Because the arrival of vehicles is continually random and their arrival rate is discrete, the Poisson distribution was adopted since it has the properties of a discrete probability distribution which is also independent of time. The vehicle arrival rate is calculated based on Poisson distribution, as Poisson distribution is considered to be an optimal algorithm for finding random arrivals and can also be used to distinguish different states of arrivals. The arrival of vehicles are always random, and their arrival time is discrete; hence, Poisson distribution is chose as it has the property of discrete probability distribution and it is independent of the time; the importance of using the Poisson distribution in the framework is to obtain information about the vehicles’ arrival.

Poisson distribution can be applied under the conditions of “free flow,” which is possible to calculate the probability of 0, 1, 2, 3, ⋯, k vehicles arriving per time interval of t seconds provided the recurring size, R, is known:

\[ t = \text{time interval (seconds)} \]
\[ R = \text{recurring volume} \]
\[ n = \text{number of intervals} \]
\[ n = 3600/t \text{ (per hour)} \]
\[ m = \text{average amount of vehicles per interval} \]

\[ m = \frac{R}{3600/t} = \frac{Rt}{3600} \quad (1) \]

Then the probability, \( P(v) \), that \( v \) vehicles will arrive at some point in any interval is

\[ P(v) = \frac{m^v e^{-m}}{v!} = \frac{1}{v!} \left( \frac{Rt}{3600} \right)^v e^{-\frac{Rt}{3600}} \quad (2) \]

The hourly frequency, \( F_v \), of intervals that include \( v \) a vehicle is

\[ F_v = nP(v) = \left( \frac{3600}{t} \right) \frac{1}{v!} \left( \frac{Rt}{3600} \right)^v e^{-\frac{Rt}{3600}} \quad (3) \]

If the considered period is different from an hour, the 3600 can be substituted by the proper time period in seconds. The variables of interest in the preliminary studies are listed in Table 1.

3.1.1. TPCA System. Transportation systems are proposed to improve transportation services such as secure and safe travel, travel reliability, road safety, informed travel choices, transport productivity, environment protection, and traffic resilience. We propose to predict the traffic congestion based on the arrival time of vehicles; this will help to reduce the traffic congestion before occurrence. This may not solve the problem completely, but it can be one of the efficient methods in improving our Indian traffic system. Along with prediction, vehicles can be rerouted; fuel consumption and green environment are the benefits that can be achieved. Speed advice for drivers before reaching the signal will make them to drive the vehicle based on the available time interval. This provides better chances to avoid pollution, and waiting time in the traffic will be reduced. The overview of the framework is to identify the better identification of the traffic scenario that in turn helps in predicting and avoiding the congestion. Initially it collects the traffic data and finds the vehicles arrival rate by computing recurring size. The size is categorized into low, medium, and heavy. Only when it is heavy, the traffic prediction and congestion avoidance algorithms are applied. This also helps in finding the alternative path for the benefit of travelers. With this, traffic congestion can also be reduced, and thereby fuel and time can also be consumed. The proposed method integrates rerouting and fuel consumption model to achieve this. These are described brief in the next sections.

This will be better in improving the traffic condition in the city, where the prediction can be made with vehicle’s arrival. We evaluate the prediction technique in low recurring volume and high recurring volume. We collect the arrival of the vehicles manually during low and moderate volume of traffic, and the same was evaluated. Testing goodness of fit with a Poisson distribution was performed with \( \chi^2 \) test for its acceptance or rejection. Huge volume of data can be collected and maintained in a cloud-based environment. The proposed framework flow is shown in Figure 1. It represents the workflow involved in the proposed system. Initially the vehicle data are gathered to attain the traffic state condition. If the predicted traffic level is high, then the proposed traffic congestion avoidance system will assist in rerouting and thereby to consume time and fuel.

3.1.2. Gathering Traffic Data. The traffic system in various places follow a structured manner as it deals with lives of human being. The traffic data for processing is obtained through various sensors and by constant monitoring which enables the s-TPCA to apply the parameters for further processing. The information from the sensor is then fed into the traffic system that aids in proper addressing of the traffic condition. The sensors provide information about the arrival time of the vehicles and the frequency in which they arrive as well as the count of the vehicles. These are the primary parameters based on which the process of traffic prediction.

\[ \]
Counters are used in collecting vehicle volumes. Detecting the vehicle getting close to an object, and road tube wave detectors are used, proximity sensors are applied in record vehicles and to detect the vehicle movements; micro-count, and classify; pneumatic road sensors are applied to traffic and avoidance works. Few sensors that are suitable for road traffic are discussed. Piezo sensors are used to collect, count, and classify; pneumatic road sensors are applied to record vehicles and to detect the vehicle movements; microwave detectors are used, proximity sensors are applied in detecting the vehicle getting close to an object, and road tube counters are used in collecting vehicle volumes.

The traffic flow is dynamic in any area and so determining the traffic state is based on the traffic parameters. Therefore, the estimation is done based on the correlation between the parameters and traffic state as follows:

\[ Q = SP(w, \theta, \rho). \]  

(4)

where SP defines the relationship that holds between the traffic flow and traffic parameters. Here the traffic parameters are \( w \), \( \theta \), \( \rho \). Traffic will be mostly dynamic in an area. This means a time-series is created which alters with time \( t \).

\[ T_t = R(T_{t-1}, T_{t-2}, \ldots). \]  

(5)

Here \( T_t \) describes flow parameter \( T \) at time \( t \) with function \( R \) to determine the series of data flow. Further, when the data is judged based on the historical data, then the relation between the two can be depicted as

\[ T_{w,t} = R(T_{w-1,t}, T_{w-2,t}, \ldots), \]  

(6)

where the \( T_{w,t} \) denotes traffic flow parameters that is recorded on a particular day of the week at time \( t \). \( R \) defines the relationship between the data signifying the day of the week as holiday or workday with respect to time.

The real-time data of a particular location is fetched using sensors, and the data is continuously stored and updated in the distributed system. Therefore, when a vehicle moves, its movement pattern is recorded in SP with the traffic parameters, and it changes with time \( T_t \). The fetched real data is then processed with the proposed traffic prediction algorithm and based on the historical traffic data of the particular location decision algorithm which helps in avoiding congestion and allows easy movement of vehicles.

There are hundreds of parameters on which the traffic system depends on. The major parameters which contributed to the traffic management include the velocity of the vehicle, arriving time of the vehicle, average number of vehicles, travel time of the vehicle, occupancy, and length of the vehicle. There are various parameters in determining the traffic flow in a particular region. The factors include the velocity, arriving time of the vehicles, average distance, average speed, average length, composition speed, composition length, and kamikaze alarm. Of these parameters, the following parameters play a major role in the proposed algorithm. This is illustrated in Table 2.

3.2. Identification of Traffic State. The traffic scenario forces to calculate the membership function and determine the traffic congestion and the method of avoidance by proposing a new technique TPCA system. This technique uses arrival time of the vehicle for the further proposition and also calculates using Poisson distribution. The primary variables used in the proposed algorithm are illustrated in Table 3.

The graph below (Figure 2) depicts the effect on application of genetic mutation, which results in making an effort to identify the traffic state of the location based on the arrival time and judge the cumulative density function accordingly.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t )</td>
<td>Time interval</td>
</tr>
<tr>
<td>( R )</td>
<td>Recurring volume</td>
</tr>
<tr>
<td>( n )</td>
<td>Number of intervals</td>
</tr>
<tr>
<td>( m )</td>
<td>Average amount of vehicles per interval</td>
</tr>
<tr>
<td>SP</td>
<td>Relationship connecting the traffic flow and traffic parameters</td>
</tr>
<tr>
<td>( \theta )</td>
<td>Speed</td>
</tr>
<tr>
<td>( \rho )</td>
<td>Density</td>
</tr>
<tr>
<td>( T_t )</td>
<td>Traffic flow</td>
</tr>
<tr>
<td>( T_{w,t} )</td>
<td>Traffic flow parameters that is recorded on a particular day of the week at time ( t )</td>
</tr>
<tr>
<td>( R )</td>
<td>Relationship between the data signifying the day of the week as holiday or workday with respect to time</td>
</tr>
</tbody>
</table>

**Table 1: List of variables.**

**Figure 1: s-TPCA framework.**
diction, the expected congestion could be avoided by
routic technique is used in the prediction of tra
dictor with the highest value is selected. Thus, big data
tics, and predictions are made as
ji belongs to the partition
0 and 1.0 that specianomaly and scalability of the new technique. Here the
the proposed technique with the existing ones to ensure sus-
s before and after applying mutation function.
This figure shows the variation of the movement of the vehi-
ces before and after applying mutation function.
Further, this data is used to compare the performance of
the proposed technique with the existing ones to ensure sus-
tainability and scalability of the new technique. Here the
algorithm specifies the threshold value \( f \) which is between
0 and 1.0 that specifies the normal motion of vehicles in the
road, whereas the values up to 0.40 specifies the moder-
ate traffic condition in the road. The values higher than 0.40
is a sign of warning which stress on the fact of heavy traffic if
the threshold moves beyond 0.40.

3.3. Traffic Prediction and Congestion Avoidance. Traffic can
be reduced by diverting the vehicles through another road.
This will be better in improving the traffic condition in the
city, where the prediction can be made with vehicle’s arrival.
We evaluate the prediction technique in high recurring vol-
ume. Huge volume of data can be collected and maintained in
a cloud-based environment.

(2) gives the prediction of the traffic in subspace \( D^j \) that
belongs to the partition \( f^j \). The algorithm activates the pre-
dictors, and predictions are made as \( t(x) \) for all \( t \). The pre-
dictor with the highest value is selected. Thus, big data
technique is used in the prediction of traffic using the traject-
ories of the various vehicles. Hence, based on the traffic pre-
diction, the expected congestion could be avoided by
rerouting the vehicles through the location, which has the
minimum traffic.

3.4. Rerouting and Fuel Consumption Model. Traffic man-
agement and driving pattern plays a major role in designing
ecofriendly fuel consumption model. The fuel consumption
ouly estimates the effective traffic structure as well as the
behavior of driving. Freight mainly causes air pollution and so has to be considered for effective model design.

The vehicle’s emission calculation is based on the speed
at which the vehicle moves and also the acceleration that is
applied to the vehicle which is given as

\[ X = a + 0.014v, \]

where \( v \) is in km/hr and \( a \) is in m/s².

Table 4 provides the design of the fuel consumption
model in various schemes. The proposed scheme is both
simulations based as well as analytical. It is similar to the
\( \Lambda_m \) scheme, yet the advanced scheme provides a way for
the simulation as well as applies the mathematical concept
to determine the fuel consumption. Thus, the proposed
model made energy more efficient than the existing systems.
The proposed TPCA model involves minimization of the
traffic by rerouting the traffic through regions of smaller
level traffic. Heavier vehicles move in the city highways.
Other vehicles are routed in paths with minimal traffic.

4. Case Study

We apply our proposed s-TPCA system in one of the metropo-
lar city in India. Indian traffic system is in need of smart
intelligent traffic management and congestion avoidance
system across various urban areas to control the traffic sce-
narios. Road traffic congestion is a major issue that takes
the breath of many people. Road traffic congestion is the
major constraint for many of the traffic accidents. A survey
on the road traffic accident deaths are shown in Figure 3
(Source: National Crime Records Bureau). This figure con-
veys the importance of an enhanced road traffic monitoring
system to improve road traffic congestions, and further it
reduces the chances for accidents. With this, accident death
rate can be reduced.

Most of the urban areas in India are affected a lot with
traffic scenario, as there is a huge increase in the number
of vehicles. When the vehicles are hugely populated, speed
and time are reduced, and it pollutes the environment. The
economic impacts of road traffic congestion are shown in
Figure 4 (Source: http://www.newagebd.net/print/article/ 18145). The impacts of road traffic congestion on the
national economy must be known to deal with the situation
effectively. An effective traffic management system is
required to ensure a better and safe transportation system
and hence reduce the impacts of traffic congestion.

Table 5 (Source: https://blog.olacabs.com) provides the
average speed of vehicles in the Indian traffic among the
top congested metropolitan cities. Overall, average speed is
22.7 km/hr.
Every big city suffers from the same predicament. Be it New York, London, or Chennai, traffic jams can leave commuters on the verge of a mental breakdown. In summer, it is unbearable to mutely watch the red light turn green as the mercury rises steadily. The signals are placed randomly so locating them is a challenge—one appears on the right at an intersection, another is situated above your head elsewhere. If that does not confuse you, then the timing of the red lights will. Normally automatic, these turn manual with a traffic police officer trying to manage the flow during peak hours. There have been various solutions and suggestions put forth, but what seems to be a novel solution is “going smart.”

New Delhi has already adopted the smarter way where signals will soon be automatic. Recently, a Chennai-based NGO has developed a similar system. It will be intelligent enough to automatically adjust timings depending upon the volume of vehicles. When the time for traffic horror stories comes around, one can almost hear the collective soul of Mumbai and Bengaluru roll up their sleeves to defend just what makes their city the absolute worst. Delhi, whose traffic is admittedly pretty insufferable too, hardly ever even gets a shot at the top prize. Chennai, as it turns out, is the worst Indian city when it comes to traffic. In this paper, we simulate our proposed smart traffic system in one of the congested traffic route in Chennai.

Chennai is all set to get an “intelligent transportation system” covering at least 150 junctions with financial aid from Japan International Cooperation Agency (JICA). The smart transport system aims at offering commuters comfortable, reliable, quick, affordable, and safe access. It is unable
to rationalize the signal timings based on traffic volume at the junction level; the Chennai City Traffic Police (CCTP) is contemplating a grid of traffic signals that can communicate with each other and ensure the smoothest possible flow of traffic within a particular zone.

Table 6 shows the most important black spots in Chennai where traffic congestion persists. The proposed s-TPCA system tries to provide solution for traffic congestion to these vulnerable areas. We consider one of the block spotted area, which has more traffic congestion in the peak hours. We had taken the traffic route from Saidapet to George Town. Most of the vehicles tend towards Saidapet as this is the main center of the city. This route passes via Nungambakkam and T. Nagar; this is one of the busiest routes in Chennai. During weekends and holidays, these places are occupied with more number of vehicles as people

<table>
<thead>
<tr>
<th>Technique</th>
<th>Fuel consumption model</th>
<th>Simulation based</th>
<th>Analytical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposed s-TPCA</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Am [32]</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>AQ [32]</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>AØ [32]</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Figure 3: Road accident deaths by mode of transport.
The probability for Poisson distribution is found to be 0.8 by substituting the values in the above formula. Based on the arrival time interval, the membership function is calculated to be 0.6. Further applying this, the fitness value \( f \) is calculated to be 0.7. Further, after applying the proposed s-TPCA algorithm, the genetic function \( G \) takes the value of 0.6, and the fitness value \( f' \) is found to be 0.834. Since \( f' \) is greater than \( f \), then new updated value can be used to identify the traffic state.

The proposed TPCA system is compared to the conventional system Am as referred in [51]. The average arrival time is an important parameter, which is taken as subject of comparison between the two models. The proposed system shows better value of cumulative distribution function than the existing system of traffic prediction.

Then in the traffic prediction system, the threshold value for determining the traffic congestion ranges from 0 to 1. In this route 1, the traffic is in peak during the interval 5PM-7PM on Sundays. The observed threshold value during this interval in route 1 is 0.85. This threshold is greater than 0.40, which is the moderate value for traffic that does not lead to congestion. Thus, traffic through route 1 is found to be high during this period. In a similar manner, traffic is predicted for the other routes, namely, route 2 and route 3. Then the excess traffic in route 1 is redirected through any other route for which the threshold value is nearer to 0.40.

The fuel consumption is also comparable, and the structure of the proposed system based on the arrival time proves to be efficient. The proposed TPCA system has the ability to predict traffic congestion based on the threshold value and provides alternative routes.

**Table 5: Average speed of vehicles in the Indian traffic system.**

<table>
<thead>
<tr>
<th>S.no.</th>
<th>Average speed (09:00 AM to 12:00 PM) KM/HR</th>
<th>Place</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>27.1</td>
<td>Hyderabad</td>
</tr>
<tr>
<td>2.</td>
<td>26.5</td>
<td>Delhi-NCR</td>
</tr>
<tr>
<td>3.</td>
<td>21.9</td>
<td>Pune</td>
</tr>
<tr>
<td>4.</td>
<td>21.6</td>
<td>Mumbai</td>
</tr>
<tr>
<td>5.</td>
<td>20.4</td>
<td>Bengaluru</td>
</tr>
<tr>
<td>6.</td>
<td>20.2</td>
<td>Kolkata</td>
</tr>
<tr>
<td>7.</td>
<td>19.6</td>
<td>Chennai</td>
</tr>
</tbody>
</table>

**Table 6: Top most black spot areas in Chennai.**

<table>
<thead>
<tr>
<th>S.no.</th>
<th>Place</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>TIDEL Park signal</td>
</tr>
<tr>
<td>2.</td>
<td>Guindy to Saidapet stretch</td>
</tr>
<tr>
<td>3.</td>
<td>Adyar</td>
</tr>
<tr>
<td>4.</td>
<td>Vadapalani Signal</td>
</tr>
<tr>
<td>5.</td>
<td>Velachery</td>
</tr>
<tr>
<td>6.</td>
<td>Usman Road</td>
</tr>
<tr>
<td>7.</td>
<td>Teynampet</td>
</tr>
<tr>
<td>8.</td>
<td>Marina Beach Road</td>
</tr>
<tr>
<td>9.</td>
<td>Jawaharlal Nehru Road</td>
</tr>
<tr>
<td>10.</td>
<td>Meenambakkam</td>
</tr>
</tbody>
</table>

The vehicles can be alerted with the current traffic scenario, and the alternate path can be chosen to be free from traffic and also to save time and fuel. The dataset collection for analyzing the traffic is done manually for the first two weeks of August considering the historical background. Based on the proposed s-TPCA algorithm, let us consider the average number of vehicles \( (m) \) in route one from August 1 to August 15 to be 5367895. The vehicle distribution includes all two wheelers and four wheelers. The average speed \( (v) \) of the vehicle is calculated to be 40 km/hr. The estimated travel time in route 1 is found to be 10 minutes. The arriving intervals for the vehicles is found to be 0.50 seconds. The time of arrival is judged based on the time period considered. Let us consider the traffic on Sundays between 5PM and 7PM. The arrival time of vehicles are distributed in the interval of 0.10 seconds from 5 to 7PM. The values for the Poisson distributed are calculated with the suggested values in the following formula.

\[
P(v) = \frac{m^v e^{-m}}{v!} = \frac{1}{v!} \left( \frac{Rt}{3600} \right)^v e^{-\frac{Rt}{3600}}. \tag{8}
\]

The vehicles can also be controlled and green environment can be protected. We have shown the alternate paths in Figure 5 and provided the information in Table 7. The figure shows the alternate path to reach the destination without getting stuck in traffic. With this alternate path, the traveler can reduce time and fuel.
avoid congestion and also enable smooth transportation. Figure 6 illustrates the comparison of the proposed technique in terms of average time interval. The proposed system shows better value of cumulative distribution function (cdf) than the existing system of traffic prediction. Figure 7 gives the comparison based on the fuel consumption. The proposed s-TPCA performs better than the other approaches in terms of fuel time and fuel, which are considered as a major constraint in traffic management system.

5. Conclusion and Future Scope

Traffic congestion is a significant problem in Indian cities. The characteristics of Indian roads and traffic make the problem interesting to solve. We have presented a prediction and congestion avoidance technique based on genetic model traffic prediction. We first obtain sample data on hourly volume in low and moderate recurring volume. We then establish a probability model and genetic prediction model for predicting traffic congestion and avoidance. The results represent the experimental relation between observed frequency and predicted frequency. This prediction technique with fuel consumption model helps to avoid congestion and also reduces pollution and protects green environment and safe
travel. The proposed solution can be applied in any of the metropolitan cities of India. The results showed that the prediction method based on mathematical genetic model is an effective approach for traffic flow prediction and congestion avoidance. For future work, it would be interesting to apply these algorithms on different public open traffic datasets to examine their effectiveness. Furthermore, the prediction technique can be extended with Traffic Light Deviation techniques. Extending it to predictors that are more powerful may make further performance improvement.

Data Availability

All the data is available in the paper.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References


