Iot Enabled Intelligent Traffic Congestion Handling System Empowered By Machine Learning

Farhad Hassan, Amir Ijaz, Mubashir Ali, Zeshan Afzal, Farrukh Arslan

Abstract: Internet of things is evolving technology which driving the world towards automation and smart systems. It is major factor of industry 4.0, smart cities and smart societies. Currently, the traffic is increasing exponentially in big cities; control and management of traffic in smart cities is well-known issue. Efficient congestion control and traffic management save many valuable resources. Various sensors are integrated in automated and smart systems to sense, collect and transfer data. Machine learning is another emerging technology that improves the intelligence and capabilities of smart systems. In this paper, we proposed an IoT-ITCHS-ML model to sense, analyze and control the traffic congestion in smart societies. The proposed system sense and notify the congested areas. The proposed systems performed significantly well in comparison with previous approaches and obtain 99.2% accuracy with only 1.2% missrate in training phase; 98.5% accuracy in validation phase. This research prosper the smart systems, IoT innovations and impact of machine learning in smart societies.

Index Terms: Internet of Things, Machine Learning, Traffic Management, Congestion Control, Smart Cities, Mathematical Modeling.

1 INTRODUCTION

Traffic control and management is raising research issue in big cities[1]. Everyday, the size of cities and towns is expanding with population; it will directly increase the number of automobiles which cause heavy traffic. The increase in traffic raises many issues like wastage of time in traffic jams, pollution in environment and wastage of other resources. To handle the traffic jams, traffic signaling systems are implemented in congested cities and points[2]. But the equal and constant time division of traffic signals is another issue. Traffic on all sides of signals are not equal due to the dynamic arrival nature which again cause the wastage of resources.As number of roads and vehicles are increased; the number of vehicles can create issues to handle the proper traffic system. Normally, each road cross has a signal and each signal have allotted time to perform their operation, this process work in sequence. This conventional structure of handling traffic has a problem which cannot notice the frequency of vehicles on each road, and if a road is empty then the signal of that road squander the time. This conventional structure of vehicle cannot handle the bulk traffic and cannot stop the traffic from blockage. This structure cannot work according to the frequency of traffic on each road. There is no method for passengers to know about road situation except google maps and present framework will jam the self-operate vehicle.This conventional structure do not give the real time update of road environment to the passengers and automatic traffic handing sense. The management of traffic with the help of traffic police or by utilizing predefined timer was an effective system in the past but with an increase in number vehicles, this system has failed to manage traffic all over the world. The biggest issue is that we cannot solve this traffic problem by existing infrastructure. And we cannot also expand our existing infrastructure due to many reasons[3]. So the easy way to solve such an issue there should be a better and efficient adaptive system for traffic managementSo, there is need of intelligent congestion control systems which reacts according to traffic and situation. The rest of the article is divided as; the section 2 review the literature to highlight the recent contribution in congestion control and traffic management. Section 3 proposes the IoT-ITCHS-ML approach while section 4 analyze our proposed approach. Finally section 5 concludes the research and shows the future directions.

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2 LITERATURE REVIEW

Author in [4]used Raspberry Pi and different ultrasonic sensors to detect the frequency of vehicle on roads. Raspberry Pi and ultrasonic electric sensors are connected with website to transfer information of traffic jam and perform their function according to that information. In this paper, authors have worked on traffic management with help of IoT [5].They have used a hybrid approach to optimize the flow of traffic in the different lanes. It also develops a contact through the main server to the rescue department for emergency situation. The data they gather from this system will also be helpful for the future planning of any other new road.It consist of three layers. In the first layer, they collect data from different devices such as ultrasonic sensors, cameras, smoke sensors, RIFD, and flame sensors. For reducing noisethey use the Blob algorithm. Then the local server measures the size of traffic and sent it to a particular microcontroller. In the second layer, according to the size of traffic present on the road duration of the signal light is divided. If an emergency vehicle is found then the signal of a particular road remains green before emergency vehicles get passes from a particular intersection. In the last layer, using the Regression Tree algorithm system will calculate rush intervals on the local server and also updates data on a daily basis in the main server. This system is also capable of dealing with an emergency situation. When this system detects fire or smoke it sent an emergency message to the relevant department for rescue work. In this paper, authors have worked on the improvement of monitoring system for traffic using IoT [6].This work installed ultrasonic sensors on each lane on road. Various sensors are classified as high, medium, and low. The data will be collected from the sensor and sent to a main system. From that data collected from the sensor, the measured the volume of traffic. Then this is used to measure time for the signal about that relevant road.Then both of the new and existing systems were compared and it has been observed that there was a huge decrease in waiting time. In this paper, authors have worked on a system in which video processing applied for vehicle counts [7]. This system improves the efficiency of vehicle count and classification.This system work in this way that the first they divide the video into frames and then other function performs the background subtraction. Then in the next step, they perform segmentation and using SIFT features are extracted from an image. Then the features are matched to classify vehicles. And then finally the number of vehicles on the road counted to manage the traffic. In this research paper author has discussed IoT based an adaptive traffic management system as a part of an intelligent transportation system [8]. This research paper is related to how we can manage the traffic on the road with the help of the IoT concept. The management of traffic is consider as integral part of an intelligent transportation system. An intelligent transportation system is the latest application that provides services related to traffic management. This system will work in this way that they place ultrasonic sensors on the road. Ultrasonic sensors will count the vehicles moving on the road within its range. This record of moving cars will be passed to Arduino. Then, this Arduino will utilize that data to update traffic lights[9] and also use that data to set the time period of the traffic light. In this research, authors have worked on the data mining application in management of traffic and they are used the case study of the city of Isfahan [10]. The aim of paper is to work on the traffic managing system. For that purpose, this paper tries to develop timing plans for a traffic signal. The time of day was identified by using the cluster technique. Historical day helped to analyze the time of day. In this paper, different data mining techniques were utilized such as a collection of data, data cleaning, data classification, and data transformation. First, they collect the data for that purpose they have used different sensors that were installed at the entrance of different intersection of road in the city of Isfahan. These sensors collect data and maintained different tables of this data for 5 traffic intersections in the city. After that, the data cleaning technique was used because when there was no vehicle on the intersection the sensors becomes inactive. So, at that time reading was not recorded which resulted in zero as reading in the database. The recorded data was classified separately for weekdays and weekends because the difference in traffic was large. In the next step, the data transformation technique was used. This technique mostly consist of queries with help them different chart and graphs were developed. Then times of different days were noted and based on match density cluster ware created. In this research, authors have worked on Controlling Traffic Corridor with help of Machine Learning [11]. The target of the research is to work on a system with having ability of self-learning. This model will control the repetitive traffic patterns. The author has mainly focused on the use of algorithms of machine learning and artificial intelligence (AI) [12]. For this purpose, reinforcement learning and Q learning is used. Reinforcement learning deals with how can a factor or agent sense and act action in a different environment. And how it learns to choose the best action according to the environment to achieve its long-term goals. In this research paper authors have worked on an adaptive system for management of traffic in smart cities through which they can control traffic during any emergency [13]. This system mainly used IoT and machine learning for this system. This system also uses different types of cameras and controllers. Network is also an integral part of our system. Traffic controllers played an important role. It will send data from CCTV to the controller of the traffic management system. If an emergency arises it will be sent messages to emergency vehicles and emergency service authority. After getting an emergency message then they will take action according to the situation. In this paper, authors have worked on an intelligent based system for traffic management using IoT [14]. They have worked on a way to reduce traffic congestion.

3 PROPOSED MODEL IoT-ITCHS-ML

Figure 1 shows the proposed model of IoT based intelligent traffic congestion handling system empowered by machine learning. The supervised machine learning approach named support vector machine is implemented within proposed system to find the congestion areas on road. Various statistical measures are taken into consideration for analyzing the congested areas such as accuracy and missrate in training as well as in validation. Further, miss rate accuracy, value of false negative, value of false positive, negative prediction rate, positive prediction rate, sensitivity, specificity etc. By considering these parameters, the congested areas are identified more accurately with comparison to literature work. The model illustrates the complete working of proposed approach. The first section is sensory section empowered by IoT which sense the road conditions and transfer the raw data over cload. The second section performs some preprocessing work on raw data such as handling missing values and forward the more justified data to third section named prediction section. The prediction section is empowered by supervised machine learning which built the model using support vector machine for prediction of results. The prediction sections as well asses the performance of predicted results by finding the congested areas and shows the corresponding suggestions.

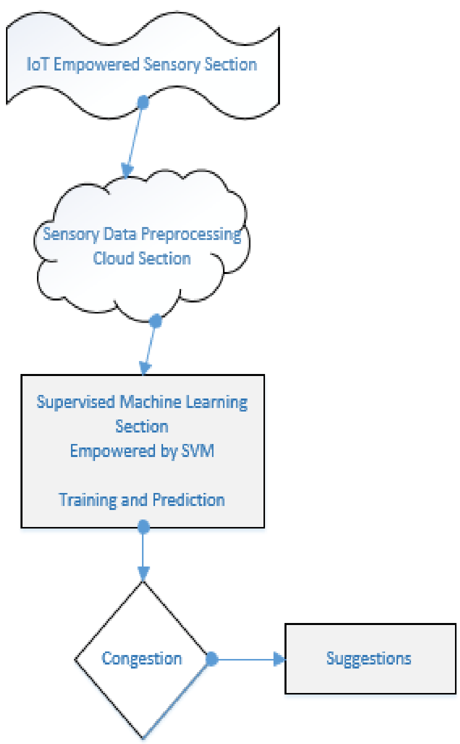

***Figure. 1**. Proposed IoT-ITCHS-ML*

The system takes various factors as input from sensory section such as

- Time
- Speed of traffic
- Traffic flow
- Speed of wind
- Humidity level in environment
- Temperature of air

and generates output in the form of congestion or clearance of road.
Equation 1 shows the justified line of equation l refer to slope and m refer to intersect of line.

$$lx_1 - x_2 + m = 0 \qquad (1)$$

suppose p=($x_1 - x_2$) and q=(l-1) then the equation of line can be

$$p.q + b = 0 \qquad (2)$$

equation 2 is represents the two dimensional vector and known as equation of hyper lane. We can extent it for n number of dimensions. So equation 2 also written as,

$$p.q = \|p\|\|q\| \cos\theta$$
$$= \frac{p1q1 + p2q2}{\|p\|\|q\|}$$
$$p.q = \sum_{i=1}^{n} pi\, qi \qquad (3)$$

Equation 3 shows the dot product of n dimensional vectors. Assume f is functional margin of the corresponding dataset D. If the value of f is greater thenzero then the dataset will be classified accurately and if the value of f is less then zero then the data will not classified accurately. The value of f for training dataset will be,

$$ft = yt(p.q + m)$$

and the functional margin will be

$$F = \min_{i=1......b} ft$$

Now our ultimate aim is to calculate the accurate hyperplance which gives us the value of congestion found or not found. P and m gives us the values of hyperplance and we calculate both in optimized forms. For this purpose, we put the values of sorted lagrangian function as

$$p(\alpha + m)^1 = \sum_{i=1}^{b} \alpha i - \frac{1}{2} \sum_{i=1}^{b} 1 \sum_{j=1}^{b} \alpha i\, \alpha j\, yi\, yj\, xi\, xj \quad (4)$$

Now we extend the lagrangian function with KKT method to obtain equal values and resolve the inequalities.

$$yi\big((pi.q* + m) - 1\big) = 0 \quad (a1)$$

The q* refers to the optimal point and above equation refers to support vectors and closest point to the hyperplance. So,

$$p = \sum_{i=1}^{b} \alpha i\, pi\, qi \qquad (5)$$

Now for computing the value of m, we consider the equation a1 and multiply it with y on both sides and put

$$y_i^2 = 1$$

Then

$$\big((pi.q* + m) - yi\big) = 0 \qquad (6)$$
$$m = yi\, pi.q* \qquad (7)$$

Now we generalize the values of m for hyperplance.

$$m = \frac{1}{n} \sum_{i=1}^{n} (yi - p.q) \qquad (8)$$

Finally we draw our hypothesis function for predictions.

$$h(pi) = \begin{bmatrix} +1 \text{ if } p.q & + & b > 0 \\ \vdots & \ddots & \vdots \\ -1 \text{ if } p.q & + & b < 0 \end{bmatrix} \qquad (9)$$

The equation 9 shows the hypothesis function which returns the hyperplance values as +1 and -1. If the value will be +1 then it refers to congestion found and vice versa in case of the -1.

4 RESULTS AND DISCUSSION

The MATLAB is used for simulation and predictions of congested areas over road. Table 1 illustrates the of training and table 2 the validation for miss rate and accuracy. The support vector machine algorithm of supervised machine learning is implied to a dataset which contains approximately 2000 records. The ratio between training and validation is 75% and 25% of dataset. Various statisitica measures are taken into consideration for comparative analysis and performance measurement which are discussed earlier.

***Table. 1**. Training of IoT-ITCHS-ML*

75% of sample data in training		Total 1500 samples	
Expected Output over following Input			
$X_{0,\ Congested}$= 1050Positive		$X_{1,\ non\text{-}congested}$ = 450Negative	
Resultant Output ($O_{0,congested}$, $O_{1,\ non\text{-}congested}$)			
O_0, Positive	1046	O_1, Positive	31
O_0, Negative	04	O_1, Negative	419

Table. 1 shows the training details of proposed model IoT-ITCHS-ML. The SVM is trained for the prediction of congested areas over the dataset of 2000 records. 75% dataset is used for training purpose which contains nearly 1500 records. X shows the expted output and O shows the resultant outputs of training.

***Table. 2**. Validation of IoT-ITCHS-ML*

25% of sample data in training		Total 500 samples	
Expected Output over following Input			
$X_{0,\ Congested}$ = 271Positive		$X_{1,\ non\text{-}congested}$ = 229Negative	
Resultant Output ($O_{0\ congested}$, $O_{1,\ non\text{-}congested}$)			
O_0, Positive	268	O_1, Positive	05
O_0, Negative	03	O_1, Negative	224

Table. 2 shows the validation results of our trained model IoT-ITCHS-ML. For given 271 records of congested areas, it predicts 268 positive and 3 negative while 229 records of non-congested records, it predicts 224 truly and 5 not-true as positive of negative records.
For the further performance measurement of each statistical parameters, they are taken from following formulas,

$$\text{Accuracy} = \frac{\left[\frac{O0}{X0}+\frac{O1}{X1}\right]}{X0+X1} \quad (10)$$

Equation 10 shows the equation for calculating the accuracy.

$$\text{Missrate} = \frac{\left[\frac{O1}{X0}+\frac{O0}{X1}\right]}{X0+X1} \quad (11)$$

Equation 11 shows the equation for calculating the missrate.

$$\text{Positive Prediction} = \frac{\left[\frac{O0}{X0}\right]}{\left[\frac{O0}{X0}+\frac{O1}{X1}\right]} \quad (12)$$

Equation 12 shows the equation for calculating the positive prediction.

$$\text{Nagative Prediction} = \frac{\left[\frac{O1}{X1}\right]}{\left[\frac{O1}{X1}+\frac{O0}{X1}\right]} \quad (13)$$

Equation 13 shows the equation for calculating the nagative prediction.

$$\text{Sensitivity} = Xc\ (Xc + Fnc) \quad (14)$$

Equation 14 shows the equation for calculating the sensitivitiy.

$$\text{Specificity} = Xnc\ (Xnc + Fc) \quad (15)$$

Equation 15 shows the equation for calculating the specificity.

$$\text{False Positive} = 1 - \text{Specifity} \quad (16)$$

Equation 16 shows the equation for calculating the ratio of false positive.

$$\text{False Nagative} = 1 - \text{Sensitivity} \quad (17)$$

Equation 17 shows the equation for calculating the ratio of false negative.

***Table. 3**. Performance of IoT-ITCHS-ML in Training*

Accuracy	99.2%
Missrate	1.2%
Positive Prediction	99.9%
Negative Prediction	97.8%
Sensitivity	99.8%
Specificity	98.6%
False Positive	0.3%
False Negative	1.2%

Table. 3 shows the performance of proposed IoT-ITCHS-ML on different statistical measures in training phase. The proposed system returns the accuracy of 99.2%, missrate of 1.2%, positive prediction value 99.9% which shows the max positive prediction. The negative prediction value is 97.8% which means there is low chances of negative prediction. Sensitivity provides highest values of 99.8% with very low false positive and false negative rates.

***Table. 4**. Performance of IoT-ITCHS-ML in Validation*

Accuracy	98.5%
Missrate	1.9%
Positive Prediction	99.1%
Negative Prediction	98.2%
Sensitivity	98.9%
Specificity	98.1%
False Positive	1.1%
False Negative	1.8%

Table 4 shows the performance of proposed model in validation phase over different statistical measure which discussed earlier.

***Table. 5**. Comparitive Analysis of Results with Previous Techniques of Literature*

Sr.No.	Reference	Training		Validation	
		Accuracy %	Missrate %	Accuracy %	Missrate %
1.	[15]	91.2	8.7	90.6	9.4
2.	[16] FM	96.2	3.8	95.8	4.1
3.	[16] TSM	98.15	1.8	97.5	2.4
4.	[17]	98.7	1.3	97.9	2.1
5.	Proposed	99.2	1.2	98.5	1.9

Table 5 shows the comparative analysis of results of proposed approach with other techniques which are presented in literature. The FM refers to fitting model and TSM refers to time series model.We have compared the results of training and validation phases with accuracy and missrate factors. The proposed approach performed well in terms of accuracy and missrate for both training and validation as shown in table 5. The IoT-ITCHS-ML returns accuracy of 99.2% with least missrate of 1.2% in training phase. Further, in validation it returns 98.5% accuracy with minimum missrate of 1.9%. The performance of proposed model is significantly improved in terms of accuracy and missrate.

5 CONCLUSION

Traffic is rising issue in big cities as well as in smart cities. Improper control and managemet of traffic cause many problems. Many valuable resources are extra consumed which also effects on environment and economy. We have proposed an internet of things empowered intelligent traffic control handling system which is supported by supervised machine learning. The system named as IoT-ITCHS-ML which predicts the traffic congestion by taking input from various sensors. Support vector machine algorithm is implemented for prediction. Our approach significantly performed well in comparative analysis with previous approaches presented in literature. The proposed system returned 99..2% accuracy in training and 98.5% accuracy in validation. Time delays are main limitation of this research which may occur due to poor collection of sensors or slow connectivity of network which may be improved in future research.

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