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A Novel Framework for Traffic Flow Prediction with Deep Learning Algorithms

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Abstract: - **Traffic flow prediction is the process of predicting future traffic conditions in short-term or long term basis, based on real time and the past traffic data. It is an important component of an Intelligent Transportation System (ITS) in smart city development. Apart from traffic data from sensors, Incidents detection, Lane closure and Weather data also some of the main reasons to cause the congestion. Combine factors and provide an efficient prediction of congestion. It provides innovative and smarter services to the transport users. Deep learning is a promising technology used to predict the traffic congestion with high accuracy. Deep belief network, Recurrent neural network, Convolutional neural network are some of the well known existing algorithms used in transportation analysis. In this paper a novel framework is proposed for intelligent transport systems which can solve so many issues such as pollution, accidents, and unwanted delays.**

Keywords: **Imputation Methods, Traffic flow analytics, Congestion, Deep learning algorithms.**

I. INTRODUCTION

A smart city is a term of designing an urban development in an intellectual way of traffic control, safety systems, security, health and all other aspects of technology. Free flow of road traffic is important for faster connectivity and smart transportation systems [19]. Traffic flow is defined as the number of vehicles passing through a specific point on a road segment in particular time, expressed in terms of vehicles per unit of time [7]. With the fast growth of urbanization and traffic demand, transportation problems are becoming important issue every part of the world. Infrastructure growth is limited because of the population, space constraints, lack of planning and technology. In smart city development of traffic data collected from various sensor technologies, loop detectors, radars, cameras, mobile Global Positioning System, crowd sourcing, social media etc. The long time usage of these physical sensor technologies produces large volume of historical traffic data and data becomes transportation data.

Accurate and real-time traffic flow prediction provides information and guidance for road users to choose their travel decisions and to reduce costs [27]. It also helps authorities with innovative traffic management techniques to alleviate congestion. With the availability of high resolution traffic data from intelligent transportation systems, traffic flow prediction has been continuously addressed using data driven approaches. In this regard, traffic flow prediction is a time series big data problem to estimate the flow count at a future time based on the data collected over previous periods from one or more observation locations [17]. One of the fundamental needs of smart cities is smart mobility. With more than a billion cars on roads of today that is expected to double to around 2.5 billion by 2050 [1]. During travel time drivers faces not only the traffic, several bad weather conditions, e.g., rain, storm and unforeseen events, e.g., accidents, concerts, and road closures. These factors impact significantly the travel time which consequently affect the overall traffic flow of transportation networks. A number of tasks are involved for predicting the traffic congestion such as imputation, dimensionality and prediction. For every process deep learning is a unique approach for higher accuracy in each step. The shallow prediction model for traffic flow prediction provides less accuracy. Generally there are two ways of traffic flow prediction, such as Short Term and Long Term Traffic Flow Prediction [26]. Long time prediction doesn't give accuracy of prediction, because it can predict after one hour. Short term prediction takes 5 to 15 min with higher accuracy. But it is a challenging task because of the uncertainty and nonlinearity [26].

Many researchers concentrate on short-term traffic flow prediction because of it is an important and need of real world operation. As a result, a large number of relevant methods have been developed by Vedat Topuz (2010), Xiaoguang Niu (2015), Qiang Shang (2016), Xiaolei Ma (2017). In general, these methods are categorized into three types [16]: traffic model-based methods, statistical methods and machine learning-based methods. Traffic model based methods uses macroscopic model and

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microscopic to predict the evolving mechanism of traffic flow. Macroscopic model based on fluid dynamics. Microscopic model focuses on behavior of single vehicle and the interactions between vehicles, such as lane changing model [16]. The statistical methods are implemented by using the historical data to obtain optimal results. They are linear regression model and Auto Regressive Integrated Moving Average (ARIMA) model. Machine learning-based methods can effectively impound the nonlinearity relationship between the input and output existed in the data by using intelligent algorithms such as Artificial Neural Network (ANN) and Support Vector Machine (SVM). Deep learning is a type of machine learning with unsupervised learning [10].

The rest of this paper is organized as follows. Section II reviews the related studies on short-term traffic flow prediction. Section III presents a Novel framework for efficient traffic flow prediction and discuss in detail about each part of the work for efficient traffic flow prediction. Section IV discusses the research challenges and issues. Conclusions are described in Section V.

II. RELATED WORK

Traffic flow prediction in smart city provides the information about the traffic congestion well in advance and it will help the users to make better travel decisions, improve traffic operation efficiency and reduce pollution and overcome traffic congestion. Smart city roads would be fully equipped with sensors for analyzing the traffic flow. Accurate traffic flow information is needed for various types of road users like, commuters, private vehicle travelers and public transportation system [19]. Short term prediction based on sensor data developed in different approaches from last decades. They consider freeways, arterial roads based on different time. Methods ranging from parametric solutions like autoregressive statistics for time series such as ARIMA Box Jenkins (1976) Williams and Hoel (2003), k-Nearest neighbors on historic data sets Leonhardt and Steiner (2012), Bayesian networks Sun et al. (2006), F. Kunde, non-parametric predictions by support vector machines SVM Lippi et al. (2013) or artificial neural networks ANN Liu et al. (2006). Machine learning models, Time serious models, support vector machine, grid computing model and big data based traffic flow prediction is used for traffic congestion prediction.

A. Machine learning based traffic prediction

Machine learning is an application of artificial intelligence (AI) that provides systems the ability to automatically learn from past and progressively improves the particular task [30]. Many works are carried out using machine learning algorithms such as logistic regression, support vector machine etc. Guy Leshem et al. [27] described a machine learning system for traffic flow management and control for a prediction of traffic flow. The new algorithm obtained by combining Random Forest algorithm into Ada boost algorithm as a weak learner. It performed relatively well on real data, and enabled the Traffic Flow evaluation model, to estimate and predict whether there was congestion or not at a given time on road intersections.

B. Time serious models

In Time series models, the data and information collected in the past and used to predict the data in the future. These data are collected in regular time intervals [14] Eleni I. Vlahogianni et al [1] proposed temporal evolution of short term approach in traffic flow. They first identified the traffic pattern based on their structure and evolution in time and then clustered the pattern based on evolution of traffic flow with respect to popular traffic flow conditions. Temporal traffic patterns were identified with respect to statistical behavior. Identifying traffic flow patterns through volumes and occupancy of traffic data and clustering was performed through neural network. Existing data driven methods used large databases for the model development. Use of huge database may restrict its application data availability, the storage and maintenance of the historical databases. It may also involve more computational time and resources for running the SARIMA (Seasonal ARIMA) model.

S. Vasantha Kumar et.al [17] proposed seasonal autoregressive integrated moving average model for short term prediction using limited input data. After differentiating the input time series a stationary one, the autocorrelation function (ACF) and partial autocorrelation function (PACF) were plotted to identify the suitable order of the SARIMA model. G. Y. Zhang et al. [5] developed traffic flow prediction including time serious and artificial neural network. They used autoregressive conditional duration model for the prediction of time intervals between vehicles in the traffic's flow and applied particle filter with measured vehicle speed data for traffic flow speed and density prediction. Different ACD models for better description and prediction of traffic flow need to implement in future.

C. Support vector machine

Support vector machine (SVM) is a supervised learning algorithm mainly used for classification and regression. It is based on statistical learning theory. Traffic flow prediction is a non linear problem can be solved by using support vector regression [13]. It has good generalization and fast convergence characteristics.

Fan Wang et al. [2] proposed a multi scale wavelet support vector regression method (MW-SVR) for traffic flow prediction. A scaling kernel function with multi resolution characteristics is constructed based on wavelet multi resolution analysis and they implemented the combination of the wavelet technique with support vector regression. A multiscale wavelet kernel function enhanced the generalization ability of the SVR. MinalDeshpande et al. [13] implemented traffic flow prediction model using support vector machine. To improve traffic flow prediction performance with accuracy rough set was used as a post processing tool to validate the prediction result. It was found that the use of rough set results in satisfactory performance improvement [13].

Sivabalaji manoharan et al. [18] used two sets of modeling approaches based on Linear Regression and Support Vector Machine for Regression. An orthogonal linear transformation of input data using Principal Component Analysis employed to avoid any potential problem of multicollinearity and dimensionality Curse.

SelvarajVasanthaKumar proposed a prediction scheme based on Kalman filtering technique and evaluation requires only limited input data. Traffic flow prediction using both historic and real time data on the day of interest was also used [17].

When you submit your final version, after your paper has been accepted, prepare it in two-column format, including figures and tables.

D. Grid computing model

Grid computing model can greatly improved the quality of traffic control system service and utilization of resources through avoiding the inefficiency and complexity by dividing the application into internodes [10]. Kang Kai et al [10]. Proposed an optimal resource service method based on grid computing pool model for traffic flow prediction by using genetic algorithm. Grid computing pool model utilized to automatically request the best CPU under the current status in traffic information platform to perform the prediction. The system achieved load balancing of computing nodes performed by the parallel implementation of the various computing nodes. It can significantly shorten the time in traffic flow forecasting.

E. Big data based traffic flow prediction

With widespread traffic sensors and new emerging traffic sensor technologies, traffic data are exploding as big data [26]. Traffic big data holds several characteristics, such as temporal, spatial, historical and multistate. This massive and multisource data brought both opportunities and challenges to effective traffic management and control [20].

Hua-pu Lu, Zhi-yuan Sunet al.[9] reviewed the real-time traffic flow state identification and prediction based on big data-driven theory. The traffic flow state identification achieved by simulated annealing genetic algorithm based fuzzy c-means based traffic clustering model. A bi level optimization model for regional traffic flow correlation analysis established to predict traffic flow parameters based on temporal-spatial-historical correlation. The traffic temporal spatial-historical correlation model can be applied in other researches such as identification and correction of abnormal data and traffic congestion analysis.

F. Artificial neural network

ANNs are designed to take off the characteristics of the biological neurons in the human brain and nervous system. Given a sample vectors, ANNs is able to map the relationship between input and output. They “learn” the relationship, and store it into their parameters. The training algorithm adjusts the weights (synapses) iteratively learning typically occurs through the training. When the network is sufficiently trained, it is able to generalize relevant output for a set of input data. ANN has been applied to a large number of problems because of their non-linear system modeling capacity by learning ability using collected data.

Back propagation algorithm divides the learning process into two stages. At First the input information is transmitted from input layer to hidden layer, processing with layer by layer, and then calculates the actual output value of every unit. In second if the output layer cannot obtain the desired output value, then recursively layer by layer calculate the difference between the actual output and expected output. Then finally adjust the weights based on their difference [3].

WushengHU, Yuanlin LIU, Li LI et al.[6] selected back propagation neural network model. The traffic flow difference applied for dynamic rolling prediction. The actual observation data of traffic flow presented the model structure and the results shown feasibility, reliability, and of some practical value.

Kranti Kumar et al. [11] presented artificial neural network for short term flow prediction. Speed of vehicles considered as input variables. ANN model predicted vehicle count accurately. ANN can be applied for short term traffic flow prediction with mixed traffic conditions for non urban Indian high ways.

Vedat TOPUZ et al. [20] proposed different artificial neural network models for predicting the hourly traffic flow. Different ANN architectures such as MLP (multi layer perceptron), RBF (Radial basis function), ERNN (Elman Recurrent Neural Networks) and NARX (Non-linear Auto Regressive and eXogenous Input type) ANN were studied and proved feed forward neural network performs better than recurrent type network.

G. Deep Learning

Deep learning approaches have the ability to learn useful features automatically from data by unsupervised learning. It solved the difficulties of learning intermediate representations. It is considered as one of the powerful algorithms that gives higher accuracy and best performance [7].

Nicholas G. Polson developed a combined linear model [15] using `1 regularization and a sequence of tanh layers. The challenge of predicting traffic flows are the nonlinearities due to transitions between free flow, breakdown, recovery and congestion. The deep learning architectures captured the nonlinear spatio-temporal effects. The first layer identifies spatio-temporal relations among predictors and other layers model nonlinear relations.

Felix Kunde Alexander Hartenstein et al. [3] implemented a concept of feeding sensor data to an Artificial Neural Network. The ANN trained with different spatial and temporal ways to find an optimal setup for an entire city. A sensor network is distributed across an entire city. The sensor data and sequence information enhance prediction result. Recurrent neural network is greater for time series analysis because they supported to learn short and long sequences.

Supervised learning based artificial neural network didn't provide successful result in traffic prediction. Hongsuk Yi, HeeJin Jung et al [7] proposed a deep-learning neural-network model based on TensorFlow. Traffic Performance Index (TPI) is used for logistic regression analyses and a hyper tangent function is used as an activation function for each layer. Due to memory capacity limitations for example, only 1 percent of traffic data for a day could be used. In order to increase accuracy of estimation and improve the DNN architecture, it is necessary to redefine the TPI according to transportation engineering knowledge. Multi GPUs could be built in future to increase the memory capacity.
Yuanfang Chen, Falin Chen et al proposed a deep learning based prediction algorithm (DeepTFP) to predict the traffic flow of the city. It uses three deep residual neural networks to model temporal closeness, period, and trend properties of traffic flow. Each residual neural network consists of a branch of residual convolutional units. DeepTFP aggregates the outputs of the three residual neural networks to optimize the parameters of a time series prediction model and outperforms the Long Short-Term Memory (LSTM) [28].
Yaguang Li et al. [23] presented a Graph Convolutional Recurrent Neural Network to incorporate both spatial and temporal dependency in traffic flow. Traffic forecasting by learning is challenging due to non-linear temporal dynamics with changing road conditions, complex spatial dependencies on road networks topology and inherent difficulty of long-term time series forecasting. Graph Convolutional Recurrent Neural Network was proposed to integrate the encoder-decoder framework and scheduled sampling to improve long-term forecasting.
Nowadays researchers are used images instead of data to predict traffic flow. Xiaolei Ma et al. [23] proposed a convolutional neural network (CNN)-based method learned the traffic as images and predicted large-scale, network-wide traffic speed with a high accuracy. Two-dimensional time-space matrix is used to represent the time and space constraints of road network. An abstract traffic feature extraction and network-wide traffic speed prediction were followed for large scale network.
Existing methods are used shallow (not in deep) prediction models which cannot extract the sequence correlations in the data. Hongxin Shao et al. [8] discovered the application of Long Short-Term Memory Networks (LSTMs) in short-term traffic flow prediction to handle abstract representations in the non-linear traffic flow data. It discovered the latent feature representations hidden in the traffic flow.

H. Weather, Rainfall and Accidents impact in traffic flow prediction

Transportation systems might be heavily affected by factors such as accidents and weather. Many researchers have implemented these factors with traffic data to enhance the quality of traffic flow prediction.
AriefKoesdwiady et al. [1] proposed holistic architecture for traffic flow prediction with weather condition. The weather conditions may have drastic impact on travel time and traffic flow. It investigates a correlation between weather parameters and traffic flow, and to improve traffic flow prediction and incorporates deep belief networks for traffic and weather prediction and decision-level data fusion scheme to enhance prediction accuracy using weather conditions.
The impact of rainfall affects traffic flow characteristics and leads to congestion and accidents. Without a comprehensive understanding of the weather influence on traffic flow, traffic management authorities cannot improve traffic efficiency and safety.
Yuhan Jia et al. [27] proposed the rainfall integrated the deep belief network and long short-term memory can learn the features of traffic flow under various rainfall scenarios. The deep learning predictors have better accuracy than existing predictors. The LSTM can outperform the DBN to capture the time series characteristics of traffic flow data.

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III. METHODOLOGY

The aim of the work is to predict the traffic congestion well in advance for make better travel decisions; improve the transport operations of smart city. Denoise autoencoder, deep neural network, and decision level fusion scheme is proposed to accomplish the task.

A. Overview of proposed framework

Traffic data is important for traffic management, traffic related researches, and applications. But missing data greatly reduce the predicting performance of the traffic volume data and also affects some other normal function of intelligent transportation systems. So for data preprocessing denoise auto encoder is used to replace the missing value by complete data using statistical learning methods. Next the complete and quality traffic data is used into the deep neural network for accurately predicting the spatio temporal traffic congestion.Decision In-Decision Out (DEI-DEO) method is used to obtain enhanced new decisions.

B. Data set

The traffic data set is collected from PEMS (performance measurement system)[31]. It is a California based transportation network. Traffic data is generated by using inductive loop detectors and are aggregated in 5 min duration. Weather is collected from Meso west [32] website, California. This traffic and weather data can be divided into training set and test set. Through the effective learning of training set, deep architectures provide the best result [1].

C. Data Preprocessing

Traffic data set is collected from loop detectors contains missing data which affects the quality of traffic data. The proposed approach replaces the missing data with statistical learning (Yanjie Duan 2014) model which replaces the missing value by learning the value of nearest location and it treated the traffic data as a whole data item and restores the complete data with the deep neural network. The dimensionality of data is reduced through deep learning.

Imputation is the process of replacing missing data with substituted values. Data imputation methods mainly classified into three types, such as Prediction, interpolation and statistical learning. Prediction methods typically use historical data. ARIMA, K-Nearest neighbor, K means Clustering technique are some of the methods for imputation [24].

The autoregressive integrated moving-average (ARIMA) model is the generic method to predict the imputed data points. An interpolation method replaces the missing data with history data or neighboring data [25]. History models using neighboring data points to interpolate corrupted or missing data points often use the data of neighboring sites or neighboring states to estimate the values of corrupted or missing data points for the current location. Each corrupted or missing data point is estimated by the average or the weighted average of the neighboring data.

A. AutoEncoder(AE)

Autoencoder is the artificial neural network based on unsupervised learning technique used to learn the input and provide the output using encoder and decoder. The output target is the same with the input thus the hidden layer is taken the encoded input data and can be decoded into the output data. Number of hidden layer is greater than the input and output layer. It makes the auto encoder to learn the representation for output layer.

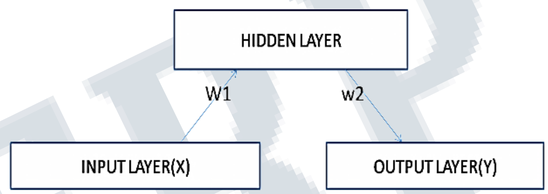

Fig 1: Structure of AutoEncoder

B. Denoise Autoencoder(DAE)

Denoise autoencoder is the variance of an autoencoder.

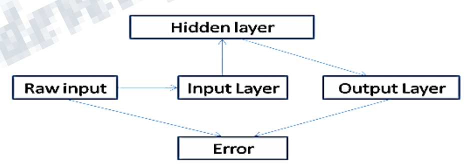

Fig 2: Structure of denoise autoencoder

The input data is the partially destroyed data or missing data in the form of noise. Denoise autoencoder replace the noise data with statistical learning. Error is calculated for raw input data and the result. That is DAE can obtain almost the same representation of the destroyed input data and can restore the raw input data in the output layer [24]. The proposed framework represented in fig 3. The raw input of traffic data which consists real time traffic data, Incidents data, Lane closure and Weather is preprocessed. After preprocessing stage the traffic data is applied in deep neural network. After prediction the result is combined with other data such as lane closure, incidents and weather. Final traffic flow prediction is evaluated and analyzed based on performance measures.

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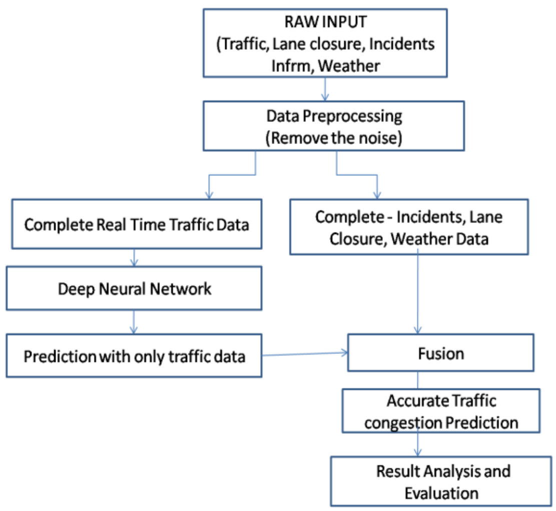

Fig 3: Proposed Framework

D. Deep Neural Network

The ANN based "Deep Learning" has the feature of latent representation and ability of handle non linear patterns. Many researches [3][20] are proposed based on deep learning. Some types of neural networks are Deep Neural network [7], Deep Belief Network [27], Deep Convolutional Network [23], Recurrent Neural Network [8][23] etc. which makes them interesting for traffic prediction. Deep learning has applied to layers of hierarchical hidden variables to capture interactions and nonlinearities. This surpass the traditional methods in many areas. From the imputed traffic data predicted the spatio-temporal traffic congestion using deep neural network. A simple deep neural network is represented in Fig 4. Number of hidden layer is greater than both input layer and output layer. Weight is added in each layer. Combination of any two deep neural networks provides the best result especially for spatio temporal prediction.

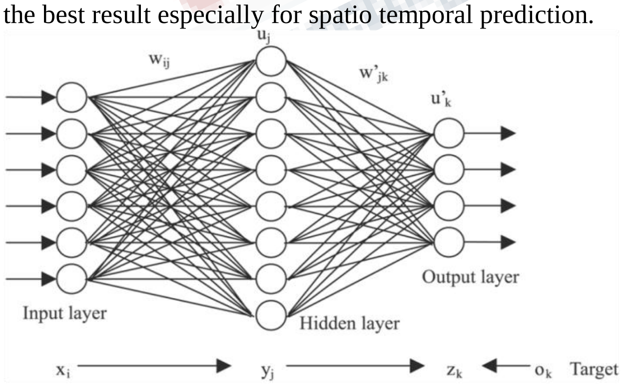

Fig 4: A simple deep neural network [2]

Convolutional neural network, Feed forward neural network and recurrent neural network with LSTM provides the best result for spatio temporal prediction [23][8].

E. Fusion

Data fusion is a combination of information from one or multiple sources to predict the information with high quality. Decision In-Decision Out (DEI-DEO) method [1] is used to obtain enhanced new decisions. Here traffic prediction from real traffic data is fused with incidents data, weather, and lane closure to accurately predict the traffic congestion.

F. Traffic flow prediction result analysis and evaluation

The mean absolute percentage error (MAPE) and root mean squared error (MSE) are utilized to measure the performance of the traffic state prediction. Compare the result with other deep learning models such as recurrent neural network, deep belief network and convolutional network to show the efficiency.

IV. RESEARCH CHALLENGES AND ISSUES

Traffic congestion prediction with deep learning provides better results in recent studies. Some of issues discussed below,

- The training efficiency can be also enhanced by optimizing pre-training methods, which may reduce the number of iterations while achieving more accurate results [32].
- Multi type data is used in de noise autoencoder [24].
- Reduce the dimensionality [24].
- The proposed model validates the seasonal variation effect on the prediction accuracy [27].
- Spatio temporal traffic flow prediction can be achieved with high accuracy [32].

V. CONCLUSION

Many works were carried out using deep learning algorithms with traffic sensor data. In this paper a novel framework proposed to predict traffic congestion as much as closer including real time traffic data, weather, incidents detection and Lane closure. This framework assured to give a better spatio temporal based prediction with good result of fusion technologies.

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REFERENCES

[1] Arief Koesdwiady, RidhaSoua, and FakhriKarray, "Improving Traffic Flow Prediction With Weather Information in Connected Cars: A Deep Learning Approach", IEEE Transactions on Vehicular Technology, 2015.

[2] Fan Wang, Guozhen Tan, Yu Fang, Multiscale Wavelet support Vector Regression for Traffic Flow Prediction, IEEE, 2009.
VIII.

[3] FELIX KUNDE ALEXANDER HARTENSTEIN STEPHAN PIEPER PETRA SAUER, "TRAFFIC PREDICTION USING A DEEP LEARNING PARADIGM", CEUR-WS.ORG, 2017.
IX.

[4] GUY LESHEM, AND YA'ACOV RITOV, "TRAFFIC FLOW PREDICTION USING ADABOOST ALGORITHM WITH RANDOM FORESTS AS A WEAK LEARNER", INTERNATIONAL JOURNAL OF MATHEMATICAL AND COMPUTATIONAL SCIENCES VOL:1, NO:1, 2007.

[5] G.Y.Zhang, Q.Zhao, Z.W.Luo and H.Wei, "Short-Term traffic flow Prediction with ACD and Particle Filter", Ninth International Conference of Chinese Transportation professionals (ICCTP), 2009.

[6] Haiyang Yu , Zhihai Wu , Shuqin Wang , Yunpeng Wang and Xiaolei Ma, "Spatiotemporal Recurrent Convolutional Networks for Traffic Prediction in Transportation Networks", Sensors 2017.

[7] Hongsuk Yi, HeeJin Jung, SanghoonBae, "Deep Neural Networks for Traffic Flow Prediction",IEEE,2017.

[8] Hongxin Shao Guy Leshem, and Ya'acov Ritov, Boon-Hee Soong, "Traffic flow prediction with Long Short-Term Memory Networks (LSTMs)", IEEE, 2016.

[9] Hua-pu Lu,Zhi-yuan Sun and Wen-congQu, "Big Data-Driven Based Real-time Traffic flow State Identification and Prediction", Hindawi, 2015.

[10] Kang Kai, Han Jinfeng, "Short-term Traffic Flow Prediction Based on Grid Computing Pool Model", IEEE, 2010.

[11] Kranti Kumara, M.Paridab, V.K.Katiyar, "Short term traffic flow prediction for a non urban highway using Artificial NeuralNetwork, Elsevier, 2013.

[12] Leni I.Vlahogianni, Matthew g.Karlaftis & John C.Golias, "Temporal Evolution of Short-Term Urban Traffic Flow: A Nonlinear Dynamics Approach", Computer-Aided Civil and Infrastructure Engineering, 2008.

[13] MinalDeshpande, "Performance improvement of Traffic flow Prediction Model using Combination of Support Vector Machine and Rough Set", International Journal of Computer Applications, 2017.

[14] M. Karimpour, A. Karimpour, K. Kompany, and Ali Karimpour", Online Traffic Prediction Using Time Series: A Case study", springer, 2017.

[15] Nicholas G. Polson, "Deep Learning for Short-Term Traffic Flow Prediction", arXiv,2017.

[16] Qiang Shang , Ciyun Lin, Zhaosheng Yan, Qichun Bing , Xiyang Zhou, "A Hybrid Short-Term Traffic Flow Prediction Model Based on Singular Spectrum Analysis and Kernel Extreme Learning Machine", PLoS ONE 11(8): e0161259,2016.

[17] SelvarajVasanthaKumar, "Traffic Flow Prediction using Kalman Filtering Technique", Elsevier, 2017.

[18] SivabalajiManoharan, "Short Term Traffic Flow Prediction Using Deep Learning Approach", National College of Ireland, 2016.

[19] Suguna Devi, T. Neetha, "Machine Learning based traffic congestion prediction in a IoT based Smart City", IRJET, 2017.
[20] Vedat TOPUZ, "Hourly Traffic Flow Prediction by different ANN Models", www.intechopen.com, 2010.

[21]Wusheng Hu, Yuanlin Liu, "The short-term traffic flow prediction based on neural network", IEEE, 2010.

[22] Xiaolei Ma , Zhuang Dai , Zhengbing He , Jihui Ma , Yong Wang and Yunpeng Wang, " Learning Traffic as Images: A Deep Convolutional Neural Network for Large-Scale Transportation Network Speed Prediction".Sensors, 2017.

[23]Yaguang Li, Rose Yu, Cyrus Shahabi, Yan Liu, "Graph Convolutional Recurrent Neural Network:Data-Driven Traffic Forecasting",arXiv,Jul 2017.

ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
Vol 5, Issue 4, April 2018

[24] Yanjie Duan, Yisheng Lv , Yu-Liang Liu, Fei-Yue Wang, “An efficient realization of deep learning for traffic data imputation ”, Elsevier, 2016.

[25] Yanjie Duan, Yisheng Lv, Wenwen Kang, Yifei Zhao, “A Deep Learning Based Approach for Traffic Data Imputation”, IEEE, 2014.

[26]Yisheng Lv, Yanjie Duan, Wenwen Kang, Zhengxi Li, and Fei-Yue Wang, “Traffic Flow Prediction With Big Data: A Deep Learning Approach”,IEEE, 2014.

[27]Yuhan Jia, Jianping Wu, and Ming Xu,“Traffic Flow Prediction with Rainfall Impact Using a Deep Learning Method”, Journal of Advanced Transportation, 2017.

[28] Yuanfang chen, Falin Chen, YizhiRen, Ting Wu, Ye Yao, “DeepTFP:Mobile Time Series Data Analytics based Traffic Flow Prediction”, arxiv, 2017.

[29] http://www.extremetech.com

[30] http://www.expertsystem.com

[31]http://pems.dot.ca.gov. (Department of transport, California)

[32] http://mesowest. (The University of Utah.)