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Investigation of Deep Learning Methodologies in Intelligent Green Transportation System

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Abstract

Due to the advancement of technologies in the past few years, huge amount of data especially in the transportation domain received through devices such as road sensors, CCTV, probes, GPS etc. It is quite challenge to build a consistent and robust prediction models using traditional machine learning models in these complicated scenarios. On demand information about traffic is highly essential for the intelligent green transportation system. Now a day's deep learning shows promising significance in every aspect of research as well as industrial applications. This research article reviews the various deep learning methodologies in intelligent green transportation system by means of automatic vehicle detection, traffic flow forecasting, transportation network representation, prediction etc.

Keywords: Deep Learning, Intelligent Transportation System, Green Engineering, Traffic Flow, Automatic Vehicle Detection

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1 Introduction

Huge data processing is highly essential to incorporate traffic forecasting and it is important in decision making systems especially in intelligent transportation. The following are the credentials of utilizing an effective supportive system for decision making.

1. Reduction of congestion duration
2. To lower the incident response time.
3. Improve the awareness of situation.

But processing and designing the traffic data is often complex due to the complication in road network and temporal-spatial dependencies in them. In addition to that, the patterns of traffic are not same because various segments of road have distinct time variant patterns of traffic scenarios [1]. Due to the difference in the quality of data, region coverage and time variations, it is quite complicated to extract or select features to train prediction models even through huge amount of data extracted from various sources. Various deep learning approaches are utilized in the modern intelligent transportation system in order to predict effectively the traffic flows dynamically [2][3].

The application includes
1. Prediction of travel demand.
2. Automatic vehicle detection.
3. Representation of transportation network.
4. Incident inference.

The traffic flow information is highly expected for
1. Government agencies
2. Corporate sectors.
3. Individual travelers.

The main motivation is to help the normal traveler to make or plan their travel, avoid traffic congestions, to enhance the efficiency of traffic operation and also to control the pollution in terms of carbon emission [4]. The main intension of prediction of traffic flow is to provide the necessary traffic information to the end users. With the fast development as well as implementation of intelligent transportation system, the prior attention has been given to prediction of traffic flow [5].

It is considered to be an essential factor for the successful implantation of intelligent transportation system especially in
1. Commercial operations of vehicles like uber, ola etc.
2. Modern traffic management system.

3. Improved public transportation system.
4. Modern information system of travelers.

The prediction of traffic flow mainly relies on real time as well as historical data gathered from variety of heterogeneous sources and also in terms of different scenarios. Eventhough we are having enormous intelligent transportation systems, still there is a space for the improvement due to the day to day increase in the amount of data and technology. Most of the traditional traffic management uses shallow traffic models and in some cases it fails to predict effectively[6] .

Generally CCTV cameras, road sensors, direct communications are used to monitor the traffic incidents and based on the information from these variety of devices, the operators high traffic areas and give essential support and guidance to clear all the traffic on real time networks. But these include lot of manual work.

In earlier days, road network operators have done huge manual processes like

1. Incident classification.
2. Incident site clearance.
3. Traffic management.
4. Management of emergency services etc.

But with the advent of deep learning technology, the classification of traffic can be done automatically by using trained data. Huge amount of data is produced every moment in the domain of transportation. Most of the current generation uses smart phones which furnished enough to collect patterns of movements through various inbuilt applications. There are plenty of various methods through which the transportation information can be generated. This equips the modern cutting edge technologies to utilize the available huge data for the better prediction of transportation.

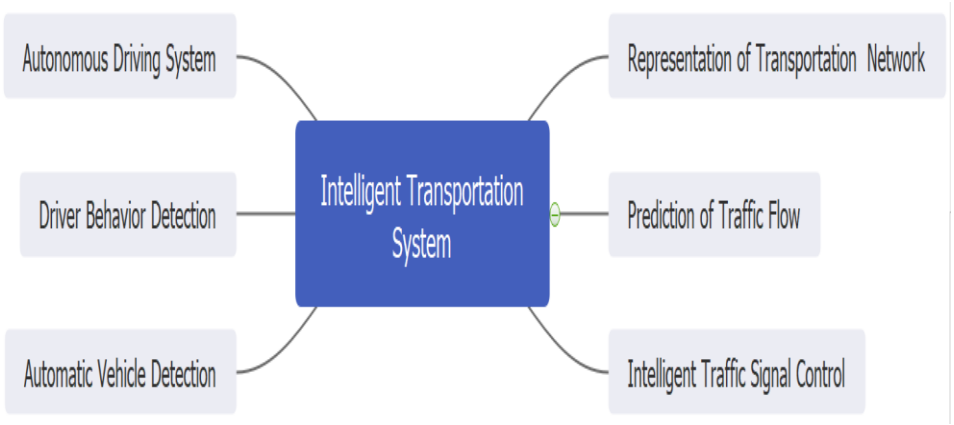

Figure 1 Overall view of Intelligent Transportation System

Figure.1 represents the overall view of intelligent transport system and its various kinds of incidents. .Unexpected accidents or events are the hectic tasks that can cause severe effects on modeling the intelligent transportation system. The remaining section deals with the overview of deep learning and intelligent transportation system.

2 Overview of Deep Learning

During past decade, deep learning is the term interpreted in most of the technical applications. It is the subset of machine learning that deals with the algorithm reflected based on concepts and functionality of brain. Figure.2 shows the general deep learning architecture works on the principle of information passing between neurons.

The basic fundamental architecture of neural network is given below.

1. Convolutional neural network.
2. Recurrent neural network
3. Recursive neural network
4. Unsupervised pre-trained network

The wide research applications of deep learning models are given as follows

1. Image recognition
2. Automatic speech recognition
3. Visual art processing

4. Natural language processing
5. Drug discovery / toxicology
6. Bio informatics
7. Recommendation systems
8. Medical image analysis
9. Image restoration

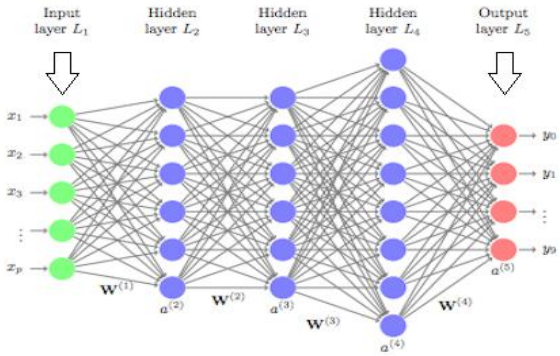

Figure 2 Deep Learning Schematic Diagram

The most common challenges faced by deep learning models in variety of applications are

- Over fitting
- Computation time

3 Intelligent Transportation System

3.1 Representation of Transportation Network

Mohammadhani Fouladger et al [7] discussed an intelligent traffic network management system using a decentralized based deep learning method. The performance of the system is improved by utilized regularized Euclidean loss function that balance the high congestion samples to the low congestion samples.

Dataset : Caltrons Performance Measurement System (PeMS), California state real traffic data.

This dataset contains

- Traffic flow data
- Car accidents
- Weather information
- Lane closures etc

The above mentioned system is categorized into two basic steps :

1. Deep traffic flow convolutional network
2. Long short-term memory traffic flow

The deep learning architecture used by the author is Lasagne Deep learning framework installed on Theano.

Xiaolei Ma et al [8] developed a large scale transportation network especially to deal with traffic bottlenecks for congestion. The study on transportation network is crucial for researchers and also practitioners who worked in transportation sector. Due to the improvement of intelligent transportation systems and internet of things for the past few years, the investigation on transportation at diversed manner becomes so critical. Here the author used deep restricted Boltzmann machine and recurrent neural network architecture to design and analyze the congestion in traffic.

3.2 Prediction of Traffic Flow

Yunfei Ai et al [9] predicted traffic flow effectively using support vector machine algorithm in Jiangxi province. Here suitable pre-processing techniques are used to remove the abnormal data as well as fill the missing data from the dataset acquired by Beidow positioning navigation system in Jiangxi province. The abnormality or missing of data is mainly due to

- Environmental interference
- Communication failure
- Equipment failure etc.

The hybrid of historical data filling method and linear interpolation methods are used to fill the missing datas and also clean the abnormal data in the data processing step. Then the verification of data is done and support vector machine algorithm is used in this approach since it has the capability of transforming non linear problems into linear problems in high dimensional space.

Huang Bohan and Bai Yun [10] developed a bidirectional recurrent neural network based traffic flow prediction system. It gives better performance when compared with long short term memory (LSTM) and gated recurrent unit (GRU) model. The traditional recurrent neural network considers only previous content but the bidirectional recurrent neural network considers both content before and after to provide the better performance. Bidirectional recurrent neural network consists of two recurrent neural network connected in an opposite direction but both connected to the same output layer in the architecture. This system mainly focus on three parameters

1. Speed
2. Time
3. Site to study

In future, more parameters can be included for further enhancement in the traffic flow predictions.

Jinhong Li et al [11] developed a short term traffic flow prediction based on the concept of long short term memory. This system considers to be crucial in optimized traffic control and planning of traffic navigation in urban areas. The three essential parameters to measure the congestion and flow of traffic are

1. Occupancy
2. Speed
3. Flow

One of the major type of recurrent neural network is the long short term memory used to store long term history information. In architecture, the system operates using three gates such as

- Input gate
- Forget gate
- Output gate

This system has the capacity of storing information for a long duration.

Hendrick Tampubolan and Pao-Ann Hsiung [12] developed an intelligent system for traffic flow prediction based on supervised deep learning method. One of the major sub division of the intelligent transportation system is the traffic management system specifically to control the traffic congestion. The concept of fully connected deep neural network (FC-DNN) used to predict the traffic flow in timely manner. The disadvantage of time consuming and over fitting issue is controlled by adopting batch normalization and dropout techniques. The weights in the neural network is updated by using stochastic gradient descent and momentum.

The dataset used is Open Data Taipei city and CWB.

The accuracy of the model is evaluated by

1. Root mean square error (RMSE)
2. Mean absolute error (MAE)
3. Mean absolute percentage error (MAPE)

Early stopping technique can be included in the model as an enhancement in the future since the training error does not show much variation in the later stage.

Lin Yu et al [13] developed a traffic flow prediction system based on the concept of deep learning network. Short term traffic flow prediction has wide applications such as

1. Traffic control
2. Traffic guidance
3. Maintenance of cross sea great bridge etc.

The dataset of great bridge of Chang Tai freeway is used for training the model. The system mainly focuses on predicting the short term traffic by

analyzing private cars and mini bus data on the Chang Tai express way and the LSTM-RNN model predicts the traffic flow on the normal cases like working days and also provides better result during abnormal traffic conditions like festival seasons and high monsoon times like rainy seasons.

3.3 Intelligent Traffic Signal Control

Sahar Araghi et al [14] implemented an intelligent traffic light control using appropriate machine learning model. Congestion of traffic is the critical issue in major cities. Here the delay in traffic signal is reduced by setting signal light timings suitably by means of Q-learning and neural network. A concept of intersection works similar like an intelligent agent in setting green times rely on the traffic information. Comparative study of Q-learning and neural network is taken. Q-learning algorithm requires

1. Huge state space
2. Complicated learning process

In future, the above mentioned neural network based approach can be extended for multi agent network.

Deepeka Garg et al [15] developed intelligent traffic light control using deep reinforcement learning. The key for improving the efficiency of existing infrastructure is optimizing the real traffic by extending the traffic control system to learn, adopt and explore based on the current environment. Here deep reinforcement learning model is used to established rely on the concept of policy gradient algorithm.

PANG Ha-li and DING Ke [16] used deep reinforcement learning method for developing an intersection signal control method. The future work mainly concentrates

- The generalization of the control method can be improved. The performance of agent can be trained well without repeated learning.
- Enhance the research for two or more intersections by appropriate communications and mutual cooperation between multiple agents.

Congcong Li et al [17] implemented a regional traffic control method by adopting suitable deep reinforcement learning. This implies the improvement in the performance of road network. Here VISSIM- python platform is used to simulate the model and study the performance of the algorithm.An appropriate denoising stacked auto encoders are used to improve the performance of the algorithm by suppressing the noisy data in the traffic. The Future work mainly concentrates

- On examine the behavior of signalized intersection control algorithm to develop efficient methodology for

1. Feature Extraction

2. Data reduction methods in order to merge with suitable multi agent system.

Li Li et al [18] developed an effective signal timing of traffic through the concept of deep reinforcement learning. The methodology of deep neural network is adopted to acquire the Q-function of reinforcement learning by analyzing the traffic or control inputs and its related traffic outputs. Suitable signal timing strategies are developed by representing system state changes and control actions.

Khaled Zaatouri and Tahar Ezzedire [19] used YOLO method for developing an effective traffic light control system which is self adaptive. The increase in traffic flow raises processing time of queue length of vehicles and the scheduling time of the traffic lights which is one of the critical research issue in the urban areas. The optimization of traffic signal phases are implemented mainly based on the collected traffic data especially

- Vehicle queue length
- Waiting time per vehicle

This makes the system to enable an efficient traffic strategy with minimum waiting time for vehicle.Three major adaptive traffic control systems are listed below:

1. Split Cycle Offset Optimization Technique (SCOOT)
2. Real time Hierarchical Optimizing Distributed Effective System (RHODES)
3. InSync

3.4 Automatic Vehicle Detection

Hilal Tayara et al [20] developed vehicle detection and counting system based on convolutional regression network in aerial images. Research in aerial images is quite challenge due to the fact that

- Vehicle size in aerial images.
- Various types of vehicle and its orientations.
- Visual appearances and similar objects.

Most of the research work in vehicle detection are carried based on shallow learning or deep learning methods. The system is evaluated on two public dataset which is mentioned below

1. DLR Munich vehicle dataset.
2. Overhead Imagery Research Dataset (OIRDS)

Even though the system shows excellent performance in terms of precision and recall rate, it takes lot of time for computation compared to other methods. The future work concentrates mainly on building model which shows better performance in a quick manner.

Qiling Jiang et al [21] implemented an intelligent vehicle system using deep neural network. Detection of vehicles from the satellite image is a complex task. Deep neural network concept is utilized since it has tremendous performance in many image based applications. The system has two major steps

1. Extraction of image patches using graph based super pixel segmentation.
2. Training and classification of these images using deep neural network.

Future work mainly deals with the training of the model using images with different resolutions.

Zhao Min et al [22] developed a vehicle detection method using deep learning and multi layer feature fusion. The feature fusion structure is used to intensify the semantic information. The accuracy of the vehicle detection using this approach is effectively higher while compared with traditional models. The future work concentrates on including more complex scenes.

Akhil Soin and Manisha Chahande [23] build a moving vehicle detection system based on the concept of deep neural network. Moving vehicle detection system is used in many applications such as

- Intelligent parking system.
- Intelligent driver assistance system.
- Automatic toll collection.
- Self guided vehicles.
- Traffic analytics like speed, vehicle count, flow.

CIFAR-10 dataset is used to train the model.

A reformative convolutional neural network is used to improve the accuracy of vehicle recognition and also reduces the cost associated with computational complexity.

Chia-Chi Tsai et al [24] implemented a vehicle detection and classification model exclusively for intelligent transportation applications using deep neural network. Following techniques are used in this model

1. Concatenated ReLu
2. Modified Inception.
3. Hypernet

To improve the performance in terms of accuracy and speed. Dataset used for fine tuning the above mentioned architecture is given below

- Comprehensive cars (CompCars) dataset.
- Standford Cars Dataset.
- Pascal VOC dataset.

Deepak Mittal et al [25] used limited heterogeneous traffic data for training a deep learning architecture to detect the vehicles effectively.

Heterogeneous traffic consists of multiple vehicles which does not follow the same lane rules.

The research in heterogeneous vehicle detection is quite challenge due to the occlusion of vehicles. The existing huge dataset is augmented with the tiny low resolution heterogeneous traffic dataset to solve the time consuming problem. The augmented dataset namely IITM-HETra is the first public dataset available for heterogeneous traffic.

Ahmad Mansour et al [26] developed an automated vehicle detection based on deep learning approach using satellite images. Vehicle detection using satellite images suffer major complexities like

1. Background complexity.
2. Color of vehicles.
3. Size of ground sample distance (GSD).
4. Jamming effect by trees, buildings etc.

An automated vehicle detection system is modeled using two deep learning frameworks. InTable.2. shows the summarization of databases and application

1. Faster region convolutional neural network (Faster R-CNN).
2. Single Shot Multi Box (SSD) based convolutional neural network.

3.5 Driver Behavior Detection

Youness Moukafih et al [27] implemented deep learning based time series classification approach for aggressive driving detection. The safety of traffic can be improved by developing an intelligent system which detect the aggressive driving automatically. Long short term memory-fully convolutional network (LSTM-FCN) is used to identify the aggressive category of driving in period of travel time. A public dataset, UAH-DriveSet is utilized to test the approach.

Chaojie Ou et al [28] used deep learning and fuzzy inferencing based tool to monitor the driver behavior. The distraction of the driver while driving is monitored by driver head pose estimation module which has the ability to determine using the driver frontal view and recognize using the deep learning model and the fuzzy inferencing measures the danger level associated with the distraction in a real time manner.

The implemented monitoring tool has three modules.

1. Module of driver head pose estimation.
2. Module of distraction activity recognition.
3. Module of danger level inference.

Eduardo Romera et al [29] presented the public dataset UAH-DriveSet for analyzing the behavior of the driver while driving. Most of the researches

in driver behavior analysis implies on machine learning and deep learning approaches which requires large dataset for training the model effectively. UAH-DriveSet provides large amount of data captured through driving monitoring application DriveSafe. This application categorizes three behavior.

1. Normal driving.
2. Drowsy driving.
3. Aggressive driving.

and mainly monitored on two different road conditions given below.

- Motorway
- Secondary road

The future work concentrates on more number of vehicles, various drivers and different road environments.

Leonel Cuevas Valeriano et al [30] developed a system for recognizing the driver distractions using deep learning methodology. The system is evaluated on State Farm dataset which categorizes ten different actions like

- Normal driving
- Talking on phone while driving
- Texting while driving
- Drinking while driving
- Operating music player while driving
- Reaching behind etc.

Future work mainly target on skeleton images as input in order to eliminate the background environment influences the prediction result.

Shiyang Yan et al [31] implemented a behavior recognition of the driver using deep convolutional neural network. Gaussian mixture model is used to extract the skin like region from the given input which then feed into deep convolutional neural network for further training and recognition. The method is tested using Southeast University Driving Posture dataset.

We analyses the review based on the categorization such as transportation network, traffic flow, traffic signal control, automatic vehicle detection and driver behavior detection. Table.1 represents the summarization of the all related works based on the parameters and Table.2 represents the various kinds of database and applications are used in papers.

Table 1 List of methodologies and metrics used in various intelligent transportation system

S.No	Author	Methodology	Metrics
1	Yisheng Lv (2014)	Stacked Autoencoder model	1. Mean Absolute Error (MAE) 2. Mean Relative Error (MRE) 3. RMS Error (RMSE)
2	Wenhang Bao (2019)	Social Influence based Multi -Agent Deep Deterministic Policy Gradient (MADDPG)	1.Spatial Influence
3	Mohammadhani Fouladgar (2017)	Deep Traffic Flow CNN and LSTM	Root Mean Squar Error (RMSE)
4	Xiaolei Ma (2015)	Deep RNN-RBM	1. Prediction Accuracy 2. Sensitivity 3. Specificity
5	Yunfei Ai (2018)	Support Vector Machine	1. Mean Absolute Error (MAE) 2. Root Mean Square Error (RMSE)
6	Huang Bohan (2019)	Bidirectional Recurrent Neural Network	1. Mean Absolute Error (MAE) 2. Root Mean Square Error (RMSE)
7	Jinhong Li (2018)	LSTM Neural Network	1. Mean Absolute Error (MAE) 2. Mean Relative Error (MRE) 3. RMS Error (RMSE) 4. Mean Absolute Percentage Error (MAPE)
8	Hendrick Tampubolon (2018)	Supervised Deep Learning based Traffic Flow Prediction (SDLTFP)	1. Mean Absolute Error (MAE) 2. RMS Error (RMSE) 3. Mean Absolute Percentage Error (MAPE)
9	Lin Yu (2019)	Deep Learning Network	1. Mean Absolute Error (MAE) 2. RMS Error (RMSE) 3. Mean Absolute Percentage Error (MAPE)
10	Deepeka Garg (2018)	Deep Reinforcement Learning	1. Maximum Speed 2. Maximum Acceleration 3. Deceleration
11	Pang Ha Li (2017)	Deep Reinforcement Learning	1. Throughput
12	Congcong Li (2018)	Improved Deep Reinforcement Learning	1.Average Delay
13	Khaled Zaatouri (2018)	YOLO	1. Accuracy 2. Efficiency

14	Hilal Tayara (2018)	Convolutional Regression Neural Network	1. recall 2. Precision
15	Qiling Jiang (2015)	Deep Neural Network	1. recall 2. Precision
16	Zhao Min (2018)	Deep Learning and Multi layer Feature Fusion	1. recall 2. Precision
17	Akhil Soin (2017)	Deep Neural Network	Detection accuracy
18	Chia-Chi Tsai (2018)	Faster R-CNN	Accuracy
19	Ahmad Mansour (2019)	Faster R-CNN & single shot multi box(SSD)	Mean Average Precision (MAP)
20	Youness Moukafih (2019)	Long Short Term Memory Fully Convolutional Network (LSTM-FCN)	1. recall 2. Precision
21	Chaojie Ou (2018)	Deep Learning and Fuzzy Inferencing	Detection accuracy
22	Leonel Cuevas Valeriano (2018)	Deep Learning	classification accuracy

Table 2 List of database and applications

S.No	Author	Database	Application
1	Yisheng Lv (2014)	Caltrans Performance Measurement System (PeMS)	Traffic Flow Prediction
2	Wenhang Bao (2019)	Not specified	Real Time Traffic Signal Control
3	Mohammadhani Fouladgar (2017)	Caltrans Performance Measurement System (PeMS)	Traffic Congestion Prediction
4	Xiaolei Ma (2015)	S1 Dataset	Transportation Network Congestion Prediction
5	Yunfei Ai (2018)	Jiangxi Daguang Expressway Vehicle	Traffic Flow Prediction
6	Huang Bohan (2019)	GPS data of Hohhot Bus Corporation	Traffic Flow Prediction
7	Jinhong Li (2018)	Road segment of WANGJI west road	Traffic Flow Volume
8	Hendrick Tampubolon (2018)	1. Open Data Taipei City 2. CWB	Traffic Flow Prediction
9	Lin Yu (2019)	Chang Tai Freeway	Short Term Traffic Flow Prediction

10	Deepeka Garg (2018)	Not specified	Autonomous Traffic Light Control
11	Pang Ha Li (2017)	Not specified	Intersection Signal Control
12	Congcong Li (2018)	Not specified	Regional Traffic Signal Control
13	Khaled Zaatouri (2018)	Not specified	Traffic Light Control System
14	Hilal Tayara (2018)	1. DLR Munich vehicle dataset 2. Overhead Imagery Research Dataset (OIRDS)	Vehicle Detection and Counting
15	Qiling Jiang (2015)	Google Map	Vehicle detection
16	Zhao Min (2018)	Darknet model	Vehicle detection
17	Akhil Soin (2017)	CIFAR-10	Moving Vehicle Detection
18	Chia-Chi Tsai (2018)	IVS1 & IVS-2 dataset	Vehicle Detection and Classifiation
19	Ahmad Mansour (2019)	Satellite images from 1. Google earth 2. JF-2 and world view	Automated Vehicle Detection
20	Youness Moukafih (2019)	UAH DriveSet	Aggressive Driving Detection
21	Chaojie Ou (2018)	ImageNet	Driver Behavior Monitoring
22	Leonel Cuevas Valeriano (2018)	State Farm dataset	Recognition of Driver Distraction

4 Conclusion

This research article gives the overview of Intelligent Transportation System based on the recent deep learning concepts, its merits and limitations over the traffic domain for analyzing the flow, speed and count of vehicles for the next generation autonomous driving and also predicting the behavior of driver while driving for safe and secure transportation. This article also aids in highlighting the significant contributions of deep learning approaches for an effective intelligent transportation system and also its future enhancement.

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