Network Traffic Prediction Model Considering Road Traffic Parameters Using Artificial Intelligence Methods in VANET

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ABSTRACT: Vehicular Ad hoc Networks (VANETs) are established on vehicles that are intelligent and can have Vehicle-to-Vehicle (V2V) and Vehicle-to-Road Side Units (V2R) communications. In this paper, we propose a model for predicting network traffic by considering the parameters that can lead to road traffic happening. The proposed model integrates a Random Forest- Gated Recurrent Unit- Network Traffic Prediction algorithm (RF-GRU-NTP) to predict the network traffic flow based on the traffic in the road and network simultaneously. This model has three phases including network traffic prediction based on V2R communication, road traffic prediction based on V2V communication, and network traffic prediction considering road traffic happening based on V2V and V2R communication. The hybrid proposed model which implements in the third phase, selects the important features from the combined dataset (including V2V and V2R communications), by using the Random Forest (RF) machine learning algorithm, then the deep learning algorithms to predict the network traffic flow apply, where the Gated Recurrent Unit (GRU) algorithm gives the best results. The simulation results show that the proposed RF-GRU-NTP model has better performance in execution time and prediction errors than other algorithms which used for network traffic prediction.

Keywords – Vehicular network, network traffic prediction, road traffic prediction, regression
methods, classification methods, machine learning algorithms, deep learning algorithms.

1. INTRODUCTION

One of the important technologies for the Intelligent Transportation System (ITS) is VANET that tries to make the environment safer and have better transportation using wireless communications [1]. The traffic flow prediction with high accuracy is a significant issue in current transportation systems. It can help have the best path planning, make a better choice in selecting the greater route for travelers and decrease the traffic flow. Distinguishing that where and when the traffic will happen is a promising solution for managing transportation [2]. However, the new perspective of network traffic flow is that the traffic in the road could affect network traffic. According to the V2V communications in VANET, vehicles can send packets to each other to forecast the road traffic. By increasing the number of vehicles and traffic on the road, the number of packets sent would grow, leading to network traffic. Previous studies worked on road traffic and network traffic separately, and we investigated them in the literature review. However, most of them addressed the traffic problem on the road or in the network independently, while in this paper, we will discover the relation between road and network traffic parameters together with the aim of network traffic prediction. Intelligent ways via machine learning (ML) techniques are the optimum solutions that can address traffic prediction problems with the aim of traffic flow prediction. There are some computational approaches like Bayesian modeling, fuzzy logic, hybrid modeling, Neural Networks (NN), and statistical modeling, which most of them, specially the NN, are promising solutions aiming to improve the accuracy of prediction in data traffic flow [3]. The significant point that should consider in all these ways, is the accuracy of prediction. ML techniques are divided into three types: Unsupervised Learning (training would be based on unlabeled data), Supervised Learning (training would be based on labeled data), and Reinforcement Learning (it learns from the performance of the learning agent). Moreover, some types of ML schemes like Transfer Learning and Online Learning are subcategorized by these three types of ML schemes [4].

Another promising solution in the case of a large and complex dataset is deep learning (DL) algorithms for prediction problems. It has different types of algorithms that Recurrent Neural Network (RNN) [5], [6] and Convolutional Neural Network (CNN) [7] are the two famous algorithms that are used in many studies. Generally, the RNN has two modules called Long Short-Term Memory (LSTM) [8] and Gated Recurrent Unit (GRU) [9], [10], where the LSTM algorithm is similar to RNN by intention to address the vanishing problem. One of the most critical features of these algorithms
is that they can learn dependencies for a long time with the aim of prediction in time-series datasets, and the GRU algorithm is like LSTM with more minor complications due to the number of its gate that leads to making it faster than LSTM [11]. Furthermore, to extract more features and bidirectional dependencies, Bidirectional Long Short-Term Memory (Bi-LSTM) algorithm can be used. In this kind of algorithm, the sequence of the process can be done in two directions (forward and backward) using two different hidden layers [12].

2. LITERATURE REVIEW

Improving dynamic and distributed congestion control in vehicular ad hoc networks:

To provide reliable communications in Vehicular Ad hoc Networks (VANets), it is vital to take into account Quality of Services (QoS). Delay and packet loss are two main QoS parameters considered by congestion control strategies. In this paper, a Multi-Objective Tabu Search (MOTabu) strategy is proposed to control congestion in VANets. The proposed strategy is dynamic and distributed; it consists of two components: congestion detection and congestion control. In the congestion detection component, congestion situation is detected by measuring the channel usage level. In congestion control component, a MOTabu algorithm is used to tune transmission range and rate for both safety and non-safety massages by minimizing delay and jitter. The performance of the proposed strategy is then evaluated with highway and urban scenarios using five performance metrics including the number of retransmissions, average delay, and throughput. Simulation results show that MOTabu strategy significantly outperforms in comparison with other strategies like CSMA/CA, D-FPAV, CABS, and so on. Conducting congestion control using our strategy can help provide more reliable environments in VANets.

A hybrid deep learning based traffic flow prediction method and its understanding:

Deep neural networks (DNNs) have recently demonstrated the capability to predict traffic flow with big data. While existing DNN models can provide better performance than shallow models, it is still an open issue of making full use of spatial-temporal characteristics of the traffic flow to improve their performance. In addition, our understanding of them on traffic data remains limited. This paper proposes a DNN based traffic flow prediction model (DNN-BTF) to improve the prediction accuracy. The DNN-BTF model makes full use of weekly/daily periodicity and spatial-temporal characteristics of traffic flow. Inspired by recent work in machine learning, an attention based model was introduced that automatically learns to determine the importance of past traffic flow. The convolutional neural network was also used to mine the spatial features and the recurrent neural network to mine the temporal features of traffic flow. We also showed through visualization how DNN-BTF model understands traffic flow data and presents a challenge to conventional thinking about neural networks in the transportation field that neural networks is purely a “black-box” model. Data from open-access database PeMS was used to validate the proposed DNN-BTF model on a long-term
horizon prediction task. Experimental results demonstrated that our method outperforms the state-of-the-art approaches.

Optimized structure of the traffic flow forecasting model with a deep learning approach:

Forecasting accuracy is an important issue for successful intelligent traffic management, especially in the domain of traffic efficiency and congestion reduction. The dawning of the big data era brings opportunities to greatly improve prediction accuracy. In this paper, we propose a novel model, stacked autoencoder Levenberg-Marquardt model, which is a type of deep architecture of neural network approach aiming to improve forecasting accuracy. The proposed model is designed using the Taguchi method to develop an optimized structure and to learn traffic flow features through layer-by-layer feature granulation with a greedy layerwise unsupervised learning algorithm. It is applied to real-world data collected from the M6 freeway in the U.K. and is compared with three existing traffic predictors. To the best of our knowledge, this is the first time that an optimized structure of the traffic flow forecasting model with a deep learning approach is presented. The evaluation results demonstrate that the proposed model with an optimized structure has superior performance in traffic flow forecasting.

Artificial intelligence for vehicle-to-everything: A survey

Recently, the advancement in communications, intelligent transportation systems, and computational systems has opened up new opportunities for intelligent traffic safety, comfort, and efficiency solutions. Artificial intelligence (AI) has been widely used to optimize traditional data-driven approaches in different areas of the scientific research. Vehicle-to-everything (V2X) system together with AI can acquire the information from diverse sources, can expand the driver's perception, and can predict to avoid potential accidents, thus enhancing the comfort, safety, and efficiency of the driving. This paper presents a comprehensive survey of the research works that have utilized AI to address various research challenges in V2X systems. We have summarized the contribution of these research works and categorized them according to the application domains. Finally, we present open problems and research challenges that need to be addressed for realizing the full potential of AI to advance V2X systems.

Visualizing and understanding recurrent networks

Recurrent Neural Networks (RNNs), and specifically a variant with Long Short-Term Memory (LSTM), are enjoying renewed interest as a result of successful applications in a wide range of machine learning problems that involve sequential data. However, while LSTMs provide exceptional results in practice, the source of their performance and their limitations remain rather poorly understood. Using character-level language models as an interpretable testbed, we aim to bridge this gap by providing an analysis of their representations, predictions and error types. In particular, our experiments reveal the existence of interpretable cells that keep track of long-range dependencies such as line lengths, quotes and brackets. Moreover, our comparative
analysis with finite horizon n-gram models traces the source of the LSTM improvements to long-range structural dependencies. Finally, we provide analysis of the remaining errors and suggests areas for further study.

3. METHODOLOGY

Previous studies worked on road traffic and network traffic separately, and we investigated them in the literature review. However, most of them addressed the traffic problem on the road or in the network independently, while in this paper, we will discover the relation between road and network traffic parameters together with the aim of network traffic prediction. Intelligent ways via machine learning (ML) techniques are the optimum solutions that can address traffic prediction problems with the aim of traffic flow prediction.

Disadvantages:

1. By increasing the number of vehicles and traffic on the road, the number of packets sent would grow, leading to network traffic.
2. Less accuracy of prediction in data traffic flow.

In this paper, we propose a model for predicting network traffic by considering the parameters that can lead to road traffic happening. The proposed model integrates a Random Forest-Gated Recurrent Unit- Network Traffic Prediction algorithm (RF-GRU-NTP) to predict the network traffic flow based on the traffic in the road and network simultaneously. This model has three phases including network traffic prediction based on V2V communication, and network traffic prediction considering road traffic happening based on V2V and V2R communication. The hybrid proposed model which implements in the third phase, selects the important features from the combined dataset (including V2V and V2R communications), by using the Random Forest (RF) machine learning algorithm, then the deep learning algorithms to predict the network traffic flow apply, where the Gated Recurrent Unit (GRU) algorithm gives the best results.

Advantages:

1. the proposed RF-GRU-NTP model has better performance in execution time
2. The proposed RF-GRU-NTP model has better performance in prediction errors than other algorithms which used for network traffic prediction.
MODULES:

To implement the mentioned project, we have designed the following modules:

- **Data exploration:** Using this module, we will load data into the system.
- **Processing:** Using the module, we will read data for processing.
- **Splitting data into train & test:** Using this module, data will be divided into train & test.
- **Model generation:** Building the model - Deep Learning - CNN, CNN+LSTM, LSTM, BiLSTM, RNN, GRU, and CNN with KFoldValidation and Machine Learning - Random Forest, Decision Tree, KNN, Support Vector Machine, and Voting Classifier.
- **User signup & login:** Using this module, users will get registration and login.
- **User input:** Using this module, users will give input for prediction.
- **Prediction:** Final predicted results will be displayed.

4. IMPLEMENTATION

**ALGORITHMS:**

**CNN:**

A CNN is a kind of network architecture for deep learning algorithms and is specifically used for image recognition and tasks that involve the processing of pixel data. There are other types of neural networks in deep learning, but for identifying and recognizing objects, CNNs are the network architecture of choice.

**CNN+LSTM:**

A CNN-LSTM model is a combination of CNN layers that extract the feature from input data and LSTMs layers to provide sequence prediction. The CNN-LSTM is generally used for activity recognition, image labeling, and video labeling.

**LSTM:**

LSTM stands for long short-term memory networks, used in the field of Deep Learning. It
is a variety of recurrent neural networks (RNNs) that are capable of learning long-term dependencies, especially in sequence prediction problems.

BiLSTM:

A bidirectional LSTM (BiLSTM) layer learns bidirectional long-term dependencies between time steps of time series or sequence data. These dependencies can be useful when you want the network to learn from the complete time series at each time step.

RNN:

Recurrent neural networks (RNNs) are the state of the art algorithm for sequential data and are used by Apple's Siri and Google's voice search. It is the first algorithm that remembers its input, due to an internal memory, which makes it perfectly suited for machine learning problems that involve sequential data.

GRU:

Gated recurrent units (GRUs) are a gating mechanism in recurrent neural networks, introduced in 2014 by Kyunghyun Cho et al. The GRU is like a long short-term memory (LSTM) with a forget gate, but has fewer parameters than LSTM, as it lacks an output gate.

Random Forest:

Random forest is a Supervised Machine Learning Algorithm that is used widely in Classification and Regression problems. It builds decision trees on different samples and takes their majority vote for classification and average in case of regression.

Decision Tree:

A decision tree is a non-parametric supervised learning algorithm, which is utilized for both classification and regression tasks. It has a hierarchical, tree structure, which consists of a root node, branches, internal nodes and leaf nodes.

KNN:

The k-nearest neighbors algorithm, also known as KNN or k-NN, is a non-parametric, supervised learning classifier, which uses proximity to make classifications or predictions about the grouping of an individual data point.

Support Vector Machine:

Support Vector Machine (SVM) is a supervised machine learning algorithm used for both classification and regression. Though we say regression problems as well its best suited for classification. The objective of SVM algorithm is to find a hyperplane in an N-dimensional space that distinctly classifies the data points.

Voting Classifier:

A voting classifier is a machine learning estimator that trains various base models or estimators and predicts on the basis of aggregating the findings of each base estimator. The aggregating criteria can be combined decision of voting for each estimator output.
5. EXPERIMENTAL RESULTS

Fig.3: Home screen

Fig.4: User registration

Fig.5: user login

Fig.6: User input

Fig.7: Prediction result

6. CONCLUSION

In this paper, we proposed an RF-GRU-NTP model with the aim of network traffic flow prediction based on the traffic in the road and network simultaneously. We divided our research into three phases. In the first phase, we focused on network traffic prediction. We used the V2R dataset and considered the receiving packets sent by vehicles to the RSUs as a network parameter to predict network traffic flow. Then, we tried different machine learning algorithms like the RF, NB, KNN, and SVM algorithms, and we evaluated them using some classification metrics. After all evaluations, the RF has the better performance to predict network traffic flow while our target was “packet receiving.” In the second phase, we tried to predict the road traffic flow using the V2V dataset while our target was “sender speed” to define the road traffic. We assumed that the traffic would happen on the road if the senders’ speed were less than 60 Km/h. Therefore, we implemented different deep learning algorithms, including the LSTM, GRU, and Bi-LSTM. Finally, we evaluated the results using some regression evaluation metrics, which, based on the results we got, the GRU was the fittest algorithm for road traffic prediction. Then at the third phase, we implemented our
target, which is network traffic flow considering road traffic flow, by combining machine learning and deep learning algorithms. For this purpose, we combined V2V and V2R datasets, and used the RF algorithm for feature selection. We found the most important features, which were “packet receive” and “receiver speed” that can affect “sender speed” and the network traffic flow. Then by implementing the proposed RF-GRU-NTP model, we predicted network traffic flow. Therefore, we compared our results with a pure algorithm like LSTM and Bi-LSTM to make sure that the proposed model has good results in network traffic flow prediction. The main complexity of the proposed model was combining two datasets in order to implementing machine learning and deep learning algorithms with the aim of network traffic prediction considering different types of parameters. To the best of our knowledge, this is the first research that predicts the network traffic flow based on road traffic flow. However, by growing up the number of vehicles, the volume of produced data by them would take shape of big data which in our future work we will implement our proposed model in big data.

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