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A SURVEY OF ROAD TRAFFIC PREDICTION WITH DEEP LEARNING

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Abstract

Road traffic prediction is a problem that can be approached in a variety of ways using various methods. Real-time road traffic prediction is an important feature in Intelligent Traffic Systems(ITS). The forecasts created by these systems have a major impact on the regulation of the road traffic on all types of freeways. Current systems of road traffic prediction do not make full use of the available resources. This project aims to demonstrate the potential benefits of incorporating the concepts of deep learning in order to predict traffic flow in the short term. The available data on traffic flow can be used to train a deep neural network to recognize patterns and give a short-term forecast for traffic flow for a particular area. This, in addition to the existing GPS-based system which gives data about real-time traffic, can potentially be used to significantly improve the accuracy and efficiency of short term traffic prediction.

***Keywords*:** deep learning, recurrent neural networks, LSTM, traffic flow prediction

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1 INTRODUCTION

Traffic flow prediction is a major task involved in intelligent traffic systems(ITS). It is important for governments, municipalities and corporations to get involved in improving the accuracy of short-term traffic predictions, which would improve the lives of the general populace. It can help road users make better travel decisions. There is also the possibility of reduced carbon emissions and improved traffic operation efficiency. Accurate real-time traffic flow prediction can provide information and guidance for road users to optimize their travel decisions and to reduce costs, and help authorities with advanced traffic management strategies to mitigate congestion.

But the problem of accurate traffic prediction is a challenging one. Traditional methodologies for traffic prediction include models like autoregressive integrated moving average(ARIMA), multivariable linear regression, and support vector regression. However, these linear models do not consider the entire range of features involved in traffic flow and hence do not perform very well. [1] Also, due to the stochastic and nonlinear feature in traffic flow, the parametric approaches with linearity cannot present a high performance for traffic flow prediction. Therefore, researchers have paid much attention to nonparametric approaches.[3]

Deep Learning[1] is one such nonparametric approach. It is a form of machine learning which is based in neural networks. By exploiting the dependencies in the high-dimensional set of variables, we can capture the sharp discontinuities in traffic flow that emerge in large-scale networks. Deep-learning is increasingly being recognized as an essential tool for artificial intelligence research, with applications in several areas. One such area is traffic flow prediction. In recent years, the use of deep learning in traffic prediction has prompted research, which has been analysed in this paper.

2 LITERATURE REVIEW

2.1 Deep Learning Algorithms

Deep learning can be implemented via various algorithms, all of which involve learning a high dimensional function using a sequence of nonlinear transformations. Deep learning can be implemented through various frameworks, the most popular of which is TensorFlow. TensorFlow[10] is an open source library for computation involving graphs, and the deep architecture is organized as a graph. The graph nodes are called units. These units are connected by links, which trigger activation in subsequent units. Each link has a weight which determines the relative strength of the connection. Also, each unit applies a specified activation function to all of the weighted sum of the incoming activations. One type of deep learning model which uses a directed acyclic graph structure is called a feed-forward neural network. [1]

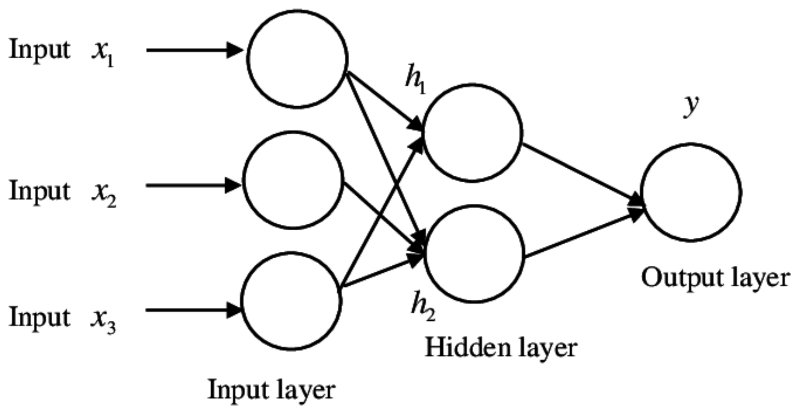

Figure 1: Feed forward neural network

Logistic Regression[12] is an algorithm which is most often used in feed forward networks and deep learning. It is often used in problems which involve binary classification. Logistic regression can be explained as a single-layer neural network, which uses either the sigmoid function or the tanh function as the activation functions.

The recurrent neural network(RNN), shown in Figure 2, is a generation of the feed forward neural networks which is adept in dealing with sequences. The structure of RNN is shown in Fig. 1. Given a general input sequence (x1;x2;:::;xk) where xi is an input state. A hidden state is obtained at each time step, resulting in a hidden sequence (h1;h2;:::;hk). The hidden state at time step t is calculated by the function

ht = f (xt;ht1) (1)

in which xt is the current input and ht1 is the previous hidden state. Then the optional output at each time step is calculated by yt = g(ht). The output of RNN can be a sequence as (y1;y2;:::;yk) or a single value yk which is dependent on the objective of the problems. [6]

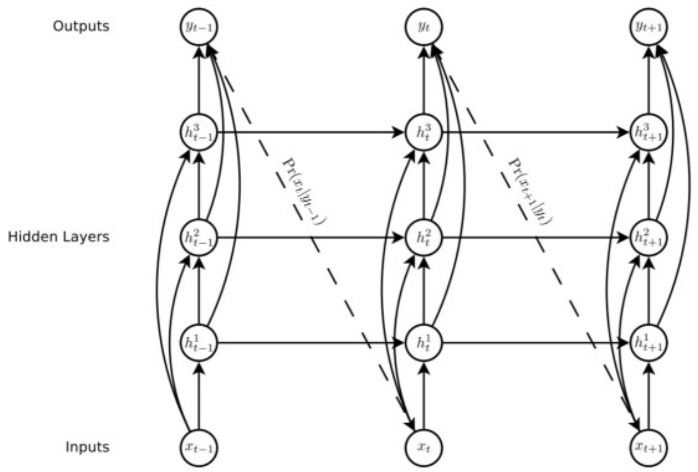

Figure 2: Recurrent neural network

Long short-term memory (LSTM)[9] unit, shown in Figure 3, is a building unit for layers of RNN. An RNN composed of LSTM units is often called an LSTM network. LSTM networks are applied for learning time series characteristics. They can also figure out hyperparameters automatically from data.

The LSTM module comprises of an input layer, a hidden layer, and an output layer. The hidden layer contains memory cells to memorize the temporal features. Hence the hidden layer is called the memory block. The input, forget and output gates control the

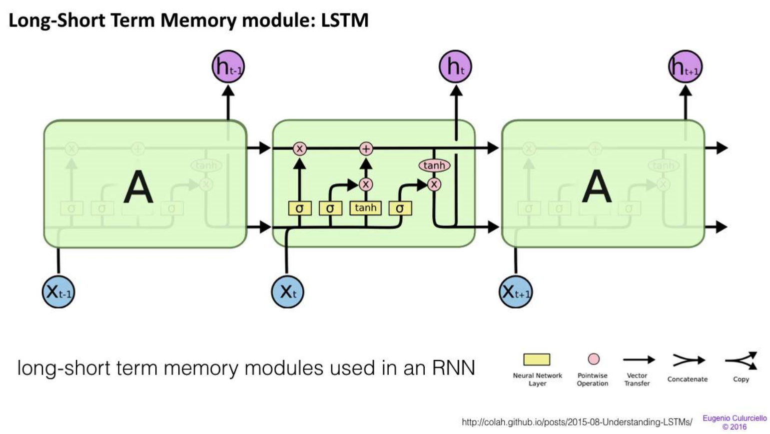

Figure 3: Long short term memory(LSTM) module

input, continual and output time series characteristics respectively. The memory cell state is recorded and the cell is recurrently self-connected. [4]

2.2 Traffic Data

The traffic data represent similar traffic conditions at the same day of the week and at the same time, and were already verified by conventional traffic theories and practical experience. Traffic information systems usually categorize historical traffic data corresponding to the day of the week, and then use them for traffic condition forecasting. The aggregated traffic data by day of week are defined as traffic condition pattern data.

In the field of transportation engineering, traffic conditions can be generally classified into two phases (congested and non-congested), three phases (congested, moderated and non-congested), or five phases (heavily congested, congested, lightly congested, non-congested, and free-flow). [6]

The traffic performance index as an indicator of traffic flow conditions, is as follows:
TPI=(Vmax Vi)/Vmax
where Vmax is the maximum speed of traffic data, and Vi is the average link travel speed at an i-th time period.

The TPI is a measure of magnitude of congestion, and gives a value between 0 and 1 inclusive, where 1 is a traffic jam state and 0 is a free flow state. A traffic jam state means that no vehicles can move, whilst a free flow state means that all vehicles travel at maximum speed with no influence from other vehicles. [5]

Traffic flow prediction depends on historical and real-time traffic data collected from various sources. These sources include sensors, cameras, mobile GPS, crowd sourcing, social media, etc. Traffic data is exploding with the combination of traditional traffic sensors and new traffic sensor technologies, crowdsourced data and big data. [2]

2.3 Metrics

Metrics are performance indexes which are used to evaluate the performance of the model. Two common performance indexes used as metrics are the mean absolute percentage error(MAPE) and the RMS error (RMSE), which are defined as below:

"The mean absolute percentage error (MAPE) is a measure of prediction accuracy of a forecasting method. It usually expresses accuracy as a percentage.

Root Mean Square Error (RMSE) is the standard deviation of the residuals (prediction errors), which are a measure of how far from the regression line data points are."

Comparison of the various algorithms with respect to the metrics, observed over a period of 30 minutes, are given in Table 1[4]:

Table 1: Comparison of different algorithms – autoregressive integrated moving average (ARIMA), deep belief networks (DBN) and long short term memory (LSTM) - using the specified metrics.

Algorithm	MAPE(%)	RMSE(veh/h)
ARIMA	25.95	413.86
DBN	20.19	374.33
LSTM	19.55	346.83

3 CONCLUSION

The various papers regarding road traffic flow prediction and deep learning have been evaluated. The main drawback of deep learning seems to be that it is not viable for large-scale networks. Hence, the papers evaluated all considered a small area or junction to evaluate. Various deep learning algorithms have been proposed and analysed. Out of these, recurrent neural networks(RNNs) are the most viable and give the most accurate results, as seen from Table 1. This is because recurrent neural networks is the deep architecture which can best evaluate time series data, such as traffic data. Therefore, it is worth conducting further research into using recurrent neural networks in traffic flow prediction, using an algorithm such as logistic regression or softmax regression, which is a generalization of logistic regression.

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