Department of Computing and Information Systems
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Masters Thesis

A Deep Recurrent Network for Traffic Prediction

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A thesis submitted in fulfilment of the requirements for the degree of Master of Science in Computer Science

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Declaration of Authorship

I , Rabindra Kumar PANDA, certify that

- this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person where due reference is not made in the text.
- the thesis is approximately 20000 words in length (excluding text in images, table, bibliographies and appendices).

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Abstract

Road traffic congestion is a serious global issue, resulting in significant wastage of resources. While improving and extending the road infrastructure has reduced the issue to some extent, this is time consuming and limited. Thus in last few decades, for better planning and control of road traffic, adaptive traffic control systems have been deployed around the world. Still the role of adaptive control systems is not fully realised without predictive capabilities in the short term. A lot of research has gone into proposing short term traffic prediction models, yet none of those models can be claimed to be perfect due to the nature of traffic data and the variable factors that affect it.

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Abbreviations

ARIMA **A**uto **R**egressive **I**ntegrated **M**oving **A**verage

Symbols

Σ Covariance matrix

Dedicated to my parents

Chapter 1

Introduction

"As a reader I loathe introductions...Introductions inhibit pleasure, they kill the joy of anticipation, they frustrate curiosity."

Harper Lee, *To Kill a Mockingbird* (1960)

1.1 Background

Road traffic congestion is a serious global issue, resulting in significant wastage of resources. While improving and extending the road infrastructure has reduced the issue to some extent, this is time consuming and limited. Thus in last few decades, for better planning and control of road traffic, adaptive traffic control systems have been deployed around the world. Still the role of adaptive control systems is not fully realised without predictive capabilities in the short term. A lot of research has gone into proposing short term traffic prediction models, yet none of those models can be claimed to be perfect due to the nature of traffic data and the variable factors that affect it.

1.2 Objectives and scope

Research objective is to propose a new model that can use the large amount of available traffic data to predict the traffic in the short term. More importantly this research tries to answer the following questions -

- Can we design a deep neural network for traffic flow prediction?
- Are we confident that the proposed model is better than existing models?

Research scope - There are several traffic characterstics that can be predicted such travel time and traffic volume. The scope of this research is limited to only traffic volume. While doing so, we are only taking the past data into consideration and ignoring other external factors such as weather, public events etc.

1.3 Thesis outline

Chapters – This thesis is divided into six chapters.

- Chapter 1: Introduction - In this chapter we present the background and research context, research objectives and scope.
- Chapter 2: Traffic Prediction: Literature Review - In this chapter we review the past research done in the area of short-term traffic flow forecasting.
- Chapter 3: SCATS Traffic Volume Data - In this chapter we present the traffic volume data collected by VicRoads using the SCATS volume data.
- Chapter 4: A Deep Recurrent Network for Traffic Flow Prediction - In this chapter we propose a model that can be used in forecasting short-term traffic flow.
- Chapter 5: Evaluation of the Model - In this chapter we evaluate the model.
- Chapter 6: Conclusions and Future Directions - Finally we conclude

Chapter 2

Traffic Prediction: Literature Review

"There is no way that we can predict the weather six months ahead beyond giving the seasonal average"

Stephen Hawking, *Black Holes and Baby Universes* (1993)

2.1 Introduction

This objective of this chapter is to provide a reasonably complete review of existing literature on short term traffic flow prediction. In the context of traffic congestion the the forecasting window of traffic flow is very important.

After three decades of intensive research, short term traffic flow prediction is still a subject of interest for many professionals around the world. The various methods that have been applied in the area of traffic prediction can be in general categorised as parametric and nonparametric methods. The parametric metric methods include linear and non-linear regression, Kalman filter and ARIMA and its variants. The nonparametric methods include nonparametric regression, support vector machines and neural networks.

2.2 Parametric models

In parametric models, we estimate the parameters from the training dataset to determine the function that classifies new unseen data. The number of parameters are fixed. The advantage of parametric models are that these perform quite well in situations where the large amount of data is not available. Some of the typical examples of parametric models include time series regression, ARIMA models, Kalman filter, linear SVM etc.

2.2.1 Linear regression

In machine learning and statistical applications, the use of linear models are predominant. These models are also important in time series domains such as traffic flow prediction. The primary idea behind the regression is to express the output variable as a linear combination of input vectors. We can express the linear regression in time series as an ouput influenced by a collection of inputs, where the inputs could possibly be an independent series

$$x_t = \beta_1 z_{t1} + \beta_2 z_{t2} + ... + \beta_q z_{tq} + w_t \tag{2.1}$$

where $\beta_1, \beta_2, ..., \beta_q$ are unknown regression coeffiecients and w_t is a random error.

2.2.2 ARIMA

ARIMA(Auto Regressive Integrated Moving Average) is a class of parametric regression models. In this section we will introduce ARIMA and related methods such as exponential smoothing and moving averages. For an in depth understanding of these models the reader is encouraged to refer to to Tong [159], Brockwell and Davis [17] and Box et al. [15].

The main idea behind autoregressive models is that past values affect the present value, i.e. x_t can be expressed as a function of past p values $x_{t-1}, x_{t-2}, ..., x_{t-p}$, where p is the number of steps into the past. We can express an autoregressive model of order p as below

$$x_t = \alpha_1 x_{t-1} + \alpha_2 x_{t-2} + ... + \alpha_p x_{t-p} + w_t \tag{2.2}$$

where x_t is stationary and $\alpha_1, \alpha_2, ..., \alpha_p$ are constants. We have added the term w_t as a Guassian white noise.

Ahmed and Cook [4] used Box-Jenkins method for short-term traffic forecast. The input data used was 166 sets of time series traffic data collected by freeway traffic surveillance

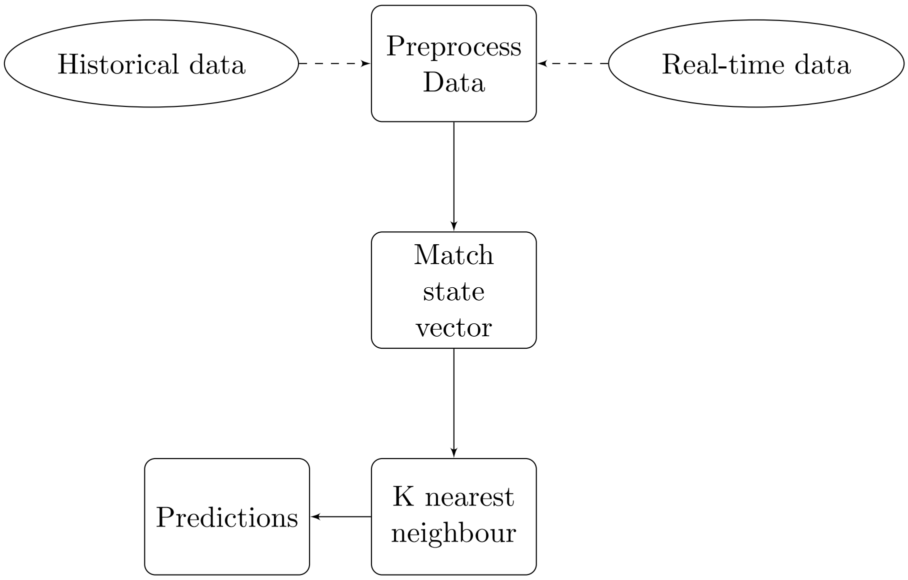

FIGURE 2.1: K nearest neighbour process flow

systems in three locations - Los Angeles, Minneapolis and Detroit. The authors concluded an ARIMA(0,1,3) model as a resonable fit for the short term prediction task.

Kumar and Vanajakshi [105] used a seasonal ARIMA in a context of limited data for short term traffic prediction.

2.2.3 Kalman filter

2.2.4 Other parametric models

2.3 Nonparametric models

In nonparamtric models the parameters are not fixed, and vary with the amount of data available. Usually more data is required for this models than parametric models. The advantage of these models is that they can model the complex non-linear data better. Some of the widely used nonparametric models are - k-Nearest Neighbour, Non-parametric regrssion and Neural Networks

2.3.1 k-Nearest neighbour

The basic process of the k-nearest neighbour algorithm can be described as in the figure 2.1

2.3.2 Nonparametric regression

2.3.3 Support vector machines

2.3.4 Neural networks

2.3.5 Other nonparametric models

2.4 Other Methods

2.4.1 Knowldge Based Systems

2.4.2 Hybrid Methods

2.5 Comparisons

Chapter 3

SCATS Volume Data

“There is no order in the world around us, we must adapt ourselves to the requirements of chaos instead.”

Kurt Vonnegut, *Breakfast of Champions* (1973)

3.1 Introduction

SCATS (Sydney Coordinated Adaptive Traffic System) is an adaptive traffic control system.

3.2 Traffic Loop Detectors

3.2.1 Handling Missing Data

3.3 Exploratory Analysis

The plot 3.1 shows the daily, weekly, monthly and yearly average traffic volume at a site location.

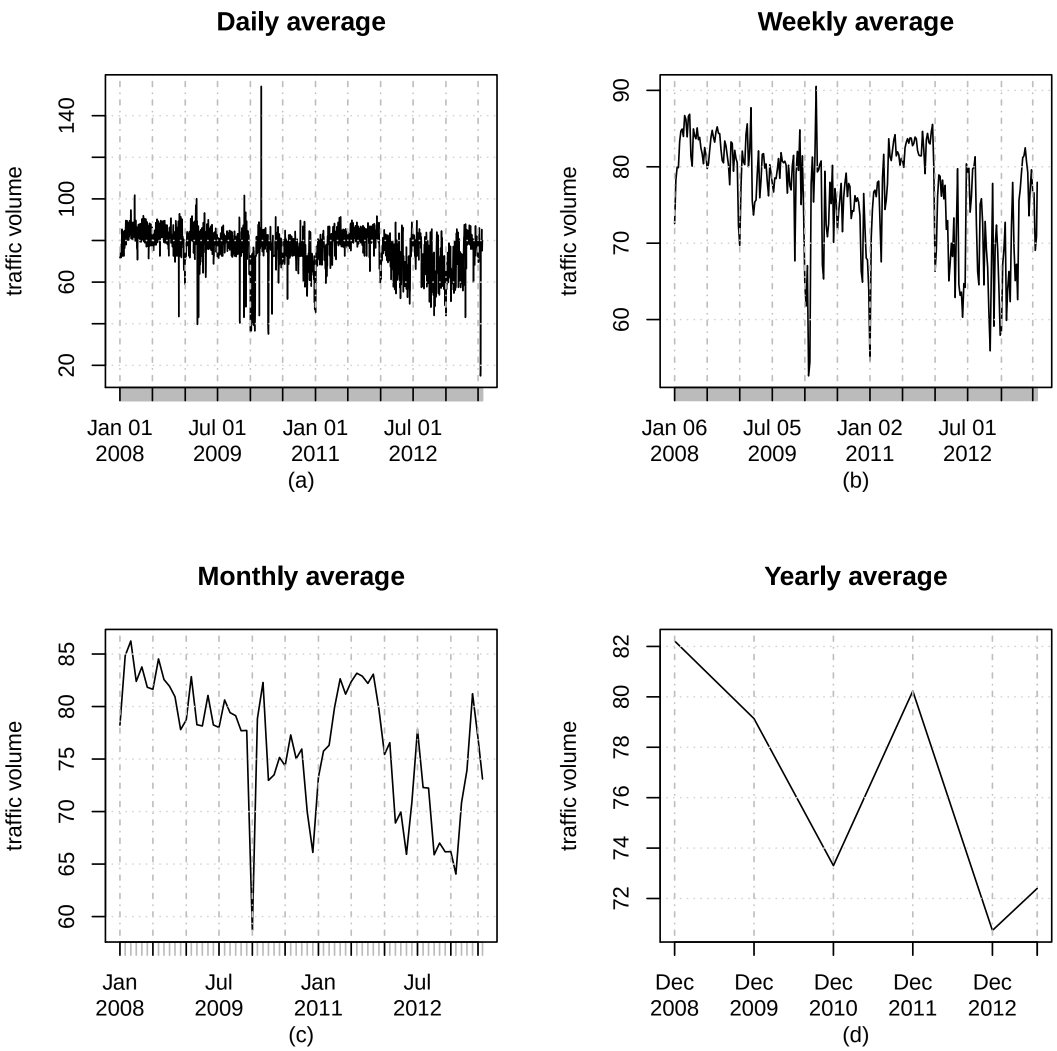

FIGURE 3.1: (a) daily, (b) weekly, (c) monthly and (d) yearly average of traffic volume (15 mins interval) at a site location from the period 01/01/2008 to 26/07/2013

Chapter 4

A Deep Recurrent Network Model for Traffic Flow Prediction

"I am a brain, Watson. The rest of me is a mere appendix."

Arthur Conan Doyle, *The Adventure of the Mazarin Stone* (1921)

4.1 Introduction

4.2 Recurrent neural networks

4.3 LSTM Netowrks

The results of the LSTM are shown in the figure 4.1

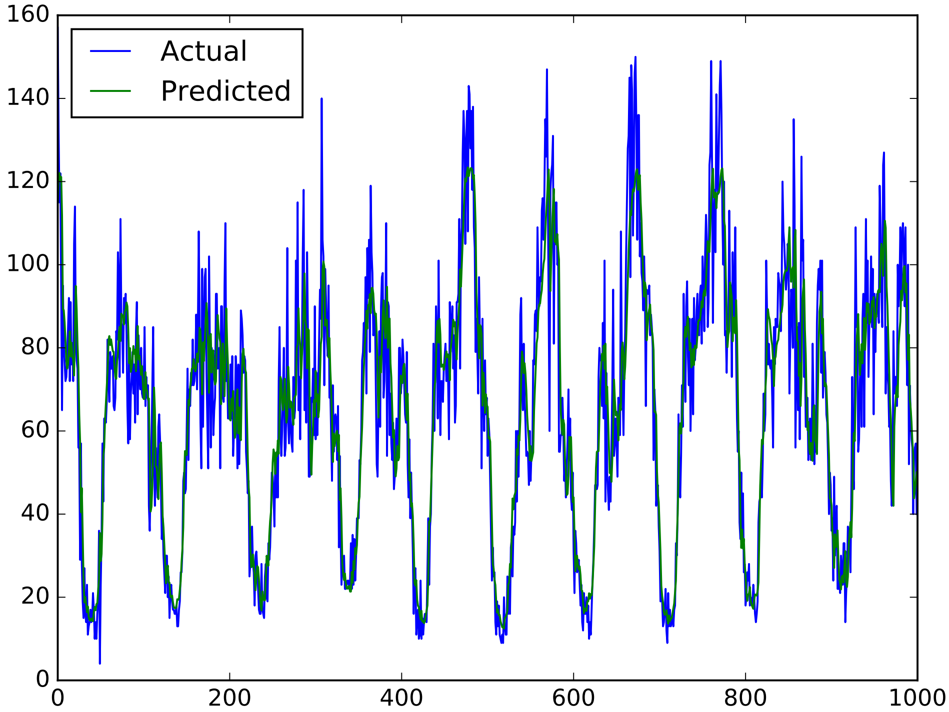

FIGURE 4.1: Long Short Term Memory predictions vs actual test data for 1000 observations.

Chapter 5

Evaluation of the Model

“Science, my boy, is made up of mistakes, but they are mistakes which it is useful to make,because they lead little by little to the truth”

Jules Verne, *Journey to the Centre of the Earth* (1864)

5.1 Setup

5.2 Results

5.3 Evaluation

Chapter 6

Conclusions and Future Directions

"Everything should be made as simple as possible but not simpler."

Albert Einstein

Appendix A

Appendix Title Here

Write your Appendix content here.

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