A Smart Application for Predicting Network-wide Congestion Hot Spots under Adverse Weather Conditions

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NJDOT Annual Research Showcase
October 23rd, 2019

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Agenda

1 Introduction
2 Objective
3 Methodology
4 Application
5 Conclusions
INTRODUCTION

• Most of the studies are concerned about monitoring traffic conditions under adverse weather conditions.

• Previous studies predict traffic speed under normal conditions using deep learning using:
  - Deep Neural Networks
  - Recursive Neural Networks

• There are some research papers that use deterministic models to predict traffic speed under weather conditions, but they lack the ability to consider various weather variables.
Why to predict traffic congestion due to adverse weather conditions?

• Predict congestion hot spots due to adverse weather conditions for congestion mitigation plans

• Allocate larger resources to higher congestion hot spot segments at certain times depending on the output of the application
BACKGROUND

- Adverse weather conditions that affect traffic speed can be categorized into:
  - Rain Conditions
  - Fog Conditions
  - Snow Conditions

<table>
<thead>
<tr>
<th>Weather Conditions</th>
<th>Freeway Average Speed Reduction*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light Rain/Snow</td>
<td>3% - 13%</td>
</tr>
<tr>
<td>Heavy Rain</td>
<td>3% - 16%</td>
</tr>
<tr>
<td>Heavy Snow</td>
<td>5% - 40%</td>
</tr>
<tr>
<td>Fog</td>
<td>10% - 12%</td>
</tr>
</tbody>
</table>

Weather Conditions

- **Fog Conditions**: Increases vehicles headways and decreases traffic speed.
- **Rain Conditions**: Can cause Capacity reduction (10% - 30%) depending on the rain intensity.
- **Snow Conditions**: Snow accumulation impedes the traffic reducing the traffic speed.
- **Wind Conditions**: Wind conditions can reduce drivers’ visibility when combined with rain or snow conditions.
OBJECTIVE

• The objective of this study is to propose a smart application that predicts freeway congestion hot spots due to adverse weather conditions.

• This study provides a system that covers the New Jersey freeway network and can capture the effect of three different weather conditions:
  - Rain Conditions
  - Snow Conditions
  - Fog Conditions
Big data analysis is conducted on traffic speed and weather conditions data. Predictions of traffic speed under normal conditions are based on the traffic speed from previous time stamps. Predictions of traffic speed under adverse weather conditions are based on the output from traffic speed prediction under normal conditions and weather data. The Smart Application is based on real-time feed from the databases and shows a network-wide prediction of hot spot congestions.
DATABASE DEVELOPMENT

- Probe Vehicle Data
  - Captures Traffic Speed

- New Jersey Congestion Management Systems
  - Estimates Traffic Volume

- New Jersey Straight Line Diagram
  - Relates All the Databases in terms of Geographical Locations

- NOAA
  - Provides Weather Information
DISTRIBUTION OF THE ADVERSE WEATHER CONDITIONS IN TERMS OF (MILES-HOURS)

- Rain: 57%
- Fog: 32%
- Snow: 11%

*The data is based on weather conditions from 2014 until 2019 in all New Jersey Freeway Network*
RECURRENT NEURAL NETWORKS

Model Inputs

Hidden Layers

Model Outputs

\[ x_1 \rightarrow x_2 \rightarrow x_3 \rightarrow x_n \rightarrow y_1 \rightarrow y_2 \rightarrow y_3 \rightarrow \cdots \rightarrow y_m \]
Predicting Traffic Speed under Normal Conditions for the next 24 hours

Model Inputs
- Traffic Speed of previous 2 days

Model Outputs
- Prediction of Traffic Speed under Normal Conditions for the next 24 hours

Recurrent Deep Learning model through two hidden layers
The Model uses recurrent neural networks through four hidden layers to account for queuing congestions over time.
APPLICATION

• Heavy Rain occurred in July 22\textsuperscript{nd}, 2019
• The rain starts around 4:00 PM at some New Jersey areas and extends until 10:00 PM
• The analysis is conducted July 22\textsuperscript{nd}, 2019 at 1:00 PM (3 hours prior to the prediction starting time)
• Interstate-78 (Eastbound direction) is selected for further illustrations
• Hot spot congestion is considered when traffic speed is below 25 mph
NORMAL CONDITIONS VS. PREDICTED CONDITIONS
ACTUAL TRAFFIC SPEED VS. PREDICTED TRAFFIC SPEED (I-78 EASTBOUND)
MAPE VS. RMSE
(I-78 EASTBOUND)
CONCLUSIONS

• This model provides a smart application to predict hot spot congestion on a network level due to adverse weather conditions.

• Transportation agencies can use this application for congestion mitigation plans when adverse weather conditions are forecasted.

• The application can be used to optimize the resources when assigned to a network-wide locations depending on the predicted level of congestion.
RESEARCH OPPORTUNITIES

Opportunity #1
Database Coverage to Enhance the Application Performance

Opportunity #2
Incorporate the Application with New Jersey Best Practices

Opportunity #3
Include Mobility as a Service aspects to improve traveler decision choice
Thank You

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