Prediction of traffic intersection saturation rates with neural networks

https://github.com/tombado/Master-Thesis

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ABSTRACT

In this thesis a prediction of traffic intersection saturation rates will be made with the help of neural networks based on binary sensor data from several traffic intersections in North Holland. The saturation is an indication of how crowded the traffic intersection is. The value of saturation is calculated with algorithms, this value is labeled to the data and this data will be used to train and test a neural network. The neural network is a combination of CNN and RNN. Since the data that is provided should be considered as a time series, a RNN should be considered. The convolutional part of the neural network is a necessity, because the data will be processed into images. Finally, the data set will be split in a training and data set with a 80/20 split. The performance of the neural network will be tested by calculating the percentage of correctly predicted saturation rates.

KEYWORDS

Machine learning, CNN, RNN, traffic intersection, saturation

1 INTRODUCTION

"Traffic congestion is a serious topic that concerns most of the population. Due to the ever-increasing traffic demand, modern societies with well-planned road management systems, and sufficient infrastructures for transportation still face the problem of traffic congestion. This results in loss of travel time, and huge societal and economic costs. Constructing new roads could be one of the solutions for handling the traffic congestion problem, but it is often less feasible due to political and environmental concerns. An alternative would be to make more efficient use of the existing infrastructure." [1] Traffic management and control approaches are used to control the traffic flows and to prevent or reduce traffic jams, or more generally to improve the performance of the traffic system. A start on tackling this problem is to generate insight into traffic jams. A traffic jam generally translates to roads being overly saturated. For this project we are interested in the saturation of several traffic intersections in the North of Holland. The goal is to predict saturation rates of the intersections, based on the sensor data generated by the sensors that are currently measuring these intersections.

2 RESEARCH QUESTION

- Is it possible to predict the saturation rates of traffic intersections accurately with a combination of convolutional and recurrent neural networks, based on sensor data?
- Why should a convolutional neural network be used?
- Why should a recurrent network be used?

The research question can probably be answered within the three months of work that is reserved for writing the thesis. This assumption is based on previous work from my supervisors at HAL24K. They have experience in using this specific data set and also analyzing it. The sub questions will be answered by creating a theoretical framework that zooms in on the characteristics of the different neural networks that will be used.

3 METHODOLOGY

3.1 Data

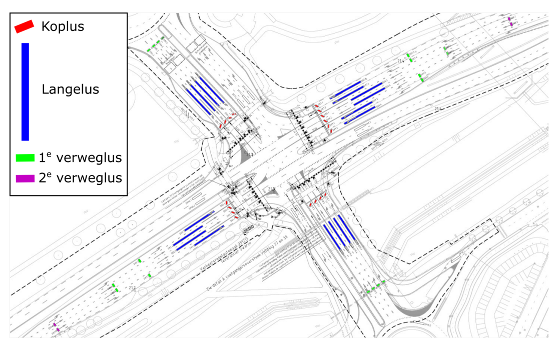

Figure 1: Traffic intersection

The data that is available is binary sensor data from several traffic intersections in the North of Holland. One intersection consists of 4 lanes on every side of the intersections. These 16 (4 sides, 4 lanes = 4 x 4) lanes each have 3 sensors (some lanes actually have 4 sensors, but this is not relevant for now); one in front of the traffic light, one in the middle of the lane and one at the far end of the lane that leads to the intersection. This results in a total of 48 (16 lanes, 3 sensors = 16 x 3) sensors. These sensors are binary; an output of 1 will be generated if a vehicle is on top of the sensor and an output of 0 will be generated if there is no vehicle on the sensor (assuming vehicles are the only entities that enter the intersection that trigger the sensor). These sensors provide an output every 0.1 second. In 2 years, around 2.5 billion of these outputs have been generated, which will be used for this project.

	FC0	DP0	DP1	DP2	FC1	DP3	DP5	DP7	DP9
time									
07:32:30.100	Rood	0	0	0	Rood	0	1	0	0
07:32:31.000	Rood	0	0	0	Rood	0	1	0	0
07:32:31.100	Rood	0	0	0	Rood	0	1	0	0
07:32:31.200	Rood	1	0	0	Rood	0	1	0	0
07:32:32.200	Rood	1	0	0	Rood	0	1	0	0

Figure 2: Slightly modified data

3.2 Data processing

The raw data needs some processing to get the most out of the data (in the case of my research project). Since a large slab of text does not tell a lot, the large slab of text is transformed into a schematic image of the intersection. Colours in the image will represent all the information from the raw data; colour of traffic lights, traffic light position and whether the sensors are on or off. This way, the slab of text is transformed into a comprehensible image that visualizes the state of the intersection. Now that the data is transformed into images, it can be used to train a convolutional network (CNN).

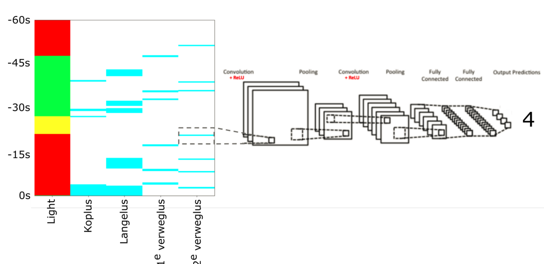

Figure 3: Data as image

3.3 Data labeling

The images that are created are unlabeled and thus need labeling in order to be used in a neural network. To label this data, the raw data is used. Two approaches are feasible. The first approach is to measure per lane how often the sensors are outputting a 1 during the period when a traffic light is green. The total time that these sensors are outputting a 1 divided by the total time the traffic light is green can provide a good estimation of the saturation at that moment. The second approach that might be feasible is to use an extra variable; queue length. Samuel and Michael have calculated the queue length of this exact data in a previous project. When the queue length (number of vehicles) is multiplied with the average vehicle length, a good estimation can be made of the queue length in meters. The length of the road entering the intersection is also known, assuming it starts at a sensor and ends at the traffic light. This makes it possible to calculate a saturation percentage for every lane. This is done by dividing the queue length in meters by the total length of the lane. More options might be considered during the project, firstly the focus will be on implementing and comparing these two approaches.

3.4 Neural networks and related work

Now that the data is labeled, neural networks can be used to analyze the problem. Since the data now consists of labeled images, the most straightforward approach is to use CNN. A CNN on its own is able to analyze images that are not related to each other in any way, except that they are part of the same data set. This case is different however. The images should be observed as a time series, since every image has a 0.1 second time difference for when the data was gathered and. Recurrent Neural Networks (RNNs), particularly those using Long Short-Term Memory (LSTM) hidden units, are powerful and increasingly popular models for learning from sequence data [2]. This means a hybrid neural networks needs to be created; one that is able to analyze image data that has the structure of time series. A similar research has been done where traffic data is analyzed by transforming it into images first, in order to use it as input for a convolutional neural network [3]. This indicates that the approach that is suggested in this paper is not uncommon in this field of research.

3.5 Evaluation of results

The data set that contains all the labeled images will be split in a training and test set. 80 percent of the data will be used for training and the other 20 percent will be used for testing. The results will be evaluated by comparing the predicted results of the neural network on the test set with the answers of the test set. The percentage of correct predictions is the result to be evaluated.

4 RISK ASSESSMENT

The data is available. No backup plan is needed.

5 PROJECT PLAN

04-Mar :First version of thesis design
11-Mar: Finalize thesis design
18-Mar: Calculate saturation in hindsight (method 1)
25-Mar: Calculate saturation in hindsight (method 2)
01-Apr: First day at HAL24K, hope to ask all my questions that week
08-Apr: Data to image implementation
15-Apr: Write introduction
22-Apr: Neural network implementations
29-Apr: Neural network implementations
06-May: First results done
13-May Go/no-go moment
20-May Improve results
27-May Write thesis / improve results
03-Jun Write thesis / improve results
10-Jun Deadline thesis
17-Jun Prepare presentation
24-Jun Thesis defense

REFERENCES

[1] Lakshmi Dhevi Baskar, Bart De Schutter, J. Hellendoorn, and Zoltán Papp. 2012. Traffic control and intelligent vehicle highway systems : A survey .

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[3] Xiaolei Ma, Zhuang Dai, Zhengbing He, Jihui Ma, Yong Wang, and Yunpeng Wang. 2017. Learning Traffic as Images: A Deep Convolutional Neural Network for Large-Scale Transportation Network Speed Prediction. *Sensors* 17, 4 (2017). https://doi.org/10.3390/s17040818