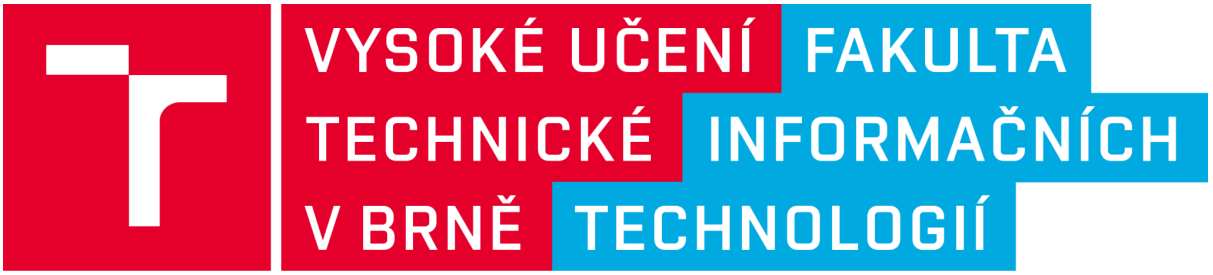

Simulation Study

T8 CA in traffic

10.12.2023

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Introduction

The goal of this work is to analyse and create simple cellular automata [IMS/211] that simulates the traffic on a specific junction, analyses the problem of predicted growth in population and its impact on the congestion and the suggested solution to the problem. This work is based upon the traffic analysis included in Bachelor's thesis BRNO, Křižíkova X Kociánka X Myslínova Crossroad - Study and verifies its solution to the increasing traffic problem.

Facts and data

The data important to this study is the information about the number of cars going from each direction in specific intervals. This data is extracted from the reference work.

From	**7:15**	**7:30**	**7:45**	**8:00**	**8:15**	**8:30**
To	**7:30**	**7:45**	**8:00**	**8:15**	**8:30**	**8:45**
A1	75	77	88	76	68	84
A2	55	49	51	48	39	35
B1	34	36	34	55	40	50
B2	8	4	5	6	5	10
C1	95	99	81	90	56	76
C2	12	6	8	4	3	5
D1	9	11	7	7	8	6
D2	8	4	12	4	5	10
Total	296	286	286	290	224	276

Figure 1: Number of cars going out of each direction
In a specific interval

The first set of data [Figure 1] is measured data from 2019 showing the current situation and the second part [Figure 2] is the predicted traffic for the year 2040. These will be used as input data to create probabilities of cars entering the system from said directions.

From	7:15	7:30	7:45	8:00	8:15	8:30
To	**7:30**	**7:45**	**8:00**	**8:15**	**8:30**	**8:45**
A1	95	98	88	76	86	107
A2	70	62	65	61	50	44
B1	43	46	43	70	51	64
B2	10	5	6	8	6	13
C1	121	126	103	114	71	97
C2	15	8	10	5	4	6
D1	11	14	9	9	10	8
D2	10	5	15	5	6	13
Total	376	363	363	368	284	351

Figure 2: Predicted data for year 2040

Conception

In this simulation the road network is represented as a 2D lattice, where each cell is of a class Point, this approach is chosen as simple integer values would not represent the system to the necessary depth. [IMS/212]
The road network is subdivided into road types and entry/exit that are used as reference by cars to determine their path. [Figure 3]
The road network is simplified to a level, where the problematic of the junction is kept but the representation can be converted to simple cells.
The car entry is simulated by taking the actual data for a specific point and calculating the probability of a car entry based on the time interval.

Each car has then a set of rules based on its Direction and Starting point.
The rules are based on the adjacent cells, wherever they are occupied by a car (simulates the driver looking around and deciding if he can proceed) and road types.
Certain road types that are not the main roads follow strict rules where they have to yield until a specific distance is unoccupied.

Then the road is reworked with a new lane for turning left from road type F to validate the claim of the reference paper that the addition of a new turning lane is the most effective way to solve the problem caused by the future growth of the traffic. [Figure 4]

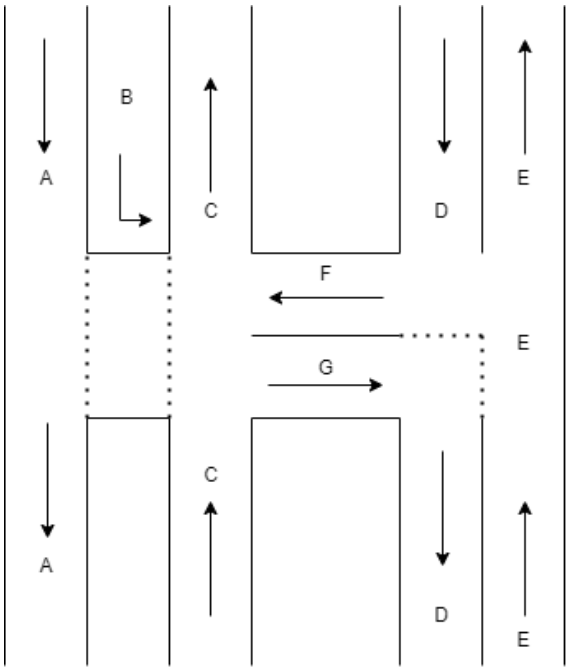


Figure 3: Road types and simplified representation of the junction

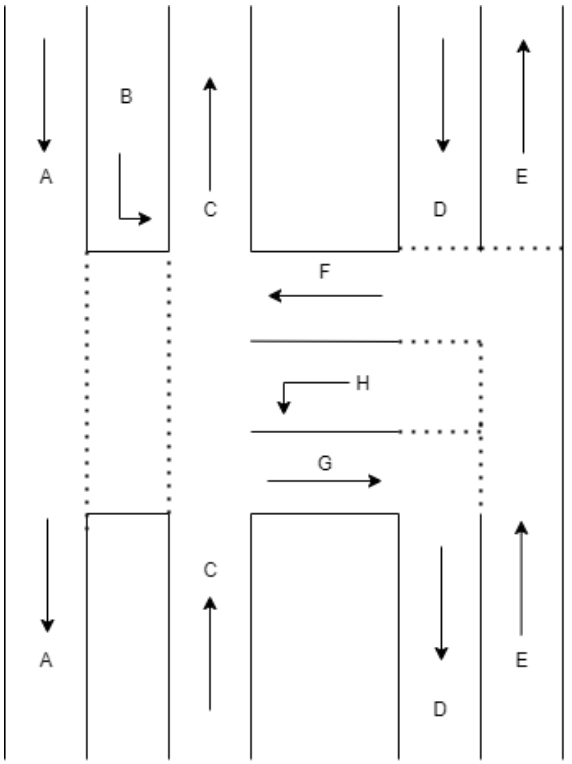


Figure 4: Implementation of the suggested solution to the traffic growth

Implementation

The lattice is realised as a static 2D array of Point classes. These classes are initialised to the corresponding road types.
Each car determines its action by taking its X,Y location in the lattice and checking X+n, Y+n spaces based on the path rules.
With the wide extent of the rules, the cell neighbourhood [IMS/213] is not of known type, but rather a custom format for the need of this model.

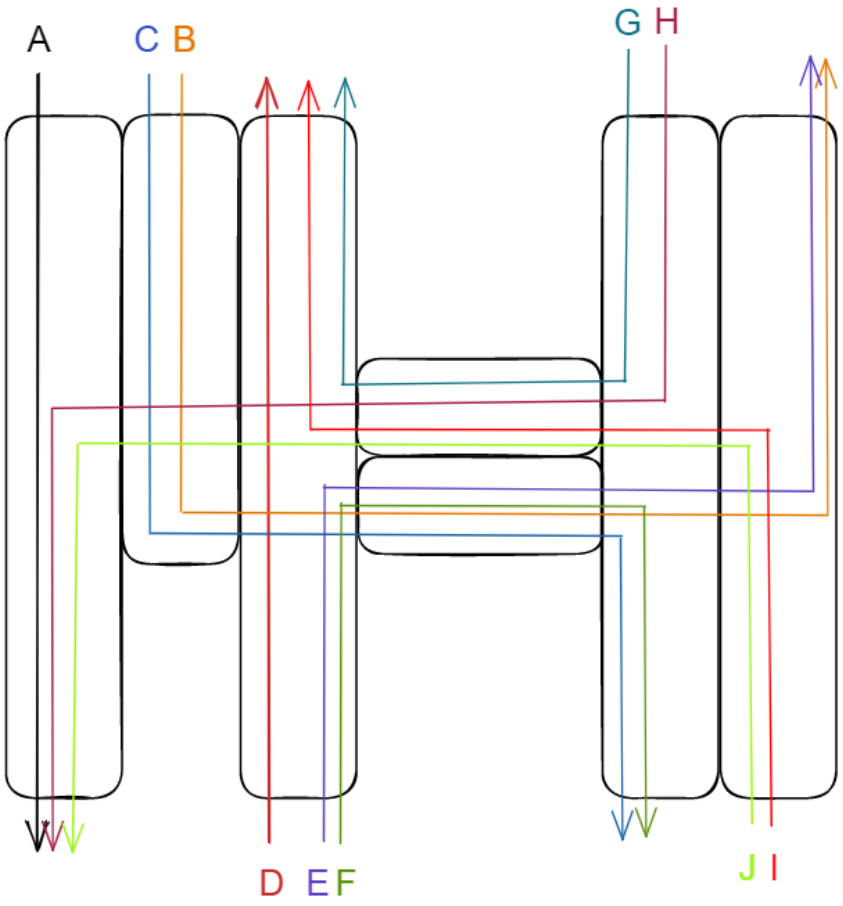


Figure 5: Paths in first road network implementation

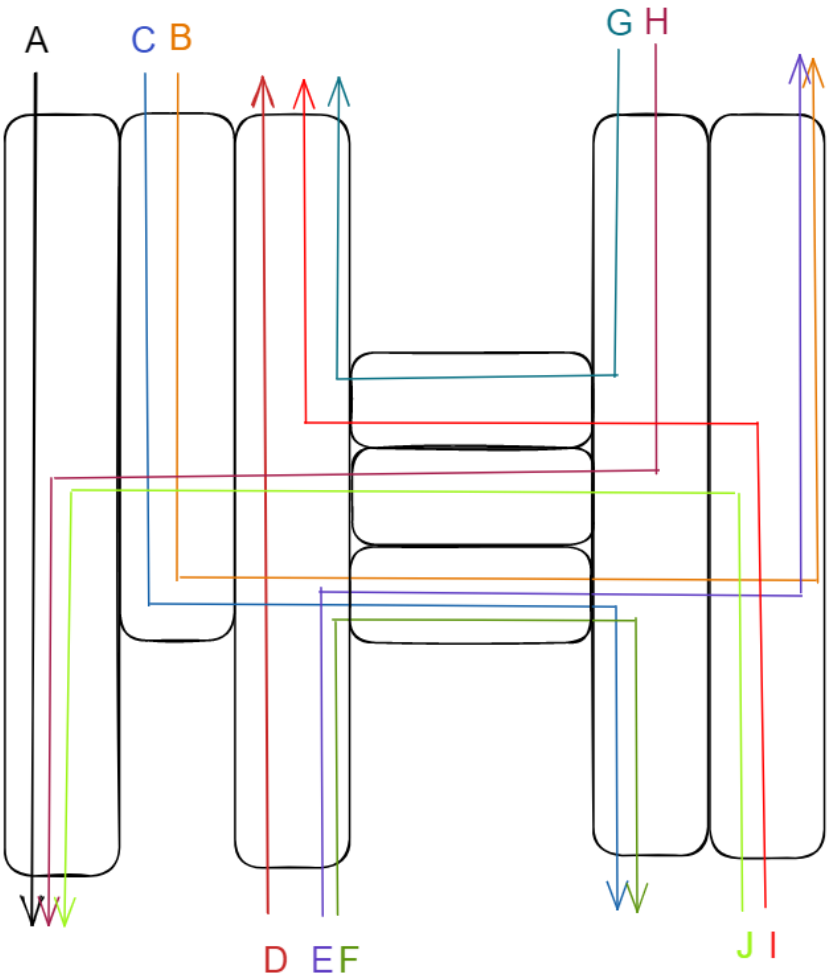
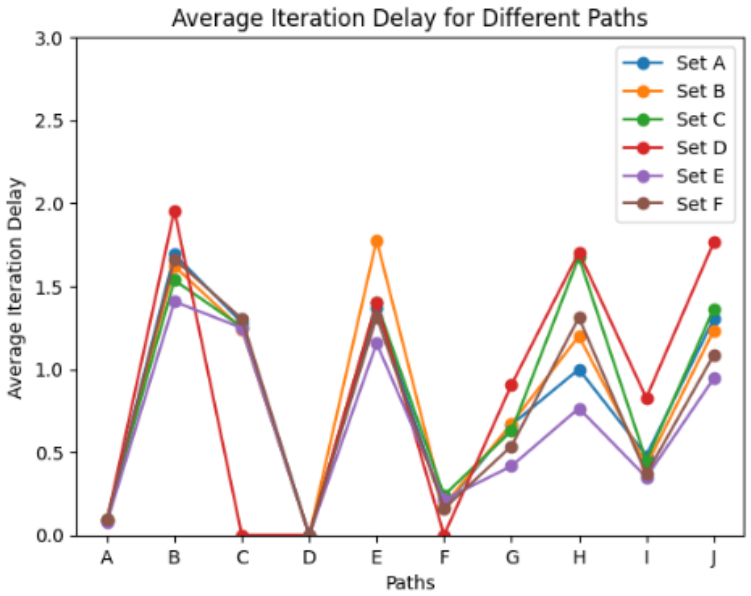


Figure 6: Suggested road rework implementation

The suggested rework of the road implements a new left turning lane to reduce the weight of the occasionally left turning vehicle, as in the original road, this vehicle would block the right turn as left turning in this situation is much more time consuming.

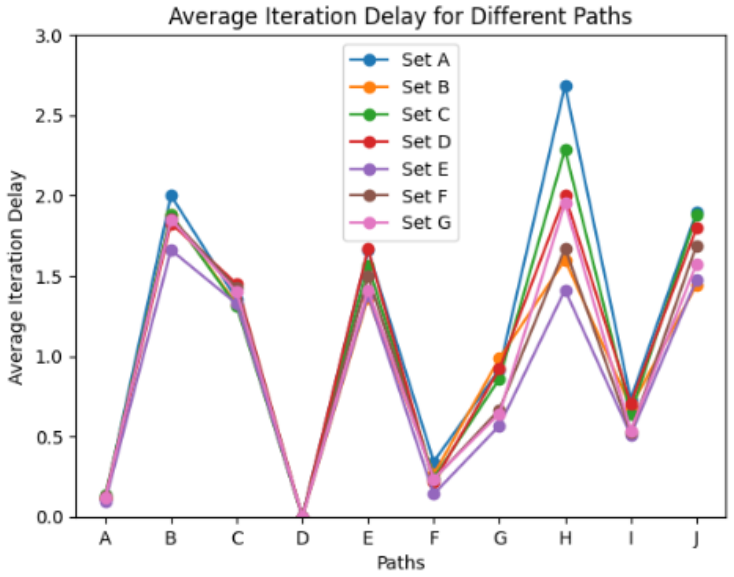
Experiments

The first round of experiments was concluded on the first set of traffic data with intervals of 15 minutes. The experiment shows significant traffic congestion on paths B, E and H. The delay is measured in how many iterations the car on a specific path had to wait on average for that specific path.



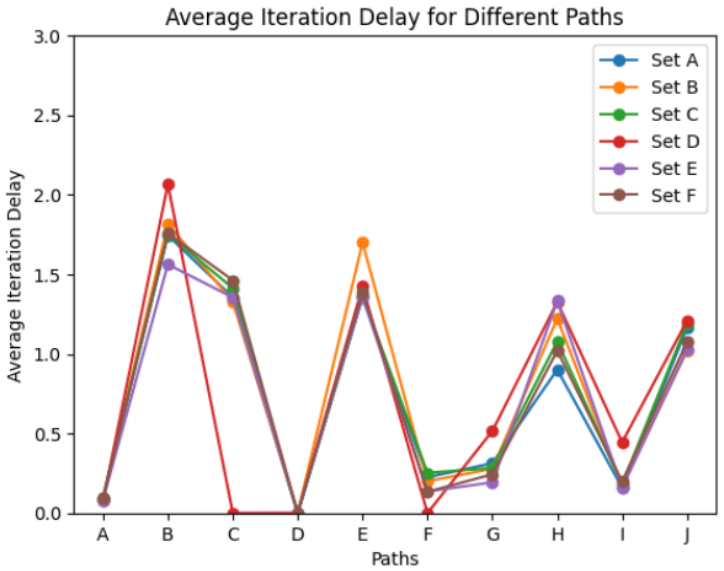
Graph 1: Simulation for 2019 data

The second simulation was done on the predicted data for 2024 with intervals of 15 minutes. The prediction shows a significant increase in delay on the path H which as expected.



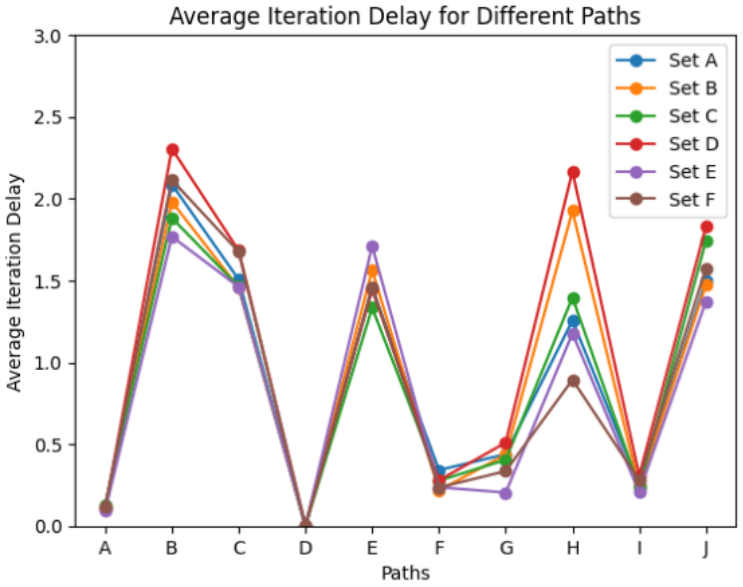
Graph 2: Simulation for 2040 predicted data

After verifying the results of the original data, the solution is implemented and simulated with the same number of cars, if the hypothesis is correct, then the traffic on path H should be impacted and significantly reduced.
With the original data of 2019 a change in congestion on path H can already be seen with smaller reductions on other paths and small increase on path B.



Graph 3: Simulation with the suggested solution with 2019 data

With already noticeable change in results the same experiment was replicated with the predicted data for 2040. The difference while being positive is not very significant, but in overall terms it does improve the traffic.



Graph 4: Simulation with the suggested solution on predicted data

Conclusion

Experiments plotted on graphs 1 and 2 do underline the issue as the increase of traffic becomes quite noticeable with the predicted data.
As the suggested solution to the traffic problem is implemented and simulations are run on the new road network, the new experiments yield improved data, but as for the predicted data, the improvement becomes less significant.
In the overall sense the suggested solution to the traffic problem does improve the situation and thus the original thesis and its claims are validated.

Testing and running the simulation

Included makefile can be run with these commands:

- make `run_simulation`
  - This commands runs the simulation with measured data and outputs into file outputSimulation.txt
- make `run_predictions`
  - This commands runs the simulation with measured data and outputs into file outputPrediction.txt
- make `run_solution_simulation`
- make `run_solution_predictions`

For graphing purposes a *graph.pynb* – Python Notebook is included containing 4 scripts for generating each graph shown in this study.

Simulation implementation is included in the file *model.cpp* and realised in C++.

The program is run as:
./model -a <A> -b <B> -c <C> -d <D> -e <E> -f <F> -g <G> -h <H> -i <I> -p <P>

Program Arguments

- Where **<A>** is a number of cars measured on point **A**
- Where **<B>** is a number of cars measured on point **B**
- Where **<C>** is a number of cars measured on point **C**
- Where **<D>** is a number of cars measured on point **D**
- Where **<E>** is a number of cars measured on point **E**
- Where **<F>** is a number of cars measured on point **F**
- Where **<G>** is a number of cars measured on point **G**
- Where **<H>** is a number of cars measured on point **H**
- Where **<I>** is a number of *iterations* in minutes
- Where **<P>** is a toggle for extended road network option

Makefile requires **gcc ++17** or higher.

The project has been successfully tested on Merlin.

Bibliography

HONZÍRKOVÁ, S. Studie úpravy křižovatky ulic Křižíkova x Kociánka x Myslínova v Brně [online]. Brno: Vysoké učení technické v Brně. Fakulta stavební. 2020.