Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

# Lecture with Computer Exercises:

# Modeling and Simulating Social Systems with MATLAB

## Project Report

# Traffic dynamics in Lugano

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Züruch

12.12.'12

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Traffic dynamics in Lugano

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# Index

# Introduction and Motivations

The reason for which we decided to analyze the traffic flow in Lugano is because many of us live near there, and are familiar with the traffic situation. Traffic has always been a serious problem in Lugano, which is known for its traffic jams and congestions. A new system was introduced during summer 2012 called PVP (Piano Viabilità del Polo Luganese), at the cost of 30 Million CHF, and the visible results are dubious.

The opinion of most car users is that the PVP has made traffic flow worse rather than better. Through our simulation we are trying to obtain quantitative data which will allow us to determine if the implemented system is an improvement, always within in the limitations of our simulation.

The source of the problem lies in the fact that very few people use public transport and that there are therefore too many commuters who travel in by car.
The idea behind the PVP is to increase the flow of traffic avoiding critical areas where it is known to be problematic. The observation we have made is that it seems to move the problem elsewhere instead of solving it once and for all.
The model also seems to count on discouraging the local people from using their own cars instead of the public services. The problem is that the Public transport system in Lugano is not capable of providing an adequate alternative to the cars, for the increased number of people. There are insufficient bus lines, the busses are often late and the fees are considered too high by many people especially considering how infrequently the busses run.

***<u>Facts about traffic in Lugano</u>***

All the data we are using was given to us by the city of Lugano in official documents, both for the city before and after the introduction of the new system. This data consists in the number of cars on every road both for rush hour and daily average, number of cars entering and exiting the city and also the internal traffic of the city.

The urban center of the city of Lugano is served by 15 access points (or entrances) which combined are crossed 200’000 times a day. 77’000 cars enter Lugano, 26’000 cars transit through the city and 120’000 vehicles travel inside the urban center without crossing the access points. This includes public transport.

***<u>How we used the data</u>***

In order to reproduce realistic traffic situations in the city of Lugano we implemented probabilities for the cars to enter and exit specific streets based on the data received with the official documents.

# Research questions

## **Does the average trip through town take less?**

We will be comparing cars in our simulation, which have travelled the same distance within a certain tolerance. Through comparison of the number of iterations (time blocks) the car took to travel a certain amount of grid blocks. We will be able to calculate an average speed which should increase as the road network becomes more efficient. We will use this as a benchmark for quality.

## **Was it worth the investment of 30’000’000 CHF?**

This is a hard question to answer because it is based on a persons opinion. Our decision will be based on the benchmark of quality and if in our judgment the increase justifies this investment.

## **Could there have been a better way to sort out the traffic issues of the city?**

In order to determine if there are better solutions we will create our own hypothetical road networks with our own traffic rules. These network will be using the average speed as a measurement of quality. Then through the process of exclusion find the smallest changes that have the biggest increase in quality. Through this process we are hoping to optimize quality gain to cost ratio.

# Description of the Model

Our program uses a system of Cellula automata in which we have a determined number of cars moving around a map. We had to use two maps to differentiate between before and after the implementation of PVP traffic system, these had to be drawn with straight lines only.
For each of the cars the program checks its surroundings (north, east, south and west) deciding on which direction the car has to move. There are different situations which we consider, whether straight roads, intersections, queues or dead ends.
For each of these we have created a function which controls how the cars have to move and what rules they have to follow.
Our primary aim is to reproduce the queues which occur in Lugano realistically and demonstrate how effective the two systems are at reducing these queues and increasing traffic flow.
All our data is saved as CSV files in folders along with a time stamp and a video, ready for analysis. We then compare the average times of cars travelling the same distance in order to have an overall idea of whether the new system is better or not.

# Implementation of the Model

***Matrix A***

In order to simulate the traffic system of the city of Lugano in our simulations we needed to create a map using straight lines, keeping it simple but still complete enough to reproduce a realistic situation. Whilst doing so we had to maintain the lengths of the roads and the distances between the intersections so as to allow the same traffic jam situations which occur in Lugano to present themselves.
We decided to consider 8 access points and 21 intersections cutting the traffic system down to what we considered important but still viable in the limited time at our disposal. In order to keep it simple we aren't considering secondary roads and outskirts which, in our view, have no influence on the traffic flow of the city.

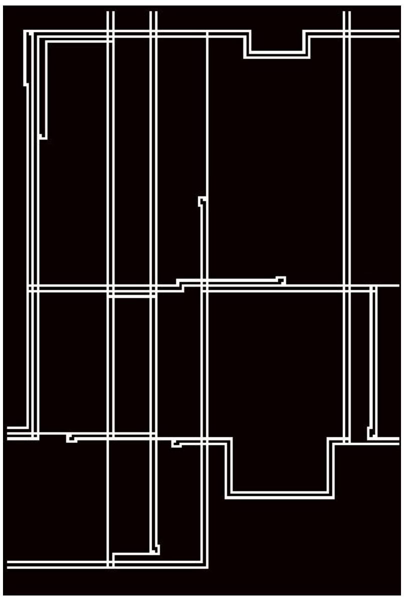
While adapting the map we decided to use a unit measure of 4 meters which is  the average length of a car (4 by 4 meters is represented as 1 pixel on our map) based on which we could reproduce the entire city.

Once we had drawn our map as a combination of straight lines we imported it into a matrix (called Matrix A) which we could then use in Matlab with the program itself.

The Matrix is composed of ones and minus ones which indicate road or not, it also contains a number from 3 to 21 which differs based on the number we have given to each intersection. These numbers tell the program how it has to act based on the rules every crossing has. We have calculated the probabilities which cars have of taking different roads thanks to the data supplied by the city of Lugano.  These change based on which map is considered whether before or after the new traffic system was introduced (more on that later).

The  area we are considering taken From Google Maps

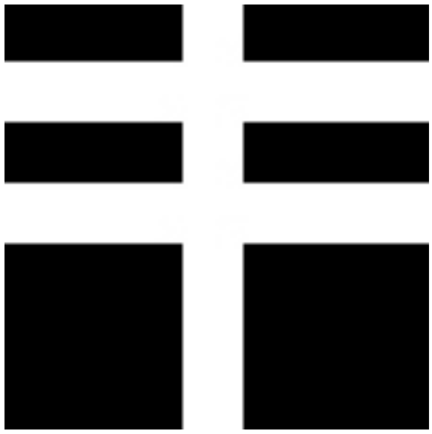

Our interpretation of the area used in the simulation



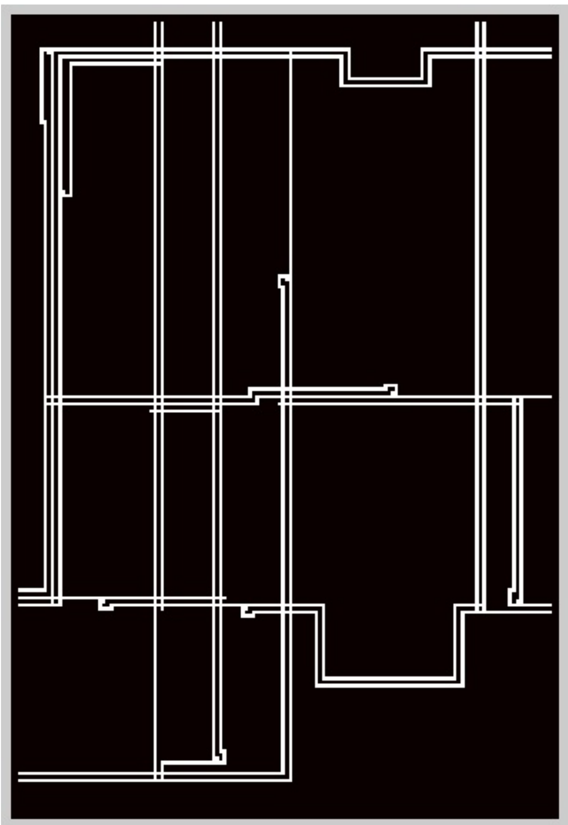
Matlab interpretation

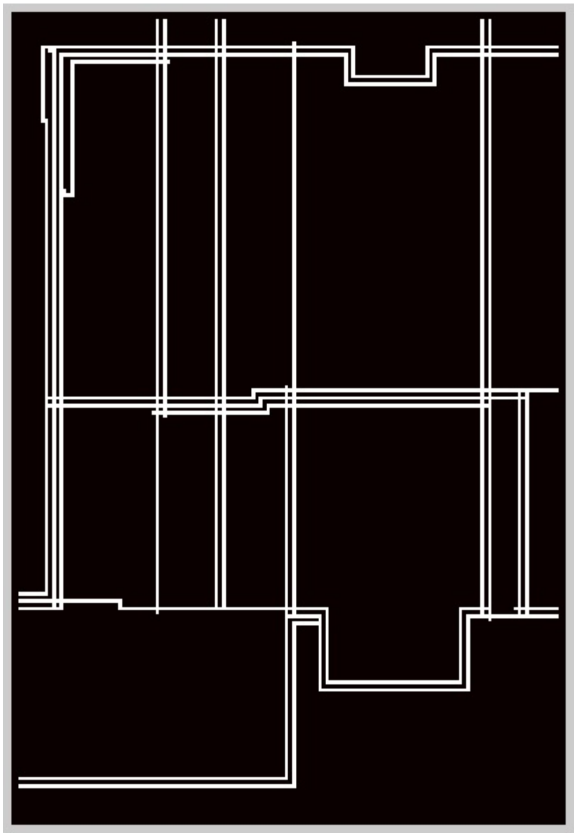
| | | | | | | |
|---|---|---|---|---|---|---|
| -1 | -1 | -1 | 1 | -1 | -1 | -1 |
| 1 | 1 | 1 | X | 1 | 1 | 1 |
| -1 | -1 | -1 | X | -1 | -1 | -1 |
| 1 | 1 | 1 | X | 1 | 1 | 1 |
| -1 | -1 | -1 | 1 | -1 | -1 | -1 |
| -1 | -1 | -1 | 1 | -1 | -1 | -1 |
| -1 | -1 | -1 | 1 | -1 | -1 | -1 |

Graphical Interpretation



Hereafter are our re-drawn and adapted maps of Lugano. Before the implementation of PVP on the left and after on the right





***Matrix B***

From early simulations we realized that the amount of work the program had to do was too labor intense. We therefore decided to use an index Matrix. This index contains all of the relevant data for the cars which have either been eliminated or are still on the map. Such information includes x,y position, color, number of movements and number of iterations the cars have been in. (This number gets updated even if the car is momentarily stationary). The index also contains data regarding where the car has been generated, where the car has exited the map (in order to track the exact path) and a car id which is used in combination with the movement matrix and is not used in the main program (more on that later).
Matrix B is used in combination with the map matrix.

While running simulations we thought about pre-allocating the matrix so as to execute all of the tasks in a faster manner, but this proved to be completely wrong because we noticed that seeing as the matrix B grows during the execution of the code, the program has an easier time at the beginning (smaller matrix) and slows down over time as the matrix B grows. This gives us a gain in time on each simulation so we decided not to pre-allocate it, but to allow it to expand dynamically.

***Color management of the cars***

Each car has a fixed color in the range from 0.2 – 0.6. This is saved in the matrix B (column 3) From there this assigned color value is read (in matrix B) and written on the map (matrix A) in the current position of the car. When a car moves the value in the new position is overwritten with the color value assigned to the car, whereas the value in the previous position is reset to 1, or in the case of a crossing, it resets the number assigned to the crossing itself. This is to avoid deleting of the crossing. This way the position is set to free and a new car can move onto this position.

***Functions***

Early on during the programming phase we noticed that many of the tasks we were performing were repetitive, meaning that many corrections we had to make were repeated multiple times throughout the code. We therefore decided to use functions in order to use the same code multiple times and make only a few changes over the entirety of our code. We started by creating the move function, which contains the most basic movements the car has to perform (north, south, east, west). The other important function is the prevmove function, which manages what function has to be called when (crossings or normal road). It does so by checking its sorroundings, and based on the result, calling the most appropriate one. This decision s mostly based on whether the next block is a crossing, and whether the next spot is free.

***Movement of the cars***
As explained before, the prevmove is a “decision maker”, which recalls the most appropriate function for each of the situations. On the next pages we take a look at all of them in a bit more detail

**Move**This particular function is responsible of the “simple” movements, making the car move either in a north, south, east or west direction.

example of code in move.m (line 2 - 9)

```
2    %south
3    if dir==2
4       A(B(j,1)+1,B(j,2))=B(j,3);
5       A(B(j,1),B(j,2))=1;
6       B(j,1)=B(j,1)+1;
7       movement(i,j)=2;
8       B(j,4)=B(j,4)+1;
9    B(j,5)=B(j,5)+1;
```

dir is the variable which prevmoveuses to transmit the desired direction to the move function. on line 4 we can see that the x and y positions of the car are recalled, and they are used inside the A matrix to “occupy” the next cell. On line 5 the old podition is made available by rewriting the value 1 onto the block. In the case of the south movement, the y position is the one that has to be updated, as seen on line 6. Line 7 writes the directon of the movement, onto the movement matrix, which contains the directions of the movements made by a car. Line 8 and 9 are just an update to the number of times a car moved and to the number of iterations a car was in, respectively.

*prevmove.m*

*as we said before, the prevmove function is the "decision maker".. this function goes through a series of if-else statements in order to decide in which direction the car must move and whether it is allowed to. It also checks the previous movement of the car in order to prevent the car from moving backwards. It selects a valid direction for the car, and if the next block is a normal road, it calls the function move.m passing down the information on which direction the car has to move. in the other case it might be that the next block is a crossing, making the decision to call the appropriate crossing function and mske the move based on the rules of the crossing, which are located inside the crossing function. <the only time a function is not called is when all of the cells surrounding a car are a "wall", or inactive, the prevmove function will delete the car, updating the color to a -2, which means the car has been deleted.*

Code of the exception (line 136-148)

```
136                 %dead-end streets control
137                elseif (A(B(j,1),B(j,2)-1)==-1 && A(B(j,1)-1,B(j,2))==-1 &&
138              A(B(j,1)+1,B(j,2))==-1)
139                  del=rand(1);
140                  if del<0.4
141                    A(B(j,1),B(j,2))=1;
142                    movement(i,j)=0;
143                    B(j,3)=-2;
144                    nCarsOut=nCarsOut+1;
145                  else
146                    movement(i,j)=4;
147                  B(j,5)=B(j,5)+1;
148                  end
```

this snippet of code tests whether the car has reached a dead end. This means all values around it are equal to -1 ,except the one it has just come from. If that is true a **random variable** is created. The car is then deleted if that variable (del) is smaller than 0.4 otherwise the car will stay in the dead end and this process will be repeated until the car is deleted. We have implemented this time delay before deleting a car in order to create a realistic backflow of traffic due to the next intersection which isn't included in our map but which we have analyzed. During our analysis we have come to the conclusion that through setting the condition to del < 0.4 we would get a reasonable time delay.

crossing_(3-25).m

*As previously mentioned the functions crossing_3.m through to crossing_25.m are responsible for the car movements inside a crossing. These are an implementation of traffic rules applied to a specific crossing. The crossing functions vary in complexity differing based on the size of the crossing itself.*

*All crossing functions handle and update matrix A and B directly avoiding the call of function move.m. The functions cause a car to move through the crossing in a way that it doesn't interfere with the other traffic. The functions also cause each car to take an exit from the crossing based on a probabilistic table.* ***another reason why each crossing has its own function, is because depending on the direction a car was coming from, it can only take acertain exit. This was one of the most difficult parts of the entire program, since t required mapping all of the crossing and writing each single rule down and also all of the exceptions.***

## The core of the Program

main_Bef.m
The main is a file which contains the main loop which allows for all of the cars to be updated, and also the entire visualization part. This part can either be toggled on or off, depending on the requirements of the current run. Also, the waitbars are initialized and updated, so that when the visualization is not required, there is still the possibility to see how far along the simulation os.

Discussion of the program in detail

The code discussed in this section can be found in the appendix. The program clears all previously allocated variables and clears the cache in order to prevent assignments made in previous runs interfering with the program. It allocates matrix A and C which are our map and our checkpoint system. The checkpoints help us count how many cars pass a certain point throughout a simulation.Each simulation creates a new folder within the directories of the program containing a time stamp as a name and the relevant data needed. The program consists of while and for loops nested in each other. The loops call various functions in order to scan the surrounding of each car. Based on that information a decision is made as to where the car moves. This decision is passed onto another function which then updates the position of the car. If-else statements control the visualization of the animation and the progress bars. They also control that each frame of the animation is recorded and patched into a video. After all the cars have left the map or a previously defined iteration limit is reached the all active animations and video recordings are stopped. The frames recorded are mounted into a video. All the relevant data is now saved into the directory created at the beginning of the program.

# Results from the Simulations

In order to  produce enough data which allows us to reach realistic conclusions we decided to run our simulations on "Brutus" a central HPC Cluster available at the ETH. Thanks to this we were able to run our program a total of 300 times with the variables for the situation before and 300 times after PVP, but for the After PVP only 249 simulations ran, the rest timed out due to the high amount of traffic which was deviated from the center, locking up the simulation. This is due to the fact that the crossngs weren't able to divert the traffic so that the flow would be sufficient to allow for all of the cars to evacuate the map, which is a real life concern for the city after the PVP. . All of these simulations have the same variables (for instance the 2500 cars) but vary partly in number of cars entering and exiting the city based on the data from before and after PVP, in order to produce data which can be compared.

- Small snapshot of the data we sourced

- Presentation of the final results
- Problems we had in sourcing

After analyzing the data that we collected, we have found out that the time required to cover the same distance has been decreased, making our initial assumptions wrong. This means tht the entire plan to reduce traffic has worked. But according to our predictions, these modifcations to the roads, only move the problem, they do not solve it. What we have seen is that the traffic has been diverted from the center of the city, and has been deviated to the outskirts, therefore creating queues elsewhere.

| Road | Before | After | Difference |
|---|---|---|---|
| Corso Pestalozzi | 193058 | 171360 | -21698 |
| Lungolago | 150307 | 255490 | +105183 |
| Viale Cattaneo | 226200 | 300676 | +74476 |
| Via Balestra | 133971 | 344935 | +210964 |
| Via San Gottardo | 291037 | 341053 | +50016 |
| Via Zurigo | 105389 | 175661 | +70272 |
| Via Ferruccio Pelli | 193090 | 179794 | -13296 |
| Via Pretorio | 98552 | 84122 | -14429 |
| Via G.B. Pioda | 186573 | 219250 | +32677 |
| Viale Cassarate (sotto) | 173813 | 117252 | -56561 |
| Viale Cassarate (sopra) | 116682 | 113366 | -3316 |
| Corso Elvezia | 105556 | 139545 | +33989 |

This table shows the amount of cars passing through some of the points that we controlled. As we can see, the results show how the entire traffic has been diverted. If, for example, we take the Lakefront as a reference, we can clearly see that there is almost 70% increase to the number of cars that travel through. This confirms the prediction made by the city of Lugano, which estimated an increase in the same area. Another really important road to analyze is Corso Pestalozzi, in where we see a 12% decrease in the traffic. This reinforces the hypothesis that the traffic has been moved away from the center.

# Conclusion and Outlook

Answers to our questions

Our problems in

Creation of a suitable model

The problem of emulating the road network with the traffic appeared to be difficult from the start. Our first challenge was deciding on a method by which the traffic should move and the traffic rules would be implied. We quickly agreed on using a grid and then expanded and refined that idea until we had the model described above. The problems we encountered were mainly related to the car movement. We are even at this stage not fully satisfied with our code. This is because there are a lot of details missing which could contribute to the accuracy of the model. As an outlook the following shortcomings would be the most immediate to improve on. The biggest one is the lack of traffic lights which unfortunately would end up being a project on its own. Other things we would like to implement are:

- Change the rate at which cars enter the map to emulate the rush-hours.
- Be able to simulate traffic accidents.
- Be able to simulate holyday traffic by increasing traffic in one direction
- Be able to simulate the traffic lights

Coding

Our problems focused mainly on the crossings. This is because there was no template existing which we found suitable for our simulation. The problem originated from the fact that each crossing required a specific set of rules regulating the movement of the cars inside of it.. another problem we encouthered was the impossibility to see some of the cars on the map , because they were assigned a value that was too close to the limits. This was easily solved by setting up limits for the color range. After we increased the amount of cars generated to over 2000 we noticed that we were having malfunctions inside the crossingsOne of the majorproblems was that the cars were deleting the crossings, which was solved by adding a block with the same value of the crossing, just outsde of it, preventing the cars from deleting the aforementioned crossing.

Sourcing

# References and Thanks

Documento ufficiale "S3" – Provided by the city of Lugano
Tio.ch – e-paper
Falò – documentary on the PVP
"Piano Viabilità del Polo Luganese" [www.**pvp**-luganese.ch/](www.pvp-luganese.ch/)

Ufficio pianificazione e tecnica del traffico
Ing. Paronesso Antonio
Ing. Ambrosini Loris

We would especially like to thank eng. Paronesso and eng. Ambrosini for the availability and helpfulness.

# Appendix

Seeing as the amount of data is very large we have decided not to attach any of the files as they can be found in Github under the user account Pennatil, repo matlab.