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ACHIEVING SOCIAL OPTIMUM AND USER EQUILIBRIUM TRAFFIC ASSIGNMENT ON SPECIFIC TEST NETWORK

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Abstract

Traffic models investigated in our research, are presented, as well as methods applied to compare them. The two main methods used are the Social Optimum and the User Equilibrium. We will examine these situations with a new micro-simulator of our design.We developed a stand-alone, PC based micro-simulator that is based on published lane-changing and car-following models, such as the Intelligent Driver Model (IDM) or the Wiedemann model [2] The simulator is capable of studying arbitrary traffic networks up to the size of a city; and being an open-source module-based software, it is easy to change the underlying mathematical models or extend the simulator with new elements.

Keywords:

Social optimum, User Equilibrium, Traffic networks

1. Introduction

Social Optimum (SO) refers to the global optimum of the traffic network system. It means that after totalling the users' journey times between their origins and destinations, SO is the lowest value found. In case of the User Equilibrium (UE), users aim for an optimum only beneficial for their routes, regardless of other external traffic information [1]. They define their routes based mainly on experience because they know the traffic specifications, different possibilities of previous journeys.

It is important to highlight that SO takes all users into account, while in UE every user can only see itself and choose the route most favourable to themselves. This can lead to traffic jams, as more users can choose the same routes lacking the knowledge of other users' decisions.

Another problematic feature with UE is when a user modifies its decision (i.e. changes the current route), it can only create a new journey as long as (or longer than) the original, but not a better one. Should it find a better route, the original situation cannot have been the UE state. With more than two users changing their routes a more advantageous opportunity may arise, but never with a single user. To get the best results, we need knowledge of the origins and destinations of the users. In case of SO, users are aware of other participants and try to reach a global optimum. However, with UE, users know only their own routes and are ignorant of the advantages (and drawbacks) of other opportunities, therefore, its global optimum is altogether worse than with SO.

Minimising the exhaust emissions and environmental damages as well as reducing the level of noise and smog affecting the population are influential motivators to find a global optimum in urban traffic environments. Reaching their destinations in a shorter time, the vehicles have a positive effect not only on the environment but it can also benefit the population to a great extent.

We will examine these situations with a new micro-simulator of our design. We developed a stand-alone, PC based micro-simulator that is based on published lane-changing and car – following models, such as the Intelligent Driver Model (IDM) or the Wiedemann model [2] The simulator is capable of studying arbitrary traffic networks up to the size of a city; and being an open-source module-based software, it is easy to change underlying mathematical models or extend the simulator with new elements. So far the IDM has been applied and validated for highway situations, however,

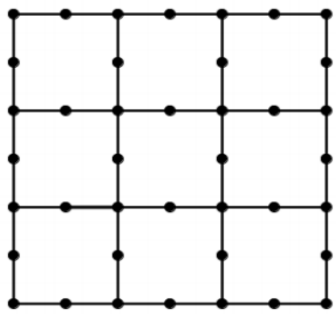

Figure 1. Manhattan network

We have determined the parameters of the IDM for an urban environment where the traffic flow is controlled mainly by traffic lamps. As a result, it was obtained that the IDM parameters in an urban situation differ definitely from those of a highway situation.

In a parallel project we applied a linear optimazation solver in order to determine the so-called System Optimum of traffic system under given boundary conditions. On the other hand, the so-called User Equilibrium state of the same system was also determined by the micro-simulator above. It was found that in the System Optimum state the optimization parameter (the total emission in this case) is better than that in the User Equilibrium state. Based on this result it is possible to design a central control system that helps to achieve a better traffic flow system than one that is formed spontaneously.

2. The traffic network

The Manhattan network shown in Figure 1 was considered for ours purposes. The main features of the traffic network are:
The roads are 500 m longs.
Every intersection is a signalized intersection.
The traffic lights cycle is 100 s long with 25 s green.
The vehicles start from and arrive to the middle of the roads.

3. The micro-simulator

The micro-simulator was developed based on the IDM (Intelligent Driver Model) with parameters calibrated in [3].

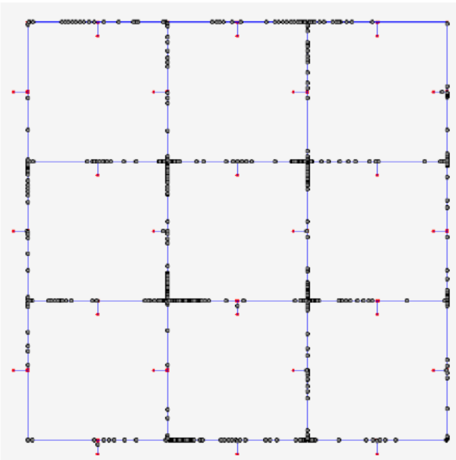
Figure 2. The Micro-simulator

The parameters of the IDM were calibrated for an urban environment where the traffic flow is controlled mainly by traffic lights. Figure 2 shows the complete Manhattan traffic network, and Figure 3 shows an intersection with traffic light, on the screen of the simulator.

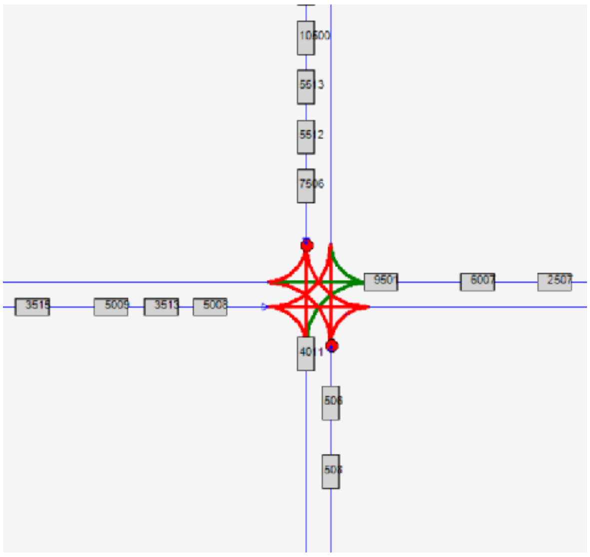
Figure 3. The micro-simulator detail

4. The link performance function (T-Q):

A measured link performance function was obtained with the micro-simulator. The figure 3 shows the measured function and its approximation with linear function, Davidson function, and BPR (developed by the U.S. Bureau of Public Roads) as was done in [4].

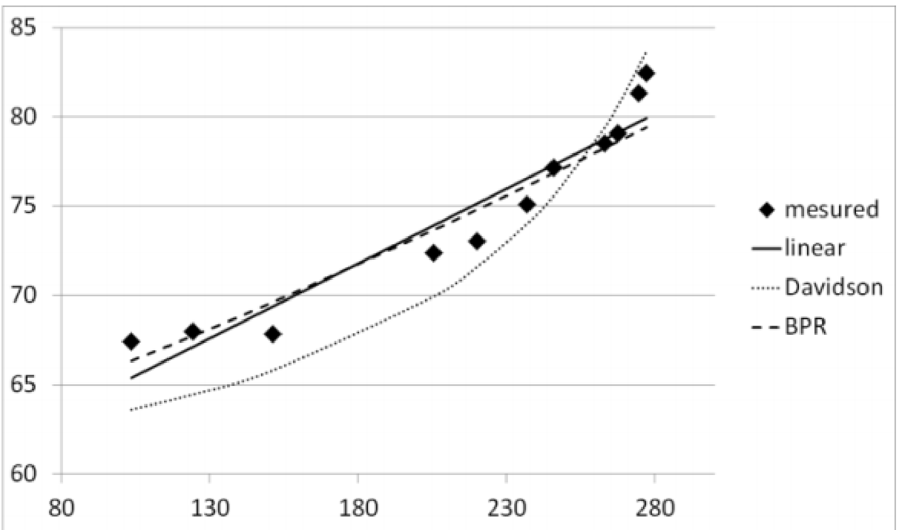

Figure 4. Link perfomance funcion (T-Q). Figure taken from [4]

5. Optimal solution obtained with AIMMS:

We consider the problem of 12,000 vehicles starting from the 24 sources and arriving to the 24 sources (500 vehicles start from each source and 500 vehicle arrive to each sink). The vehicles start with uniform distribution in a given interval of time. The AIMMS (Advanced Interactive Multidimensional Modeling System), [5], was used to obtain the optimal solutions according to:

$$optimum = \min(total\ travel\ time) = \min\left(\sum_i t(v_i)\right),$$

where $t(v_i)$ is the total travel time of the $i-$th vehicle.

Table 1 shows the optimal solutions obtained using a linear approximation of the link performance function and limiting the flow to maximum value (360 vehicles/hour), the capacity of the traffic lights.

Table 1.

Vehicles number	vehicles depature time interval	optimal total travel time (s)	mean travel time (s)
12 000	8 000	4 174 754	347,90
12 000	9 000	3 559 706	296,64
12 000	10 000	3 478 285	289,86
12 000	12 000	3 356 152	279,68
12 000	18 000	3 152 599	262,72

In each case we got a table containing for each source the frequency values that indicate how often continued from each node into neighboring nodes the vehicles departed from that source. Table 2 shows a section of the table obtained in the case that the time interval for the departures of the vehicles is 8000 s.

.Table 2.

From/ To	1	1	3	3	3
Src	2	8	2	4	9
2		71,256		102,767	50,976
4		37,782	47,565		64,934
6		33,625	43,408		49,576
8	71,256			51,691	9,7826
9		9,7826	19,565	40,269	

6. Simulation of the optimal solution

Using the frequency tables we reconstructed the trajectories of the vehicles in the optimal case. With the reconstructed trajectories the optimal solution was simulated in the micro-simulator obtaining very similar results in time to those obtained by the AIMMS as shown in Table 3.

Table 3.

Vehicles number	vehicles depature time interval	total travel time (s)	mean travel time (s)
12 000	8 000	4 276 499	356,37
12 000	9 000	3 595 809	299,65
12 000	10 000	3 380 226	281,69
12 000	12 000	3 269 839	272,49
12 000	18 000	3 180 703	265,06

7. User equilibrium:

In the User Equilibrium state none of the vehicles (drivers) can improve their travel time by choosing an alternative trajectory. In other words, if any user decides to change his route, the total time of the new route will be greater or equal.

The user equilibrium was determined by an iterative process. The results are shown in Figure 5, while the process is illustrated in Figure 6.

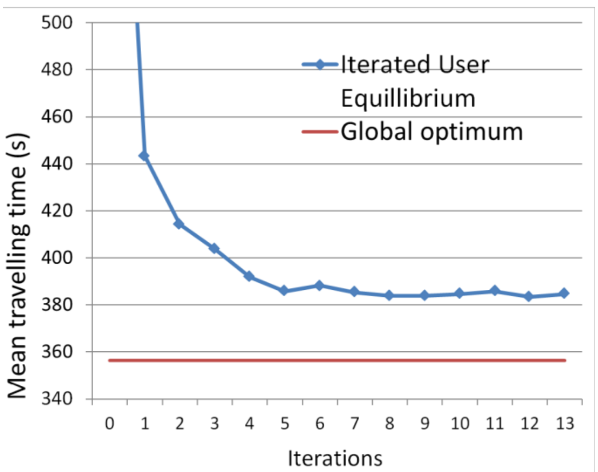

Figure 5. Iterated user equilibrium

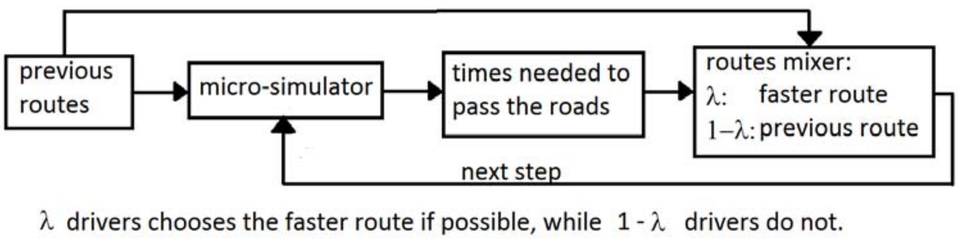

Figure 6. Iterative process to determine the user equilibrium

8. Conclusion

As was noted in the introduction, it was found that in the System Optimum state the optimization parameter (the total emission in this case) is better than that in the User Equilibrium state. So based on this result it is possible to design a central control system that helps to achieve a better traffic flow system than that is formed spontaneously.

A possible future work is to scheme this central control system in details, and using the micro-simulator at hand test the success rate of the various implementations. With the help of the simulator it is possible to take into consideration the limits of the applied real communication systems.

Another future possibility is to combine our micro-simulator with a validated macroscopic simulator, so that the coupling constants between the road elements are determined by the micro-simulator, while the time evolution of the flow-rates is calculated by the macroscopic simulator. Such a system promises a much faster and alternative traffic design tool beside the time consuming real measurements.

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