

# Intelligent Traffic Control

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## 1 Introduction

An intelligent traffic control system adjusts traffic in order to assure all people reach their destinations in the most optimal time and distance. These systems are important for the daily workings of major cities by alleviating traffic congestion and identifying problem areas. It is important to constantly keep these systems updated to assure optimal performance and safety of the general public. With advancements in technology and artificial intelligence, new and more sophisticated strategies for traffic control become possible.

### 1.1 Goal

In this work, we aim to evaluate different such "intelligent" traffic control strategies and compare their effect. Thereby, we hope to identify the best working solutions to traffic jams and other occurrences (such as closing of roads/tunnels) in cities and to show their workings. We attempt to to recreate a real life city's traffic flow in order to see how these systems would work in a realistic setting. Our simulation aims to model the dynamics of a realistic environment as close as possible within the scope of the project, so that the comparison of strategies is meaningful and provides valuable data regarding the potential application of the strategies.

Our main contributions are as follows:

### 1.2 Approach

Hence, in order to test the effect of different intelligent traffic control strategies, an appropriate simulation is required. For this purpose, we created a simulation environment which allows the incorporation of different such strategies into a dynamic traffic model. Maps are realised as undirected graphs in which vertices represent intersections and roads appear as edges between those. The simulation is *microscopic*. That is, instead of globally controlling traffic (*macroscopic*), the atomic parts of the simulation are locally controlled cars (see also Krajzewicz et al., 2002). Driving behaviour is modelled using the time- and space-continuous *Intelligent Driver Model* (IDM) (Treiber, Hennecke, and Helbing, 2000).

### 1.3 Related Work

There has been extensive work on the simulation of traffic flow as well as the development of traffic control strategies. Following up on different approaches on

modelling car following behaviour (e.g. Gipps, 1981), Treiber, Hennecke, and Helbing (2000) developed the influential Intelligent Driver Model for the simulation of urban traffic. Similarly to the former, it creates a collision free environment where cars mind the a spacial and time-wise gap to the leading vehicle. The SUMO package (Krajzewicz et al., 2002; Behrisch et al., 2011) utilizes the model by (Gipps, 1981) in an extended version (Krauß, 1998) in a complex simulation software. In contrast to their work, we use the IDM. Hence, our simulation is (quasi) time-continuous, rather than time-discrete.

In the following sections we further describe our approach and the results of our experiments. We begin by elaborating on the implementation of the simulation environment (section 2), followed by a description of different control strategies (section 3). Following, we describe the experiments we conducted for those strategies and our evaluation methodology (section 4). In section 5 we will report the results of these experiments. We conclude this work by discussing our results and proposing future directions.

## 2 Simulation Environment

In the following subsections we describe the implementation and design choices of the simulation environment in which we evaluated the effect of different traffic control strategies.

### 2.1 Graphical User Interface

The Graphical User Interface (GUI) is designed for simplicity. It consists of three panels. On the left side the main panel is located. Here, maps can be created and navigated through and the simulation process is visualized. Maps can be interactively constructed by clicking and dragging on the panel. Above the main panel there is an info panel that indicates different values such as the current time and day of the simulation. Finally, the right panel contains the controls for different functionalities such as the creation of maps, setting of experimental parameters and controlling the simulation. Figure 1 shows this interface with a small map.

### 2.2 Traffic Flow Simulation

As mentioned beforehand, we apply the IDM (Treiber, Hennecke, and Helbing, 2000) for the simulation of car dynamics. It models traffic flow time- and space-continuous as a combination of *free-road* and *interaction* behaviour. The *free-road* term is governed by a



using the thinning algorithm by Lewis and Shedler (1979). The data used is shown in figure 2. As can be observed, this creates rush hours around the hours of 8 to 9 am and 5 to 6 pm.

## 2.6 Path Finding

Whenever a car enters the traffic, it needs to get a predefined route to take to its destination. In the simulation, each car runs an instance of a path finding algorithm, two of which were implemented.

**A\*** This popular path finding algorithm, based on Dijkstra's algorithm (Dijkstra, 1959), was first introduced in 1968, by Hart, Nilsson, and Raphael (1968). It finds the shortest path between the origin and the destination of the cars, given the map only taking the length of the path into account.

**Advanced A\*** The advanced A\* path finding algorithm is very similar to the original version, but also takes the traffic density of the roads into account. This is realized by calculating the traffic density of each road whenever the route of a car is created. The density of a road equals the number of cars on it divided by the length of the road, to get the number of cars per meter of road. The algorithm then adds a weighted density value to the G and H scores of the road to calculate the current best route.

## 3 Traffic Control Strategies

In this section, different traffic control strategies are highlighted as well as their effectiveness in different environments.

### 3.1 Benchmark Strategies

In order to provide a baseline of what advanced strategies should be able to outperform, we implement several simple benchmark strategies. *Basic Cycling* refers to traffic light control based on a simple, fixed-time cycle in which one traffic light at a time is green. *Informal Cycling* refers to a similar strategy, in which though a road's green phase is skipped if there are no cars on it. Ultimately, *Weighted Cycling* adjusts the green phases linearly based on the density of the roads going into the intersection.

### 3.2 Coordinated Traffic Lights

Coordinated traffic lights are traffic lights that exchange information with each other in order to predict future traffic patterns and assure the least amount of congestion possible. Each intersection is outfitted with different types of sensors, depending on the environment in which they are needed. These sensors can include inductive loops, cameras, or microwave radar systems, each of which has its own pros and cons.

The coordinated traffic light strategy currently implemented uses features resembling that of a microwave motion sensor. The reason of using this type of sensor is mainly because the detection range can be

altered to each one depending on the area it is installed, the ability to accurately detect distance of vehicles, and also it is able to tell if cars are moving towards or away from it. Other reasons for implementing this type of detection system is that in real-world situations, this device can be installed above ground, which greatly reduces cost of installation, and can also be installed very quickly at very low charge and cause minimal traffic disturbance.

This type of traffic control system is preferred for areas with minimal obstructions (such as road signs or buildings). Since our current traffic simulation does not have any external obstructions other than cars, this is the best strategy to use. In cases where many obstructions are in play, it would be more recommended to use inductive loops (commonly thought of as 'pressure plates' installed into the road, but quite costly).

**Weighted Cycling** At first, the weighted strategy tried to replicate the effect of pressure plates that are placed close to its respective intersection. This would allow the intersection to know which traffic light should be turned green. However this was changed because this method would not be able to recognize which road should be prioritized to turn green. For example if we have a crossroad and all roads have at least one car on them it would not know which road should be turned green first, if one road has ten cars waiting they could still be waiting for a long time. To prevent this from happening it was decided to put the pressure plates as far away from the respective intersection as possible. This way it was possible to measure the traffic density for the road and prioritize the one with the highest density to prevent long waiting times.

## 4 Methodology & Experiments

In order to be able to measure and compare the efficiency of the different strategies applied, various measurements are taken while the simulation is running. One of these is the average speed of the vehicles for each road. Measuring this is done by starting a timer for a car when it enters a road and stopping it when it leaves it. Then, by using the following formula, the average speed is calculated:

$$v = \frac{s}{t} \quad (4)$$

where  $v$  is the velocity,  $s$  the road length and  $t$  refers to the time spent on a road. Using this, we can also easily derive the average speed on each road. The second statistic measured is the amount of time each car spends waiting at traffic lights. This is achieved by checking at each time step if a car is under a certain speed and is not accelerating. Whenever the previous conditions are fulfilled, the total amount of waiting time is increased by the size of the time step. The purpose of the control strategies is to maximize the average speeds and minimize the time spent waiting in congestions.

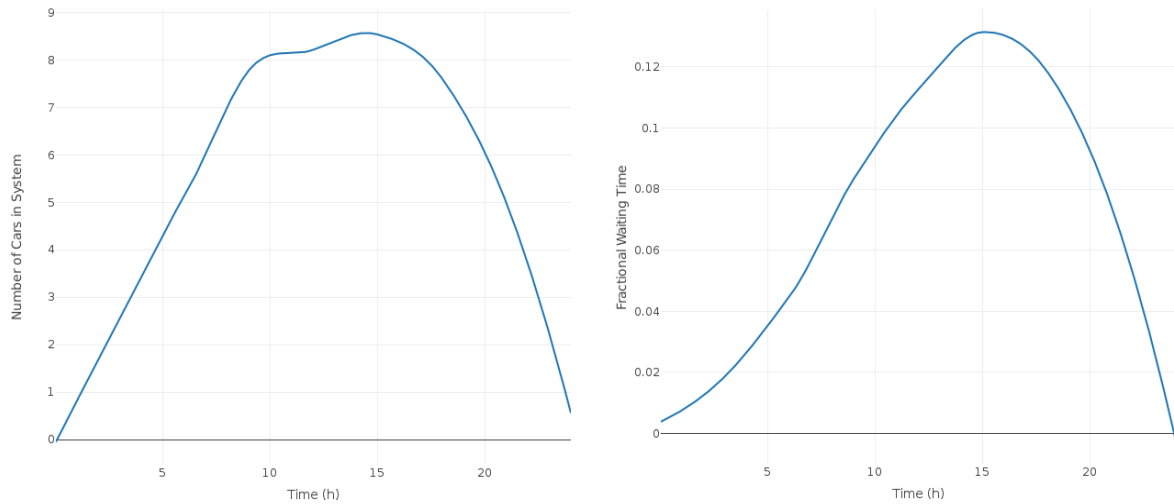


Figure 3: Number of cars (left) and average fractional waiting time of cars (right) in the system simulated for one day. IATs are generated from the empirical distribution shown in figure 2

#### 4.1 Simulation Validation

In order to validate both the IA generation as well as the general behaviour of different measures and dynamics, we validated the simulation environment using the average speed of cars, their number on the map as well as fractional waiting times in the simulation as a development over one day. Figure 3 shows the results in three graphs. As can be observed, not only the density, but also both other dependent measures resemble the rush hour pattern from the original data.

## 5 Results

## 6 Discussion

## 7 Conclusion

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