Intelligent Transportation Systems ITS - II

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Contents

ITS for Smart Mobility

Context

Traffic congestion on urban roads is a problem of great interest nowadays since it strongly affects security and pollution. Workfoce centralization, population and economic growth alongside with continuous urbanization are the main causes of traffic congestion. As cities strive to update/expand the current infrastructures the development of Information Technologies bring new possiblities as an alternative solution for transportation systems.

The current project aims to explore some of the new technologies used in the so called Intelligent Transportation Systems (ITS). They objective is to study to a certain level of detail some of the new traffic management systems that will conduct new ways of transportation in the XXI century. The general idea is based on the fact that information collected by sensors within traffic networks or in-vehicles sensors can collect information regarding the traffic condition, perform estimation of unknown traffic states and decide on specific actions to modify this state.

Projects

Specially, in this case the project will be focused in four main activities:

- **Trafic signal design:** This projects aims to study how to optimally deal with the design of light cycles to optimize the traffic performance. Based on information collected by infrastructure based sensors the traffic state can be determined and specific decisions in terms on green/red light times can be dynamically adapted.

Figure 1: New connected vehicles https://pixabay.com.

- **Vehicle Platooning:** New in-vechicle sensors create situations in which vehicles may exchange information to improve traffic conditions. This project aims to study control algorithms implemented in the V2V (Vehicle-vehicle) communication layer that can be used to design traffic decisions.
- **Density reconstruction:** Sensors installed in traffic infrastructures provide information regarding the traffic state. Nevertheless the solution is not scalable to cover large cities due to the economical leverage required to deploy this technology. Algorithms to reconstruct traffic information may provide a promising future for accurately determine the traffic state of a city. The aim of this project is to study how multiple sources of information can be integrated to reconstruct traffic variables within a city.

General Objectives

- Identify new technologies implemented in the Intelligent Transporation Systems and investigate how these technologies are deployed in real systems.
- Define and determine adequate models that are suitable for deploying new ITS technologies.
- Develop specific solutions for ITS that can be tested under pre-defined scenarios.

Project information

Deliverables

The project is mainly composed in 3 phases.

1. **Problem identification & literature review:** This phases consists in:
    1. Identify particularly the problem under study, meaning the system to be controlled and the way it is assesed.
    2. Retrieve bibliographical information about the problem under study.
    3. Summarize the already proposed alternatives in the existing literature.

    The main objective of this phase is to understand what are the main challenges when solving the specific project under study and to present in general ways how this problem has been solved.
2. **Setting up a suitable model:** Once the problem has been identified the main objective is to precisely describe the traffic models that are suitable for the approach. For this phase the stages are divided as:
    1. Determine a specific traffic model that can be used for the corresponding situation
    2. Define the scenario in which the solution should be tested
    3. Pre establish parameters and requirements for the solution to be implemented.
3. **Experimental results:** Finally, the main objective is to perform a validation and solution for the problem under study. Several tools are provided for this purpose like micro/macro

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Reporting

In order to fullfill the requirements for each phase each group should provide a report as follows:

- *Report 1:* Summarizes the results of the 1. Problem identification & literature review and 2. Setting up a suitable model. (***Due date: January 9th, 2018***)
- *Report 2:* Summarizes the results of the phase 3.Experimental results (***Due date: January 23rd, 2019***)

Chapter 1

Project 1: Signalized Traffic

The main objective of this project is to design *traffic light signal* controls in order to optimize particular traffic conditions. Traffic signals regularly pre-establish fixed values *red* or *green* for a particular intersection. In fact the behavior can be modeled as:

The relationship between the switched green/red time in a traffic light can be represented by a pulse signal (Figure 1.1). The red line in the figure represents the *duty cycle* which represents the fraction of time the light was in green (1) with respect to the total cycle time ($60s$). In this case, the main objective is to study traffic models that can model signalized intersections and design control laws.

Objectives

The main objective of this project is to:

1. Study the fundamental aspects of traffic signal control strategies.
2. Obtain and simulate a macroscopic traffic model for a urban network with traffic signals
3. Create and design control strategies applied via traffic signals in urban traffic networks.
4. Compare the behavior of fixed-time traffic signal polices and dynamic-time traffic signal polices.

Description

Task 1: Modeling

Check models for macroscopic networks: (Grandinetti, Canudas-de-wit, and Garin 2015), (Grandinetti, Garin, and Canudas-de-wit 2015),(Varaiya 2013). Determine the parameters required to model a road traffic network.

Context

Before implementing a real scenario in this phase we aim to describe the context of a virtual example. Consider the following traffic urban corridor which obeys a simplified version of the real arterial scenario.

The network of Figure 1.2 represents a regular corridor in a city like. The priority for this type of corridors is to maximize the priority of green time so the traffic does not get congested along the

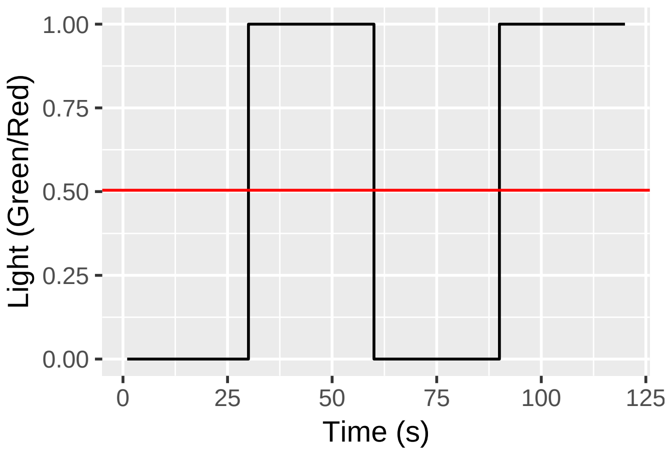


Figure 1.1: Traffic light signal example.

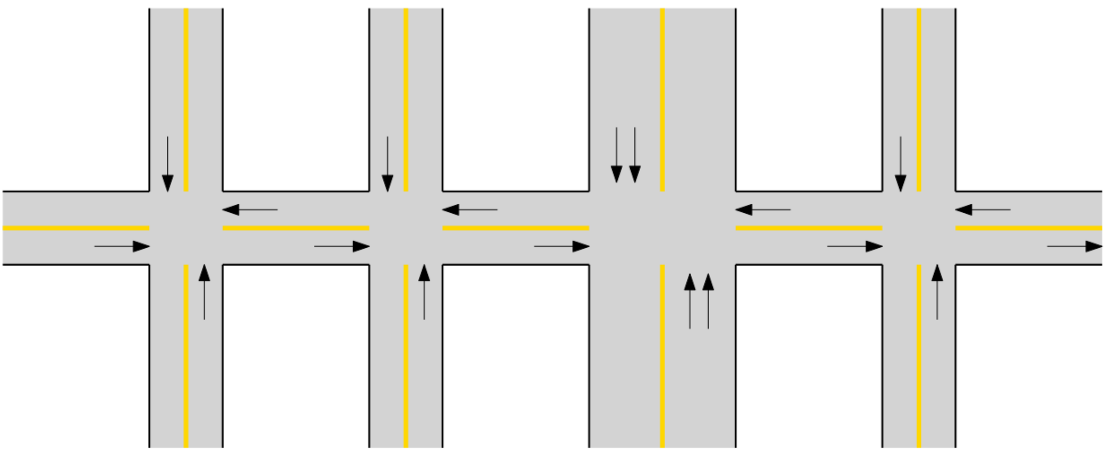


Figure 1.2: Example of traffic network.

network. It is important to highlight that for the proposed network

Questions

- Based on a literature review, determine current existing traffic models for signalized traffic networks.
- For the network in Figure 1.2, build a macroscopic signalized traffic model.
- Determine the *signalized/averaged* traffic model for the case where lights are installed along each intersection of the corridor. For those roads in which direction is not explicitly defined, consider the direction of a regular intersection.

Expected outcomes

- Present a brief summary of the existing current models for signalized traffic networks. At same time highlight the key features of these models and the remaining difficulties. Consider including references for the presented models.
- Based on (Grandinetti, Canudas-de-wit, and Garin 2015) obtain a model for the signalized network of Figure 1.2 and the parameters required model this corridor.
- Define the set of parameters for the traffic network, notably those related to the fundamental diagram as well as the traffic light signal timings. Consider a fixed setup of this parameters for the moment and overall explain the reason of the choice.

Task 2: Simulation

Dynamic simulation of open loop traffic networks. For this task be sure to review already implemented simulations available at Link. Get familiar with the code here developed before you enter into details of implementation.

Context

Based on the model established in the **Task 1** and considering a family of specific parameters, perform a simulation for a constant demand value of demand in veh/hr as specified in the Figure1.3.

Questions

- Simulate and obtain density plots of the dynamic the behaviour when the *duty cyle* of lights is similar for all the traffic lights. 50%
- Does the current values create a congestion in the proposed network?
- How can the performance of the network be improved? Create a second set of parameters for the traffic lights *duty cycle*
- For the existing model and according to (Grandinetti, Canudas-de-wit, and Garin 2015) obtain the two different *density* and *flow* dynamic profiles between a *switched* signalized traffic model and an *averaged* traffic model

Expected outcomes

- Present the dynamic profiles for density on each one of the roads under different setups of traffic lights. The dynamic profiles should specify density per road in time
- Provide comparisons between different traffic signalized models and an analysis on how this error evolves according to different values of demand.

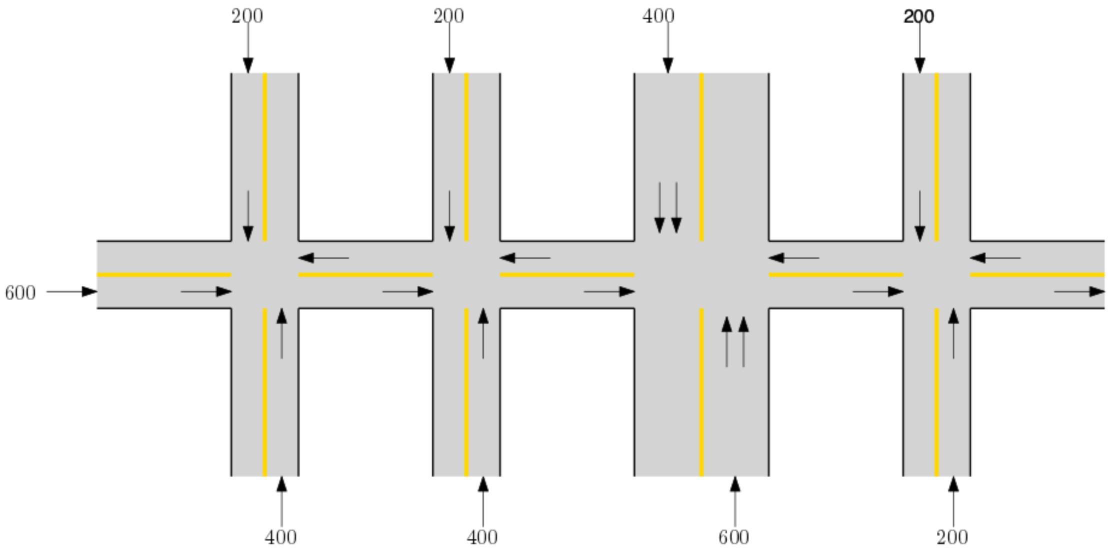


Figure 1.3: Demand profiles for a specified scenario.

- Specify a second set of parameters for *duty cycle* that could improve the performance of the network with respect to the 50% case. Justify the reason of your choice and verify in results the desired behavior.

Task 3: Control strategy

For this task we aim to consider the *duty cycle* as a control input variable to regulate the flow within the traffic network. In this case take into account that the decision variable needs somehow to be determined dynamically via a control algorithm.

Context

For the Figure 1.1 the average value can be found as:

$$\bar{u} = \frac{1}{T}\int_0^T u(\tau)d\tau \tag{1.1}$$

As it is illustrated in (Grandinetti, Garin, and Canudas-de-wit 2015), in Eq. (1.1) is easier to design a value for $\bar{u}$ rather than u due to its binary character.

Questions

- Explain and construct a block diagram illustrating the control of the road traffic network via traffic signals
- Design and present an algorithm that takes decisions for the traffic signals based on the state of the network. How would you construct the value of u based on the congestion state of the network.
- Perform simulations of the system under a preestablished manual control and compare it to a situation where the control depends on the congestion state of the network.

Expected outcomes

- Present a comparison between the traffic network with signalized control and without signalized control.
- Apply the controller over different versions of the model notably *averaged* and *switched*
- Compare the open loop situation with the closed loop situation and provide conclussions on the control performance.

Task 4: Performance evaluation

Finally in order to compare it is important to determine indicators than can be designed in order to compare the effects of introducing an automated control strategy.

Context

Indicators for traffic networks are regularly expressed in terms of the state of the network, for example the *Service of Demand* (SoD) measured in terms of flow:

$$SOD = \int_0^T \sum_{r \in R} f_r(\tau) d\tau \tag{1.2}$$

Or the *Total Travel Distance* (TTD) measured in terms of the density

$$TTD = \int_0^T \sum_{r \in R} \rho_r(\tau) d\tau \tag{1.3}$$

Questions

- What does the aforementioned indicators represent?
- Measure the indicators over the traffic network with a manual setup of traffic signals *open-loop* vs a controlled setup of traffic signals *closed-loop*.

Expected outcomes

- Report indicators for both cases and conclude about the results.
- Provide recomendations on how to design u for the corridor

Sources

For more details on how to deploy traffic simulations and traffic models please check:

- Traffic Macrosimulator - Github
- For traffic models check (Grandinetti, Canudas-de-wit, and Garin 2015) available Link and (Grandinetti, Garin, and Canudas-de-wit 2015) available at Link

Chapter 2

Project 2: Vehicle Platooning

The main objective of this project is to design a controller for a platoon of vehicles in order to optimize the flow and reduce the fuel consumption. A platoon of vehicles can be seen as:

Objectives

This project consists in works based on (Grandinetti, Canudas-de-wit, and Garin 2015)

Description

Task 1: Platoon modeling

Context

Questions

Expected outcomes

Task 2: Open loop simulation

Context

Questions

Expected outcomes

- Obtain the trajectories for a platoon of 4 vehicles

Task 3: Vehicle platoon control

Context

Questions

Expected outcomes

Task 4: Performance evaluation

Context

Questions

Expected outcomes

Sources

- Simulation results - Github
- Check (Duret, Wang, and Ladino 2019) available Link

Chapter 3

Project 3: Connected Vehicles

This project is related to V2V modeling and the effects on the transport network. Let's consider first the work of

Objectives

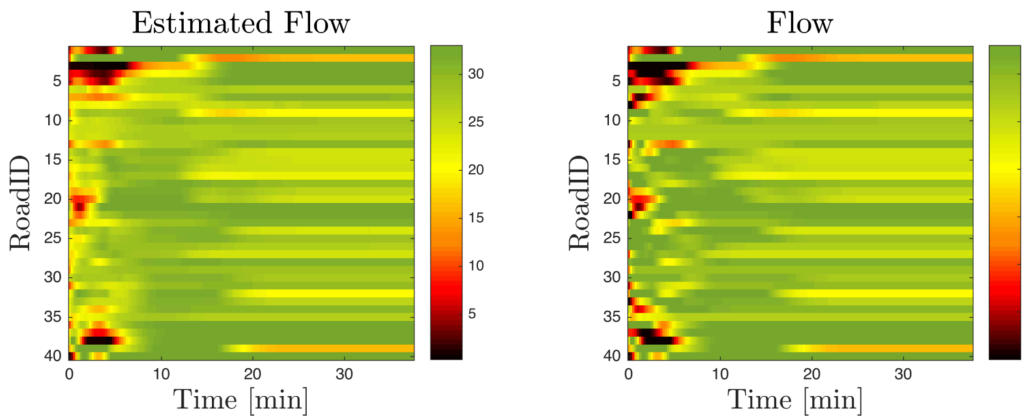
This project consists in works based on (Grandinetti, Canudas-de-wit, and Garin 2015)

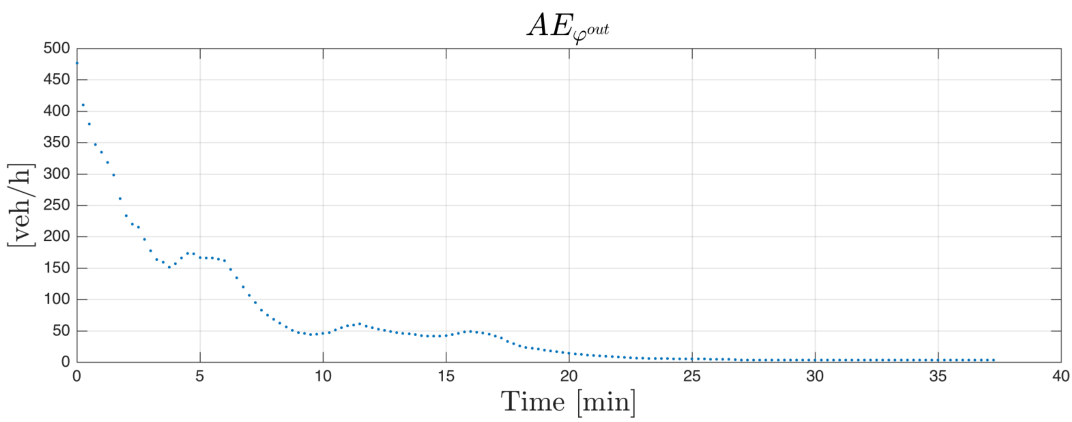
Description

Sources

Chapter 4

Project 4: Density Reconstruction






```r
plot(cars)   # a scatterplot
```

$$f(k) = \binom{n}{k} p^k (1-p)^{n-k} \tag{4.1}$$

In (4.1)

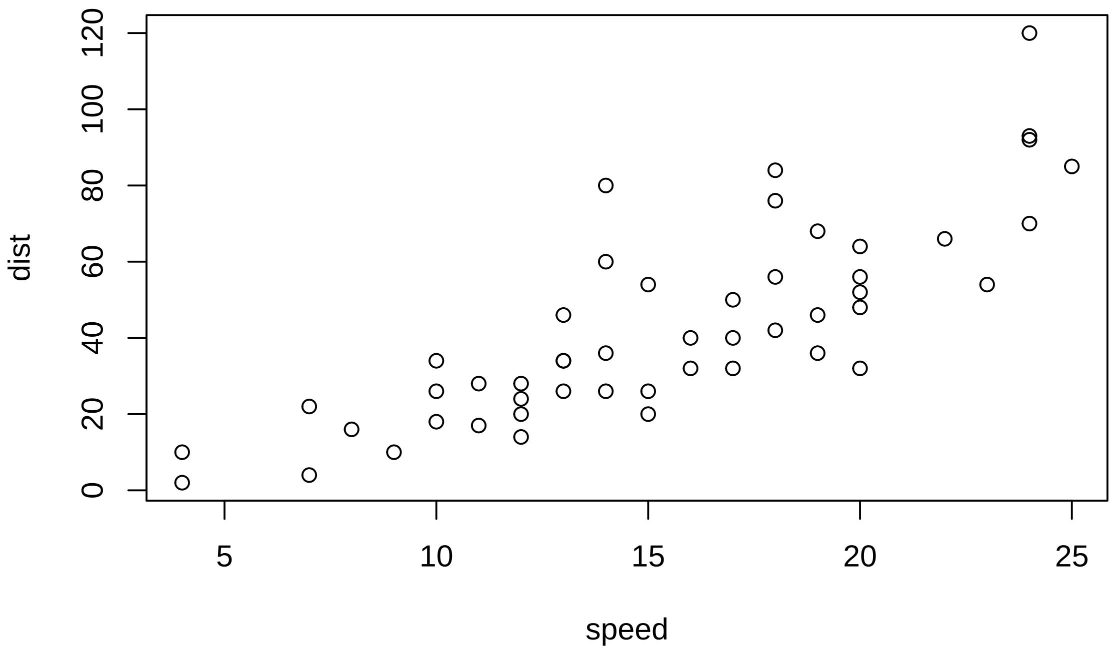


Figure 4.1: A scatterplot of the data `cars` using **base** R graphics.

Below is an `align` environment (4.3):

```
\begin{align}
g(X_{n}) &= g(\theta)+g'({\tilde{\theta}})(X_{n}-\theta) \notag \\
\sqrt{n}[g(X_{n})-g(\theta)] &= g'\left({\tilde{\theta}}\right)
  \sqrt{n}[X_{n}-\theta ] (\#eq:align)
\end{align}
```

$$g(X_n) = g(\theta) + g'(\tilde{\theta})(X_n - \theta) \tag{4.2}$$

$$\sqrt{n}[g(X_n) - g(\theta)] = g'\left(\tilde{\theta}\right)\sqrt{n}[X_n - \theta] \tag{4.3}$$

Sources

For more details on the project please check:

- Simulation results - Github
- Check (Ladino et al. 2018) available Link and (Lovisari, Canudas-de-wit, and Kibangou 2016) Link

Reference

The main reference for this project is (Ladino et al. 2018)

Duret, Aurelien, Meng Wang, and Andres Ladino. 2019. "A Hierarchical Approach for Splitting Truck Platoons Near Network Discontinuities." *Submitted to 23rd International Symposium on Transportation and Traffic Theory.*

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Grandinetti, Pietro, Federica Garin, and Carlos Canudas-de-wit. 2015. "Towards scalable optimal traffic control." In *54th IEEE Conference on Decision and Control (CDC 2015)*. Osaka, Japan. https://hal.archives-ouvertes.fr/hal-01188811.

Ladino, Andres, Carlos Canudas-de-wit, Alain Kibangou, Hassen Fourati, and Martin Rodriguez. 2018. "Density and flow reconstruction in urban traffic networks using heterogeneous data sources." In *2018 European Control Conference, Ecc 2018*, edited by IEEE. Limasol, Chyprus.

Lovisari, E., Carlos Canudas-de-wit, and Alain Y Kibangou. 2016. "Density/Flow reconstruction via heterogeneous sources and Optimal Sensor Placement in road networks." *Transportation Research Part C: Emerging Technologies* 69: 451–76. https://doi.org/10.1016/j.trc.2016.06.019.

Varaiya, Pravin. 2013. "Max pressure control of a network of signalized intersections." *Transportation Research Part C: Emerging Technologies* 36 (2): 177–95. https://doi.org/10.1016/j.trc.2013.08.014.