Distributed Traffic Flow Controller

☞ to all students of ANU/FEIT/DCS/COMP4330, 6433, and 8140

This is the only marked assignment. Thus extra care is expected on all levels.

1. Overview

Keeping the traffic flowing in a dynamically changing traffic situation is a challenging task which does not have a single, optimal solution. Many, partly contradicting constraints need to be considered. In this assignment we assume a simple, but scalable scenario which focuses on the usage of traffic lights in order to control the traffic flow.

2. Sensors, actuators, communication

The only actuators available are the existing traffic lights which can all be controlled individually. The sensors provided are able to send out a message for every car which passed (or stands) inside the detection zones. The message also contains the measured speed of this individual car. It is assumed that all roads are equipped with a communications network which will provide message passing between traffic control modules as well as from sensors to traffic control modules. All sensors send their messages in both directions along the road to the next traffic control module. Crossings can host one or multiple traffic control modules.

3. Layout

The assumed topology is simplistic, but rich enough that many complex situations are possible (see figure 1 on page 3). As the dashed lines at the edge of the topology indicate, there could be many more of the same or similar crossings assumed around. The blue ovals on the road are the installed traffic sensors, providing occurrence and speed (Assume for instance that they send out a message package with the measured speed for each car detected). Represent the topology in a flexible structure, allowing you to model other topologies later. One way of approaching the topology is to model (legal) traffic streams rather than roads. Note that is also legal to change lanes closer than 200m to the crossing.

4. Design constraints

In order to avoid communication congestions and complex central planning, all modules operate on a local basis only. Information can be passed along between traffic control modules but only to topological neighbours. Those modules can be responsible for a complete crossing or for one or multiple individual streams over one crossing. Traffic sensors report to all topologically connected control modules (i.e. potentially all modules at the next and previous crossing). Information can still be made global as control modules can pass on any information they see fit to topologically connected control modules.

5. Real-time constraints

Two aspects need to be kept in balance in your design:

a. Estimating traffic densities, speeds, and ETA’s. Obviously the longer you observe the more precise your estimate becomes. On the other hand, the traffic light signals control these very same values, and you can only refine your estimations along the currently open traffic streams.

b. Changing traffic streams (controlling the traffic lights). This is based on your estimates (and enables you to analyse different streams), but also on given timing constraints attached to each stream.

Timing constraints per stream express the ‘tolerated pain thresholds’ in your system. The only required parameter here is the maximal tolerated waiting time per stream. Other parameters can be introduced.

6. Optimization goal

The required optimization is a combination of multiple (contradicting) goals:

• Optimization of the overall throughput. The guiding concept is to keep as much traffic flowing as possible. This can often be achieved in a simplistic way by keeping the traffic on one or multiple major roads flowing at all times. Unfortunately that would also mean to accept infinite delays on mi-
nor streams, which also need to be considered (below).

- Balance waiting times. This goal can be bend, or even ignored if you wish, as such a sense of ‘fairness’ might severely interfere with the overall traffic flow maximization.

- Limit absolute waiting times. There always need to be an upper limit to acceptable waiting times on all traffic streams. Also try to avoid annoying situations like traffic participants observe traffic lights going through the same sequence multiple times before opening a specific traffic stream.

- Limit throughput on selected streams (used to limit city-inbound traffic on specific times of the day for instance). While most streams should be kept at the highest possible flow rate, some streams should be kept close to a predetermined flow rate in order to avoid overflow situations further down this traffic stream.

Define a set of parameters per traffic stream which enables the traffic control authority to moderate the behaviour of your system according to their wishes. If you trust in the capacity of your local decision making to a high degree, this list can be short.

7. **A few scenarios**

Test your system (among other situations) in the following scenes:

- A single car wanders around on your roads. Can you guarantee that this driver will only see green lights?

- If you block one of your roads completely, how will this incident percolate through your system?

- If you experience a significantly higher load in one of your streams, how will this effect the overall system?

- Simulate an unbalanced load in different directions on your roads (the classical rush-hour scene).

8. **Simulator**

Be wise here! Try to limit your simulation to the essential features which you would like to test. Simulating drivers in individual cars with individual acceleration and distance keeping behaviour is done in major traffic simulator projects, and is far beyond the scope of this assignment.

9. **Deliverables**

- Based on the general description of the problem at hand, make the constraints which you will address in your design explicit and list them as precisely as you see fit.

- Documentation of your design. Specific emphasis should be given to explain your design decisions. Give reasons for each of those. Make clear which constraints you employed as ‘driving concepts’, which have been considered, and which have been purposefully ignored (for instance to allow for a cleaner, easier maintainable design).

- Provide documentation of test runs. Give an precise motivation for each of your tests.

In addition answer the following questions based on your design:

- How does your design scale?

- Which real-time constraints are or could become critical if the system is extended?

- Do you provide for graceful degradation in case that parts of your system become unresponsive or provide ‘unreasonable’ information?

- To which parts of your system could you apply strict temporal-logic verification?

Use graphical and/or any other means to express your ideas as precisely as you can. Be also prepared to ‘defend’ your documentation in an oral exam situation. The documentation should be printed and submitted at least three days before the lab. exams. Overall assignment time is six weeks. Due date according to web-site.
Figure 1: Traffic layout