Exercise Set 5
Traffic Simulation

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Week 11–13 Spring Semester 2015

Project 1 *Implement a simulation of traffic in a roundabout. Use it to analyse the traffic throughput, that is the number of vehicles passing through per time unit (say ten minutes), under different circumstances.*

This project has three primary learning objectives:

1. become more familiar with agent-based modelling and implementation of simulators for such models.
2. practice application of statistical estimation.
3. learn to use statistical hypothesis testing.

We will analyse the throughput using two different techniques of statistics, namely estimation (with which you should be familiar) and hypothesis testing (which is new).

1 Modelling

To model traffic in a roundabout, we can use many of the same mechanisms as we used in the agent-based predator/prey model.

landscape The landscape is a configuration of roads, including the roundabout and segments of roads leading into and out of the roundabout.

agents Anything moving on the roads is an agent. As a minimum, you will need one type of vehicle agents.

In a simple model, the each road will be single-lane and one-dimensional, i.e. vehicles can only move along the road. It is not possible to change location sideways on the road. It may be useful to model the in-coming and out-going lane as two separate unidirectional roads.

A more complex model would have multiple lanes through the roundabout, and could also have two-dimensional roads, allowing bicycles and cars to pass side by side, and even reckless drivers bypassing close to the roundabout. It is recommended to keep the landscape as simple as possible.

Exercise 1.1 *Sketch a landscape model. Identify key parameters such as roundabout diameter, position and angle of adjacent roads, etc. Assign matematical symbols to the key parameters.*

Exercise 1.2 *Look up a real roundabout on google maps, and describe it using the model from the exercise above. Approximate all the key parameters for this particular roundabout.*

Note the range between mini roundabouts around Brosundet, to large main road roundabouts around Moa. If you want a real simulation challenge, look up the Magic Roundabout *of Swindon, England.*

The agents in the model are vehicles. It is not recommended to introduce cyclists or motor cyclists at this stage. In the simplest case, there would be only one type of agent, with fairly homogenous behaviour. There are many good reasons to vary the type of agents:

1. lorry versus car: the lorry is slower to accelerate and decelerate
2. cautious versus aggresive driver: different speeds, different safety margins
3. consciencious versus sloppy driver: are signals used?

Be careful not to overcomplicate the model. Only introduce additional agent types when you are sure that you know what you are doing.

Exercise 1.3 *Describe the behaviour of an agent as it approaches, enters, and leaves the roundabout.*

1. *Identify any quantitative parameters of the behaviour (e.g. the movement). Introduce mathematical symbols for all key parameters.*
2. *What does the agent perceive? I.e. what elements of the surroundings are relevant to the behaviour? Which are available?*
3. *What decisions does the driver have to make, depending on his perception of the surroundings?*

Exercise 1.4 *Make an object-oriented software design which you can use to implement a simulator of the model described in previous exercises.*

1.1 Presentation 26 March

In the presentation, you should cover three themes:

1. Challenges and trade-offs in the domain problem modelling.
2. The final domain problem model you want to use.
3. High-level, object-oriented model for your software implementation.

2 Implementation

Exercise 2.1 *Using the models designed in the previous section, implement the software to simulate traffic in a roundabout. You must include features to ...*

1. *change the speed of vehicles in the system.*
2. *change the frequency of vehicles entering the system on each input road.*
3. *count the number of vehicles passing through the roundabout in a given time period.*

You may want to include a range of other, optional features, such as driver's with different behaviours with respect to speed, safety margins, etc., visualisation, varying road configuration, et cetera. You are free to use your creativity and control your level of ambition, as long as it is not at the expense of the must-have features.

2.1 Presentation 9 April

In the presentation, you must include a demo of your software simulator, showing how you change parameters, run, and observe output.

3 Analysis

In the analysis phase we want to work with the following research question:

> *when we increase the speed of vehicles, does the throughput increase or decrease?*

Obviously, the answer to this question can depend a lot on driver behaviour, traffic density, road configuration, et cetera. Depending on the flexibility provided by your implementation we may be able to investigate a wide or narrow range of scenarioes.

Exercise 3.1 *Discuss your own intuitive take on the research question in your group. Under what conditions do you think that the throughput*

1. *... decrease?*
2. *... increase?*
3. *... remains the same?*

Give reasons for your answers.

To do the analysis we need to define a test statistic X which we want to measure, and a number of scenarios to study and compare. We define the *throughput* X to be the number of vehicles exiting the roundabout in a ten-minute period.

You need to define at a number of test scenarios. Each scenario defines fixed values for every parameter of the model. This includes variables like

- maximum speed.
- frequency of vehicles entering the model from each direction.

As a minimum, you should define two scenarios which are identical except for the maximum speed. Thus you have a low speed scenario (e.g. 20mph) and a high speed scenario (e.g. 30mph). Let X_l and X_h denote the throughput in the low and high speed scenarios respectively.

Exercise 3.2 (Data gathering) *Run $n = 100$ simulations of each of the two scenarios, making n observations each of X_h and X_l.*

Exercise 3.3 (Estimation) *Calculate 95% confidence intervals of the* expected throughput *in each scenarion, i.e. confidence intervals of $E(X_l)$ and $E(X_h)$.*

Comment on the result. Does speed affect the confidence interval?

Exercise 3.4 (Hypothesis test) *Let the null hypothesis be that the throughput is independent of speed limit, i.e. that $E(X_l) = E(X_h)$. Calculate a p-value for the two-sided hypothesis test.*

Comment on the result. What can we confidently say about the relationship between speed limit and throughput? Does throughput increase or decrease with speed?

Exercise 3.5 (One-sided hypothesis test) *By now, you probably have a hunch about whether the throughput increase or decrease with speed. Let's do a hypothesis test to validate the hunch. If you think that the throughput is independent of speed, you can still do the one-sided hypothesis test.*

1. *Redo Exercise 3.2 to get fresh data which have not been tainted by previous study.*
2. *Use the same null hypothesis as in Exercise 3.4 and formulate an alternative hypothesis (one-sided).*
3. *Can you reject the null hypothesis at a significance level of 5%?*

Feel free to increase the sample size n, or try additional scenarios, if you don't think your initial results are interesting. Just make sure to keep a record of all your experiments, according to good scietific practice.

3.1 Presentation 16 April

In your presentation you have to present your results from each of the exercises in this section.