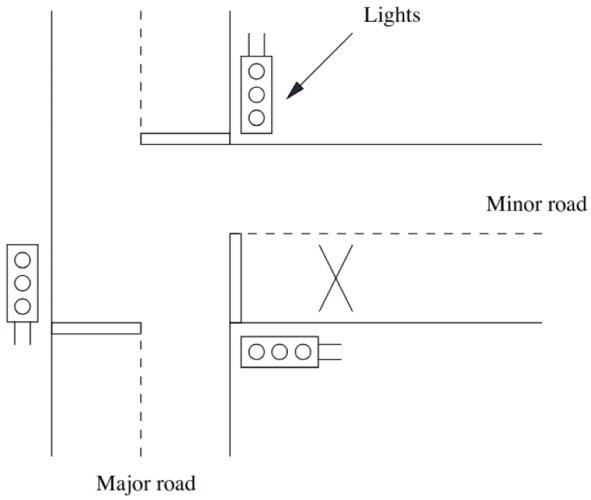
Modelling and verifying behaviour in mCRL2

System Verification 2025/2026, José Proença, FCUP, Portugal

(based on a previous assignment from Renato Neves, U.Minho, Portugal)

1. The T-Junction Scenario

The first goal of the assignment is to **model** and **analyse** a system that ensures the **correct** functioning of traffic lights at a T-junction. The latter connects a "major" and a "minor" road and is depicted below (together with the respective traffic lights):



In this scenario vehicles drive on the left side of the road and the cross in the picture represents a sensor that tells whether a car is waiting in the minor road or not.

In order to guarantee a reasonable traffic flow, the system has the following constraints:

1. The lights on the major road will be always set on green, and red on the minor road **unless** a vehicle is detected by the sensor.
2. In the latter case, the lights will switch in the standard manner and allow traffic to leave the minor road. After some time, the lights will revert to their default position so that traffic can flow on the major road again.
3. Finally, as soon as a vehicle is detected by the sensor the latter is disabled until the minor-road lights are on red again.

The system also respects the following **behavioural** constraints:

1. Each traffic light has a green, a yellow, and a red light.
2. There is a waiting period between one light becoming red and the next one becomming green, when all lights are red.
3. The major-road light must stay on green right after the sensor is triggered; only after some waiting the light can respond.
4. the sensor can *always be triggered*, even when the major road has red light, although it will not affect the lights until the major road has green light.

What to do

1. Model in mCRL2 the system of traffic lights described previously, using a composition of processes in parallel. **Include the code** in your report.
2. Express in process logic and test in mCRL2 the following properties. Note that they do not necessarily have to hold.
   a) [reachability] *The minor-road light **can** go green.*
   b) [reachability] *The major-road light **can** go red.*
   c) [safety] *The system **never** enters in a deadlock state;*
   d) [safety] *The minor-road and major-road lights **cannot** be green at the same time.*
   e) [liveness] *If there is any car waiting, it will **eventually** have green light, even if no other cars appear.*
3. Can you think of other desirable properties? If so please register at least one property and check whether they hold or not in mCRL2.

2. Extension: using a traffic sensor

The previous system of traffic lights works reasonably well under the assumption that one of the roads has more traffic than the other. But such an assumption is often *too strong*: it may be the case that both roads have the same amount of traffic, or even that their traffic flow varies drastically throughout the day. The second part of this assignment (more exploratory) aims to address precisely this problem which is well-known to have significant impact in the economy and the environment.[1] To this effect, we can now assume that each traffic light has a smart sensor attached to it. The sensor informs whether the traffic near the light is **high**, **low**, or simply **non-existent**.

What to do

1. Adapt your previous mCRL2 model to take into account the information provided by the sensors. One expects, for example, that if the rightmost sensor outputs `high` and the other sensors output `no` then the rightmost traffic light should be on green at least until the sensors provide new information.
2. Verify that all the properties mentioned in the first part of the assignment still hold.
3. (Valorisation) Note that the second part of the assigment is of a more exploratory nature, and thus we give freedom to adjust sensor parameters as seen fit in order to promote different and creative solutions. We will value properties expressed in propositional logic that say something about the efficiency of the system developed by the students. Such a property can be for example, *"If the rightmost sensor always detects high traffic and the others detect no traffic at all, then we will observe at most one change in the traffic lights".*

3. Submission instructions

Write a report for the first and second part of the assignment that explains (1) your design choices, (2) your models, (3) the formulae that you used for benchmarking your systems, and (4) the conclusions obtained.

The report in PDF **and** the respective mCRL2 models. Send by email (jose.proenca@fc.up.pt) a unique zip file "`SV2526-N1-N2.zip`", where `N1` and `N2` are your student numbers. The subject of the email should be **"`[SV] mCRL2 assignment`"**.

Deadline: 31 Oct 2025 @ 23h59

[1] https://ourworld.unu.edu/en/green-idea-self-organizing-traffic-signals