Railway Station with Java, Prover9 and Mace4

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1 Description

In this homework, we considered the task of construction the Railway station. Link to the description of the task:
https://cw.fel.cvut.cz/wiki/courses/a4m33au/term_en

2 Physical model

Model modifications:

1) We formalized the physical model of the station: how trains are moving, how they appear. We use the axiom *go(T, Train)* which express the will of a driver.

2) Then we add additional conditions which say that a train moves from one node to another as soon as possible, that means *go()* is always True.

We consider two models separately: 1) and 1) + 2). The program takes as an input a graph and generates associated axioms according to the homework description.

As a first step, we prove the consistency of both models (they are not contradictory). The result you can see in corresponding text files: physical_consistent.txt and physical_with_additional_axiom_consistent.txt.

The result of the physical model you can find in the file physical.p and physical_with_additional_condition.p.

3 Control system model

Control system does the following things: it can open the signaling device, and change the direction of switches. Here we have several important properties:

- At every moment only one signaling device can be opened by the system. We need it to get rid of collisions. For this, we have an analogy of clocks which allows to do it.
- How the system decides: for every train, we have an entrance and its gate, which doesn't change during the ride. When there is a time to decide open the signaling device or not, the system does several things:

1. Checks if there is a train there
2. Look where the train is going
3. Build the road from an entrance to a gate
4. Checks if the road is safe for a ride. The save road is such path that there are no other trains such they can intersect this path.
5. It opens signaling device and changes the switch state such that switches allow the train to go by this path.

Then we prove that the Physical system and the Control system are not contradictory.

4 Theorem proving

We prove theorems for the Control system and for a Physical system with the second condition where the axiom *go()* is always True.

For have the following theorems to prove:

1. *"A train is situated at a switch node when the switch is switched"* =¿ one theorem for every switch.
2. *"There are two or more trains at the same node at the same time."* =¿ one theorem for every node.
3. *"A signaling device never opens (it stays closed all the time)."* =¿ one theorem for input node.

We were able to prove all these theorems in the case if all trains are entering the entrances at any moment. Without this condition only 1st and 2nd groups of theorems.

We consider two architecture of the stations:

```
   digraph station {
in1 -> s1;
in2 -> s2;
s1 -> out1;
s1 -> out2;
s2 -> out1;
s2 -> out2;
}
```

```
   digraph station {
in -> v;
v -> out1;
v -> out2;
}
```

For the second station, we also proved the following theorem: *"A railway station must allow a train to enter the railway station as soon as there is a free path from its starting entrance node to its departure exit. You need to prove that in the following railway station with 2 trains at time T, the first at out1 and the second at in both going to exit out2, the signaling device at in will be opened at time T+1."*

5 Tools

We use Prover9 for theorem proving and Mace4 to check that the models are not contradictory. We wrote the program in Java to generate TPTP code.