



## Tutorial for Cyber-Physical Systems - Discrete Models

### Exercise Sheet 4

#### Exercise 1: Railroad Crossing

6 Points

*The goal of this exercise is to demonstrate how synchronous communication (handshaking) can be used to control the possible behaviours of a transition system.*

In the lecture on October 27th (slides *Transition Systems* on slide 32) we discussed a model of a railroad crossing involving a train, a controller and a gate. We saw that the transition system  $Train \parallel Controller \parallel Gate$  for this model can reach a configuration where the train is on the crossing (state *in*) but the gate has not been lowered (state *up*). This is of course undesirable, the train should only be on the crossing when the gate is lowered.

- (a) Identify the design flaw that causes this problem.

**Hint:** Consider for instance the case where the gate is stuck and cannot be lowered.

- (b) How can this design flaw be fixed? Give the transition systems  $Train'$ ,  $Controller'$  and  $Gate'$  for the repaired components.

**Hint:** You can introduce additional states as well as new actions, which can be used to synchronize components and reduce nondeterminism. It is not necessary to change the gate.

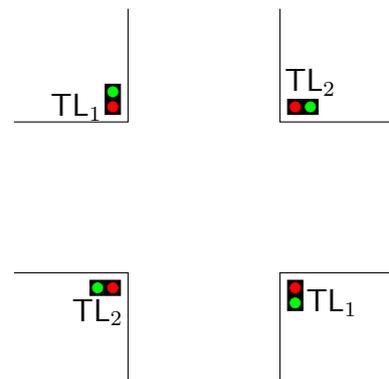
- (c) Draw the transition system for the new model, i.e., the parallel composition of the three components  $Train' \parallel Controller' \parallel Gate'$ .

#### Exercise 2: Crossroads Traffic Lights

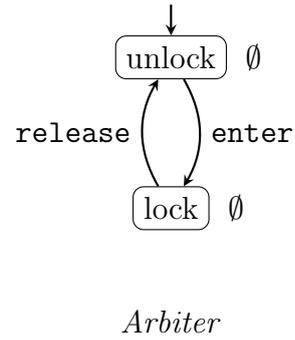
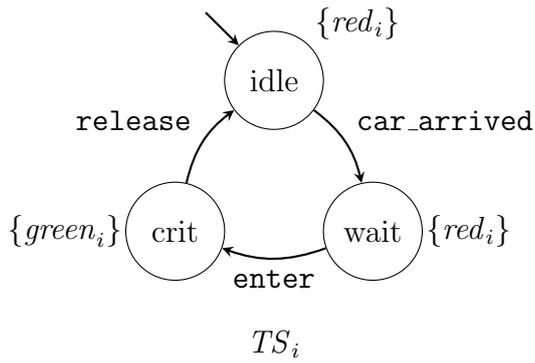
5 Points

*The goal of this exercise is to practice using an arbiter for synchronization, and to understand the limitations of this approach.*

Consider the crossing of two roads with four traffic lights as depicted on the right. The two traffic lights labelled with  $TL_1$  always show the same color, and likewise the two traffic lights labelled with  $TL_2$  always show the same color. The traffic-lights are demand-driven and only switch to green when they have detected the presence of a car.



We model this system with two transition systems,  $TS_1$  and  $TS_2$ , for the traffic lights, one for each direction of the crossing. To avoid car crashes, these transition systems are connected via an arbiter that ensures only one traffic light can be green at a time.



- (a) Draw the parallel composition  $(TS_1 \parallel TS_2) \parallel Arbiter$  of the three transition systems. The traffic lights do not synchronize with each other, but they both synchronize with the arbiter. A configuration of the composed system is labeled with all atomic propositions that hold in any of its local states.
- (b) Use the transition system to answer the following questions.
- Is the system safe, i.e., can the traffic lights for both streets be green at the same time? Explain using the atomic propositions.
  - What other property would we expect from a traffic light? Why does it not hold here?