Systeme hoher Sicherheit und Qualität
Universität Bremen, WS 2017/2018

Lecture 12:

Tools for Model Checking

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Organisatorisches

Wir bieten an folgenden Terminen mündliche Prüfungen an:

- Mi, 07.02.2018
- Do, 15.02.2018
- Mi, 28.02.2018

Anmeldung per Mail beim Veranstalter.

Where are we?

- 01: Concepts of Quality
- 02: Legal Requirements: Norms and Standards
- 03: The Software Development Process
- 04: Hazard Analysis
- 05: High-Level Design with SysML
- 06: Formal Modelling with OCL
- 07: Testing
- 08: Static Program Analysis
- 09: Software Verification with Floyd-Hoare Logic
- 10: Correctness and Verification Condition Generation
- 11: Model Checking
- 12: Tools for Model Checking
- 13: Conclusions

Introduction

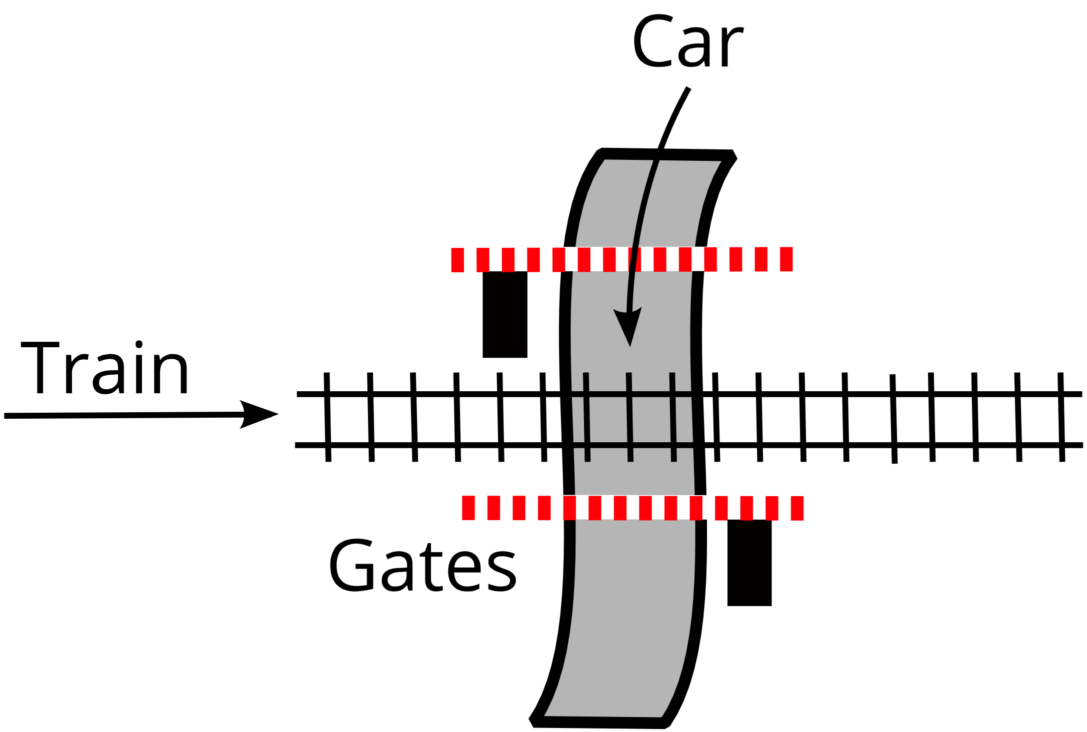
- In the last lecture, we saw the **basics of model-checking**: how to model systems on an abstract level with **FSM** or **Kripke structures**, and how to specify their properties with **temporal logic** (LTL and CTL).
- This was motivated by the promise of "efficient tool support".
- So how does this tool support look like, and how does it work? We will hopefully answer these two questions in the following...

- Brief overview:
  - An **Example**: The Railway Crossing.
  - Modelchecking with **NuSMV** and **Spin**.
  - Algorithms for Model Checking.

The Railway Crossing

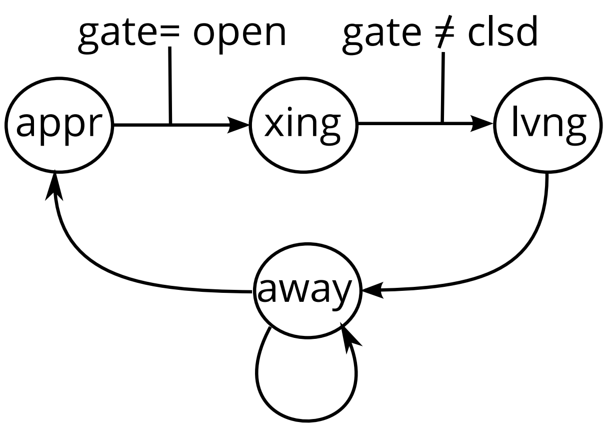
Quelle: Wikipedia

First Abstraction

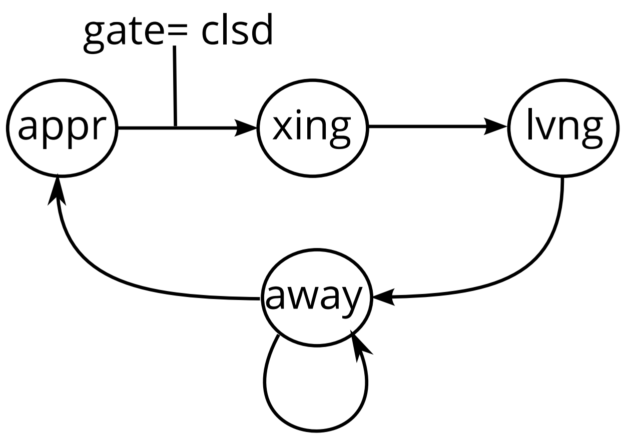


The Model

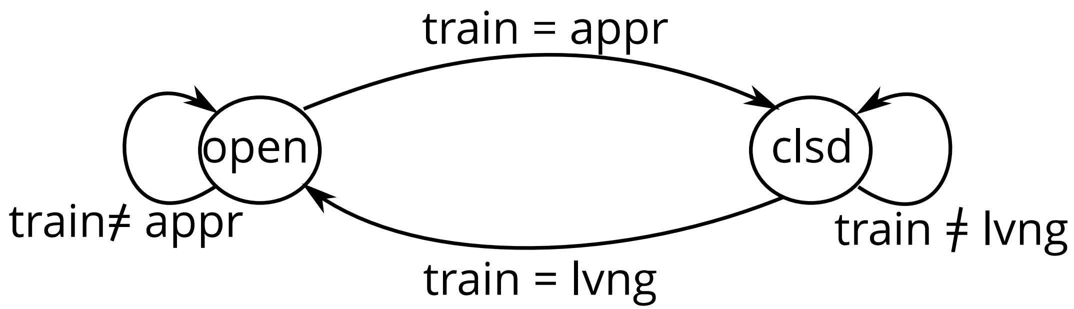
States of the car:



States of the train:



States of the gate:



The Finite State Machine

- The states of the FSM is given by mapping variables $car, train, gate$ to the domains

$$\Sigma_{car} = \{appr, xing, lvng, away\}$$
$$\Sigma_{train} = \{appr, xing, lvng, away\}$$
$$\Sigma_{gate} = \{open, clsd\}$$

- Or alternatively, states are a 3-tuples

$$s \in \Sigma = \Sigma_{car} \times \Sigma_{train} \times \Sigma_{gate}$$

- The transition relation is given by

$$\langle away, away, open\rangle \rightarrow \langle appr, away, open\rangle$$
$$\langle appr, away, open\rangle \rightarrow \langle xing, away, open\rangle$$
$$\langle appr, appr, clsd\rangle \rightarrow \langle appr, xing, clsd\rangle$$
$$\langle appr, xing, clsd\rangle \rightarrow \langle appr, lvng, clsd\rangle$$
$$\langle appr, lvng, clsd\rangle \rightarrow \langle appr, away, open\rangle$$

…

Properties of the Railway Crossing

- We want to express properties such as
  - Cars and trains may never cross at the same time.
  - The car can always leave the crossing.
  - Approaching trains may eventually cross.
  - There are cars crossing the tracks.
- The first two are **safety properties**, the last two are **liveness properties**.
- To formulate these in temporal logic, we first need the **basic propositions** which talk about the variables of the state.

Basic Propositions

- The basic propositions $Prop$ are given as equalities over the state variables:

  $(car = v) \in Prop$ mit $v \in \Sigma_{car}$,
  $(train = v) \in Prop$ mit $v \in \Sigma_{train}$,
  $(gate = v) \in Prop$ mit $v \in \Sigma_{gate}$

- The Kripke structure valuation V maps each basic proposition to all states where this equality holds.

The Properties

- Cars and trains never cross at the same time:

$$G\neg(car = xing \land train = xing)$$

- A car can always leave the crossing:

$$G\left(car = xing \rightarrow F\,(car = lvng)\right)$$

- Approaching trains may eventually cross:

$$G\left(train = appr \rightarrow F\,(train = xing)\right)$$

- There are cars which are crossing the tracks:

$$EF\,(car = xing)$$

  - Not expressible in LTL, $F\,(car = xing)$ means something stronger.

Model-Checking Tools: NuSMV2

- NuSMV is a reimplementation of SMV, the first model-checker to use BDDs. NuSMV2 also adds SAT-based model checking.
- Systems are modelled as synchronous FSMs (Mealy automata) *or asynchronous processes**.
- Properties can be formulated in LTL and CTL.
- Written in C, open source. Latest version 2.6.0 from Oct. 2015.
- Developed by Fondazione Bruno Kessler, Carnegie Mellon University, the University of Genoa and the University of Trento.

* This is apparently depreciated now.

Model-Checking Tools: Spin

- Spin was originally developed by Gerard Holzmann at Bell Labs in the 80s.
- Systems modelled in Promela (Process Meta Language): asynchronous communication, non-deterministic automata.
- Spin translates the automata into a C program, which performs the actual model-checking.
- Supports LTL and CTL.
- Latest version 6.4.7 from August 2017.
- Spin won the ACM System Software Award in 2001.

Conclusions

- Tools such as **NuSMV2** and **Spin** make model-checking feasible for moderately sized systems.
- This allows us to find errors in systems which are hard to find by testing alone.
- The key ingredient is **efficient state abstraction**.
  - But careful: **abstraction** must **preserve properties**.