Explainable Restart-Behaviour of Reactive Systems Software

Dimitri Bohlender | Stefan Kowalewski

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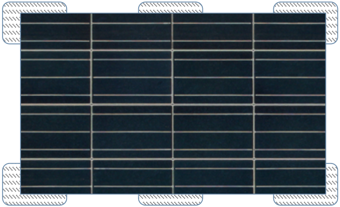
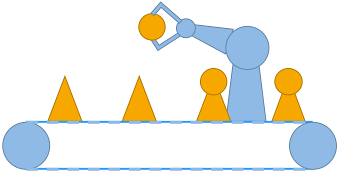
The Setting

- Control software is at the heart of many complex systems
- May be distributed over one to several controllers





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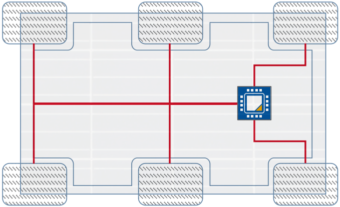

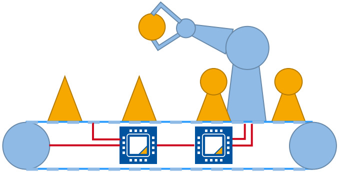

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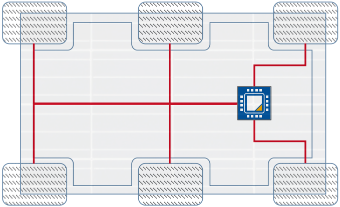

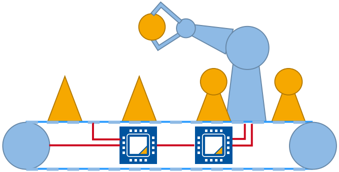

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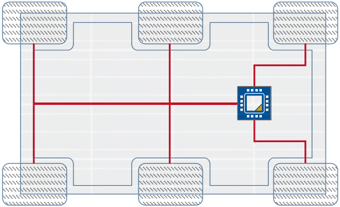

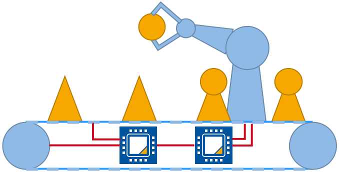

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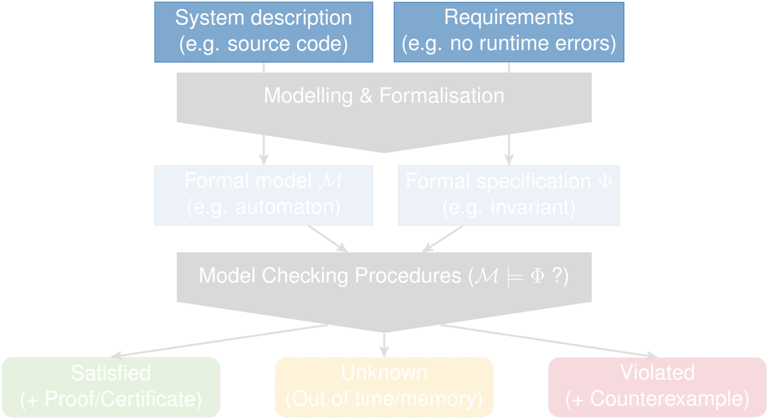

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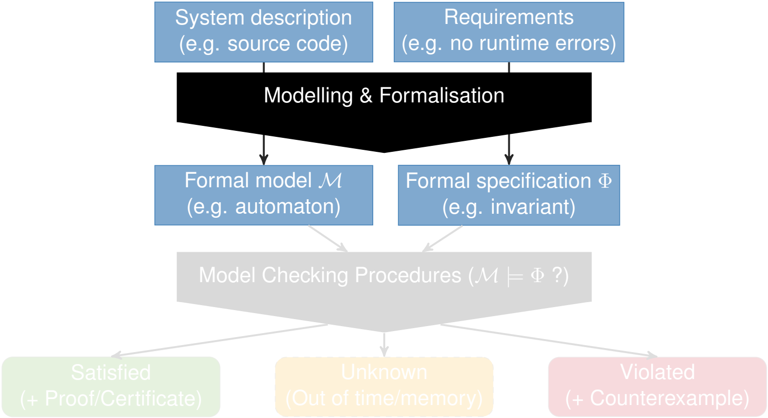

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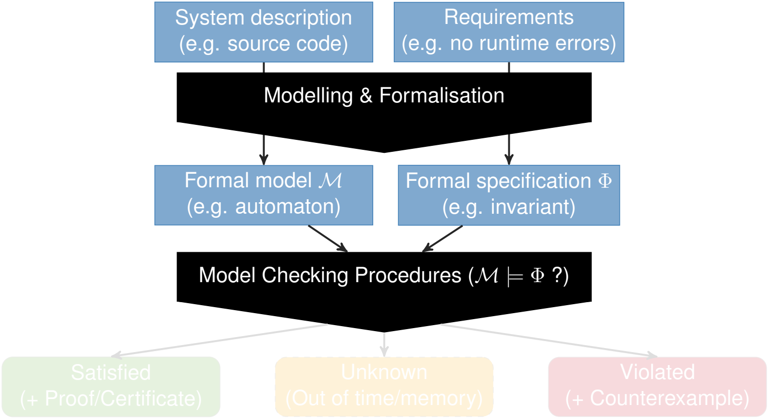

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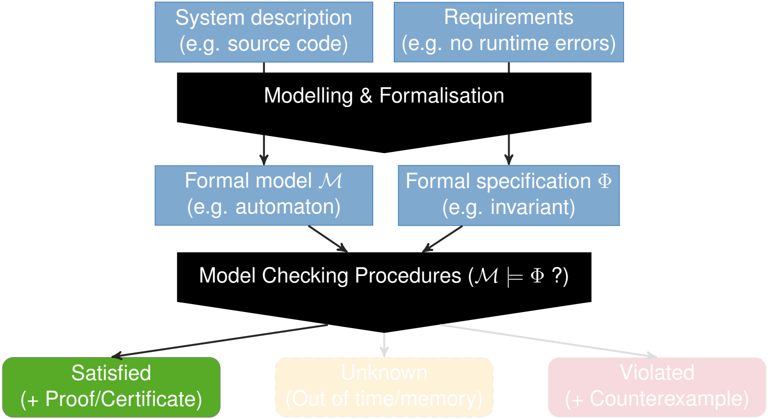

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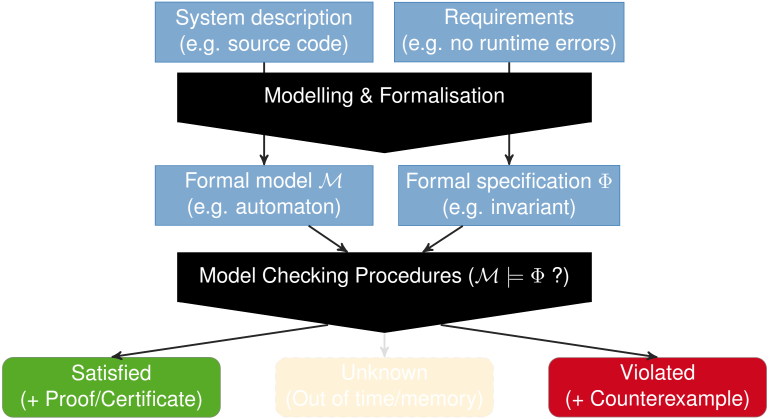

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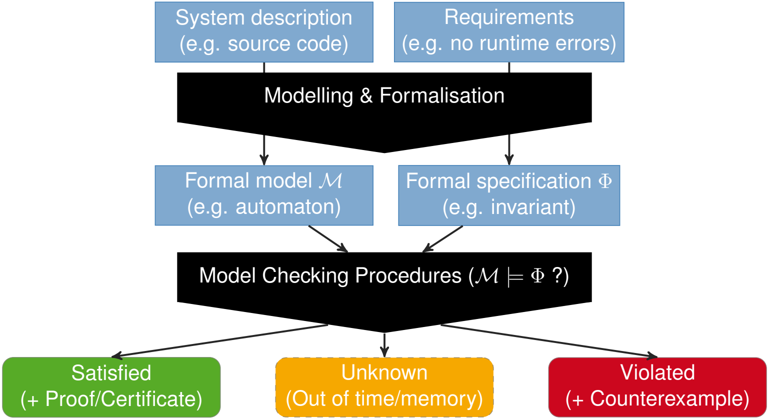

Restart-Behaviour

However:

- Such proof holds w.r.t. the model – not the real system

⇒ Model is usually missing behaviour enabled by hardware

Battery-backed memory & restart-functionality are widespread

- Non-volatile state variables allow for "restart-robust" designs
- Restarts may be
  - triggered by a watchdog timer
  - the result of a power outage or voltage fluctuation
  - triggered manually, e.g. during testing

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- Restarts significantly increase the number of corner cases
- Different semantics of writing to battery-backed memory exist
- Choice of retain-variables left to developer

⇒ Difficult to reason about manually and explain defects

Example (Automated drilling of holes in workpieces)

- Let drill's position be volatile
- A restart may result in unintended movement and damage
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- We work on ARCADE.PLC, a framework for
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- Errors that only occur after restart are a common problem in industrial control code[1]

⇒ We developed procedures considering restart-robustness w.r.t. a specification, i.e. compliance in the context of restarts[2]

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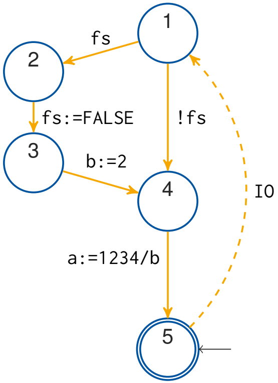

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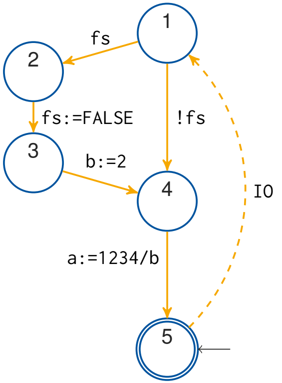

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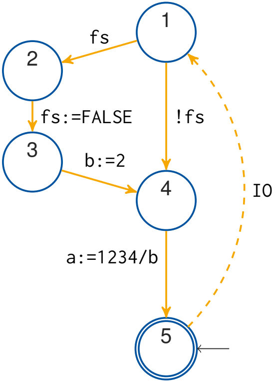

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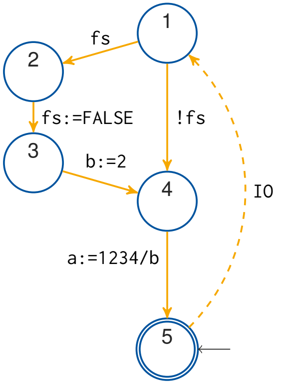

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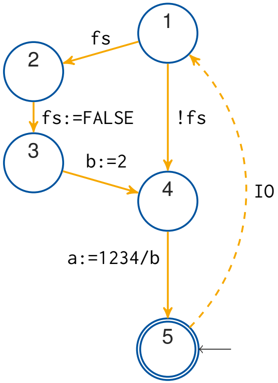

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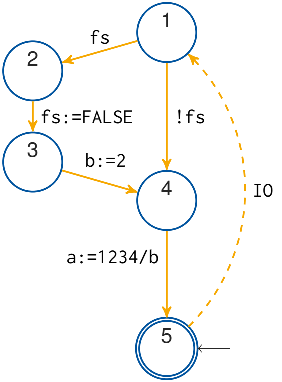

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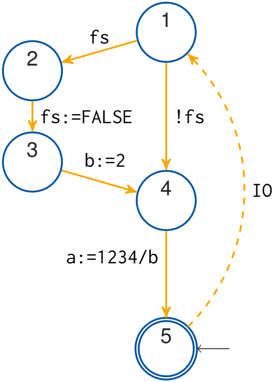

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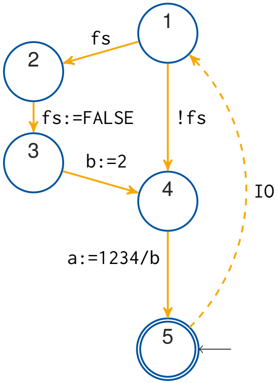

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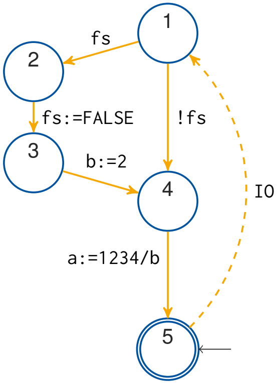

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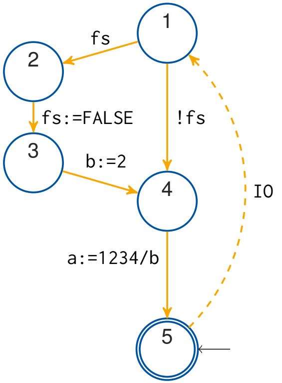

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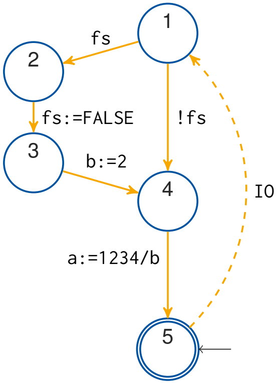

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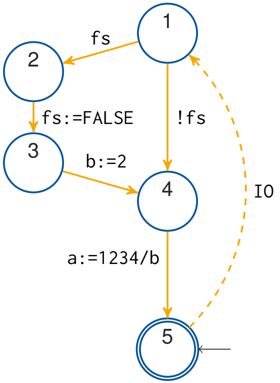

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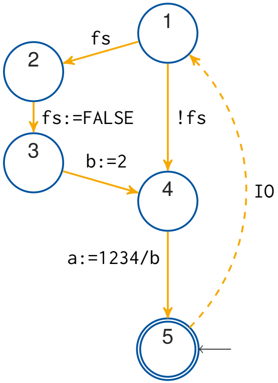

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⇒ Require existence of specifications and checking all of them

- In practice, software is often under-specified

⇒ Many (mis-)behaviours not considered by verifier

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"What is a reasonable definition?"

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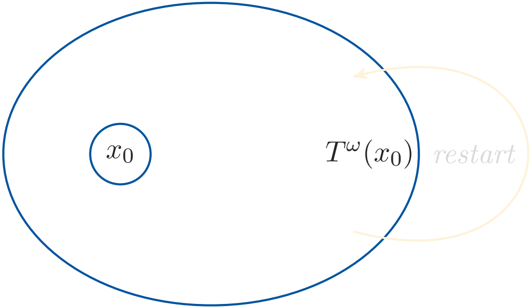

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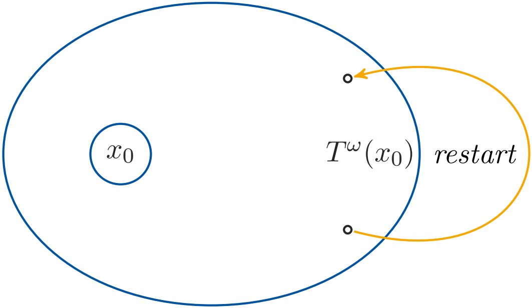

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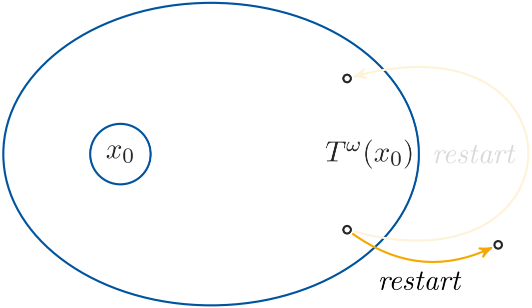

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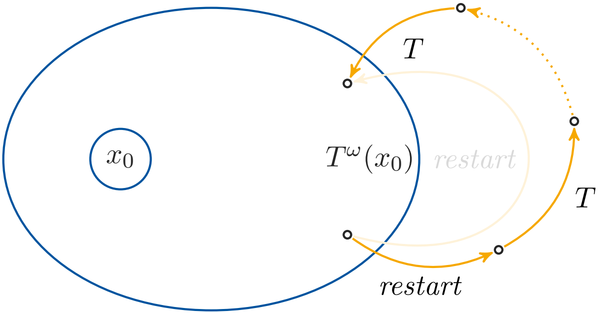


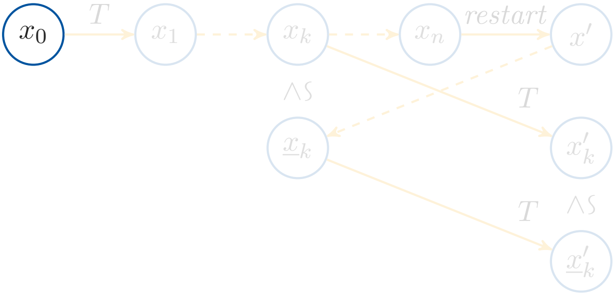
- Restart-augmented program must stay within original states
- Might need grace period of k program cycles

Relate Executions

- After restarting, a state that is (simulation-)equivalent to a pre-restart state will eventually be reached[3]

[3] Eric Koskinen and Junfeng Yang. “Reducing crash recoverability to reachability”. In: *POPL 2016*. 2016, pp. 97–108.

Relate Executions



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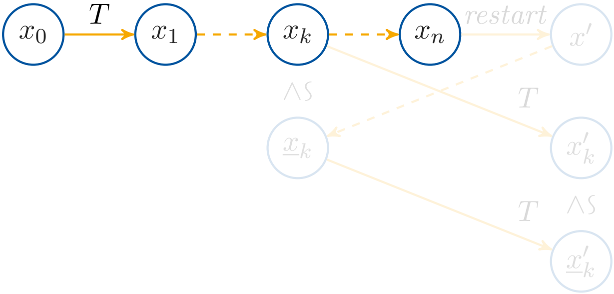
Relate Executions



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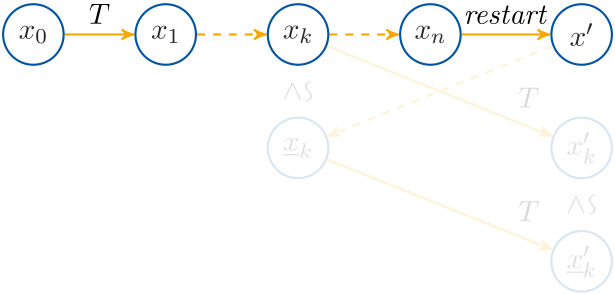

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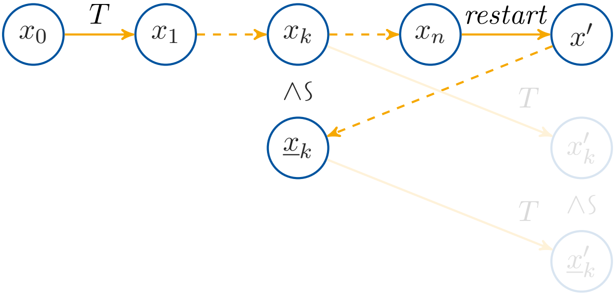

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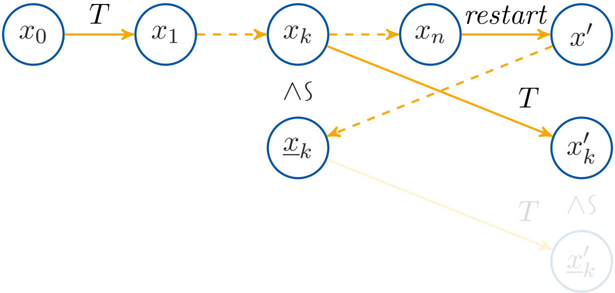

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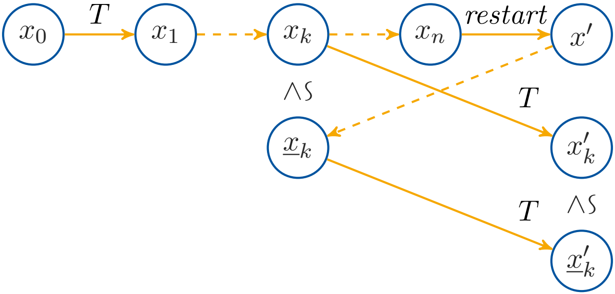

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Summary

- Battery-backed memory & restart funcitonality are common features that enable the design of systems resilient to restarts
- Currently, we consider restart-robustness w.r.t. a specification
- A relational definition of restart-robustness is more practical

But Insight needed to define to what extent the restart-augmented program is allowed to deviate from the original

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