Real-Time Systems
Lecture 19: Wrapup

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Content

Introduction
• First-order Logic
• Duration Calculus (DC)
• Semantical Correctness Proofs with DC
• DC Decidability
• DC Implementables
• DC Proof Systems

Timed Automata (TA), Uppaal
• Networks of Timed Automata
• Region/Zone-Abstraction
• Extended Timed Automata
• Undecidability Results (Uppaal)

PLC-Automata

\[ \text{obs} : \text{Time} \rightarrow \mathcal{P}(\text{obs}) \]

\[ \langle \text{obs}_0, \nu_0 \rangle, t_0 \xrightarrow{\lambda_0} \langle \text{obs}_1, \nu_1 \rangle, t_1 \ldots \]

• Automatic Verification...
• ...whether TA satisfies DC formula, observer-based

Recap
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- Lecture 02: Timed Behaviour
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- Lecture 06: DC Properties I (RDC in Discrete Time)
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Motivation/Big Picture

Lecture 1:

- What is a real-time system?
- In contrast to reactive, hybrid, ...?
- What is a safety-critical system?
- When do we call a real-time system correct?
- What is an approach to the development of correct real-time systems? What prerequisites does it have?
- What could justify this high effort?
- What are hard/soft deadlines?
- How did we partition reactive systems?
- Can you give an example for a “plant” from the tutorials.
- What’s discrete and what’s continuous time? Which did we use and why?
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Timed Behaviour

**Lecture 02:**

- **Educational Objectives:**
  - Get acquainted with one (simple but powerful) formal model of timed behaviour.
  - What is the idea of Time-dependent State Variables?
  - What is a timing diagram?
  - Can you formalise this requirement using first order predicate-logic?
  - What classes of timed properties did we distinguish?
  - To what classes of timed properties does this property belong?
  - Why is it useful to consider classes of properties?
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Duration Calculus

Lecture 03, 04, 05:

- **Educational Objectives**: Capabilities for following tasks/questions.
  - What does this Duration Calculus formula mean?
    (Intuitively and formally.)
  - Please formalise this requirement/design in DC.
    (In particular: get the syntax right.)
  - Why is DC called duration calculus? What’s special about DC?
  - What’s an interval logic?
  - What’s the difference between global variables and state variables? What’s their semantics?
  - Is a DC term a DC formula?
  - What’s a rigid term?
  - What does this DC abbreviation “unfold” to?
  - There was the question whether the DC semantics is well-defined. What was the issue and how did we address it?
  - Please give an interpretation of the state variable which satisfies/realises (from 0) this DC formula.
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DC Properties

Lecture 06 & 07:

- **Educational Objectives:** Capabilities for following tasks/questions.
  - Facts: decidability properties. What is/is not decidable for (R)DC?
  - Why would a decision procedure for this problem be useful?
  - How is (un)decidability of the Hmm problem proved? (What’s the idea of the proof? What steps are conducted? What is established?)
  - What’s RDC? What is it useful for?
  - What’s (R)DC in discrete time?
  - Can we distinguish by a DC formula whether we’re in a discrete or continuous time model?
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DC Implementables

Lecture 08:

- **Educational Objectives**: Capabilities for following tasks/questions.
  - What does this standard form mean? Give a satisfying interpretation.
  - What is a control automaton?
  - What’s a basic phase of a control automaton?
  - What are implementables?
  - Please specify (and prove correct) a controller which satisfies this requirement.
  - Do you like gas burners?
  - What property of implementables is interesting in the context of TA?
Lecture 09:

- **Educational Objectives:** Capabilities for following tasks/questions.
  - What is the “philosophy” of PLC? What did we generalise/abstract them to?
  - Why did we discuss PLC?
  - What if we don’t have a PLC at hand but only a real-time Linux and a C compiler?
  - What would distinguish a real-time from a plain Linux anyway?
  - What is a PLC automaton?
  - What’s the issue with the cycle time in a PLCA?
  - What does this PLC automaton do?
  - How would you solve this control problem with a PLCA?
  - How does the proposed approach work, from requirements to a correct implementation with DC?
  - **Dynamics of DC**

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Timed Automata

Lecture 10, 11 & 14:

- **Educational Objectives:** Capabilities for following tasks/questions.
  - What’s notable about TA syntax? What’s a simple clock constraint?
  - What’s a configuration of a TA? When are two in transition relation?
  - Is there something remarkable about the definition of configurations?
  - What’s the difference between guard and invariant? Why have both?
  - What’s a computation path? A run? Zeno behaviour? Timelock?
  - Does this TA have a run? Which/why not?
  - Where does “time pass”?
  - Can you imagine what somebody means by saying “TA are closed under parallel composition”?
  - In how far are Uppaal TA non-compositional?
  - What’s an urgent/committed location? What’s the difference?
  - Is this location of that TA network reachable?
  - Where has the notion of “input action” and “output action” a correspondence in the formal semantics?
  - Can you give a network of TA which has this behaviour?

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Regions and Zones

Lecture 12:
- **Educational Objectives**: Capabilities for following tasks/questions.
  - What are decidable problems of TA?
  - How can we show this? What are the essential premises of decidability?
  - What is a region? What is the region automaton of this TA?
  - What’s the time abstract system of a TA? Why did we consider this?
  - What can you say about the complexity of Region-automaton based reachability analysis?

Lecture 13:
- **Educational Objectives**: Capabilities for following tasks/questions.
  - What’s a zone? In contrast to a region?
  - Motivation for having zones?
  - What’s a DBM? Who needs to know DBMs?

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Undecidable TA Problems

Lecture 15 & 16:

- **Educational Objectives:** Capabilities for following tasks/questions.
  - What’s a TBA and what’s the difference to (extended) TA?
  - What is a timed (regular) language?
  - What language does this TBA accept?
  - Can you give a TBA with this language?
  - What’s undecidable for timed (Büchi) automata?
  - Why is this unfortunate?
  - What’s the idea of the proof?
  - What’s the universality problem?

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Automatic Verification of DC Properties for TA

Lecture 17 & 18:

- **Educational Objectives:** Capabilities for following tasks/questions.
  - How can we relate TA and DC formulae?
  - What’s a bit tricky about that (regarding semantics and intuition)?
  - Can we use Uppaal to check whether this TA satisfies this DC formula?
  - How? What do we have to be careful with?
  - What is a testable DC formula?
  - What could this monitor/observer/test automaton be useful for?
  - Can the TA and DC formulae for which we can check something be (syntactically) characterised?

References
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