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~~
- **PLC-Automata**

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

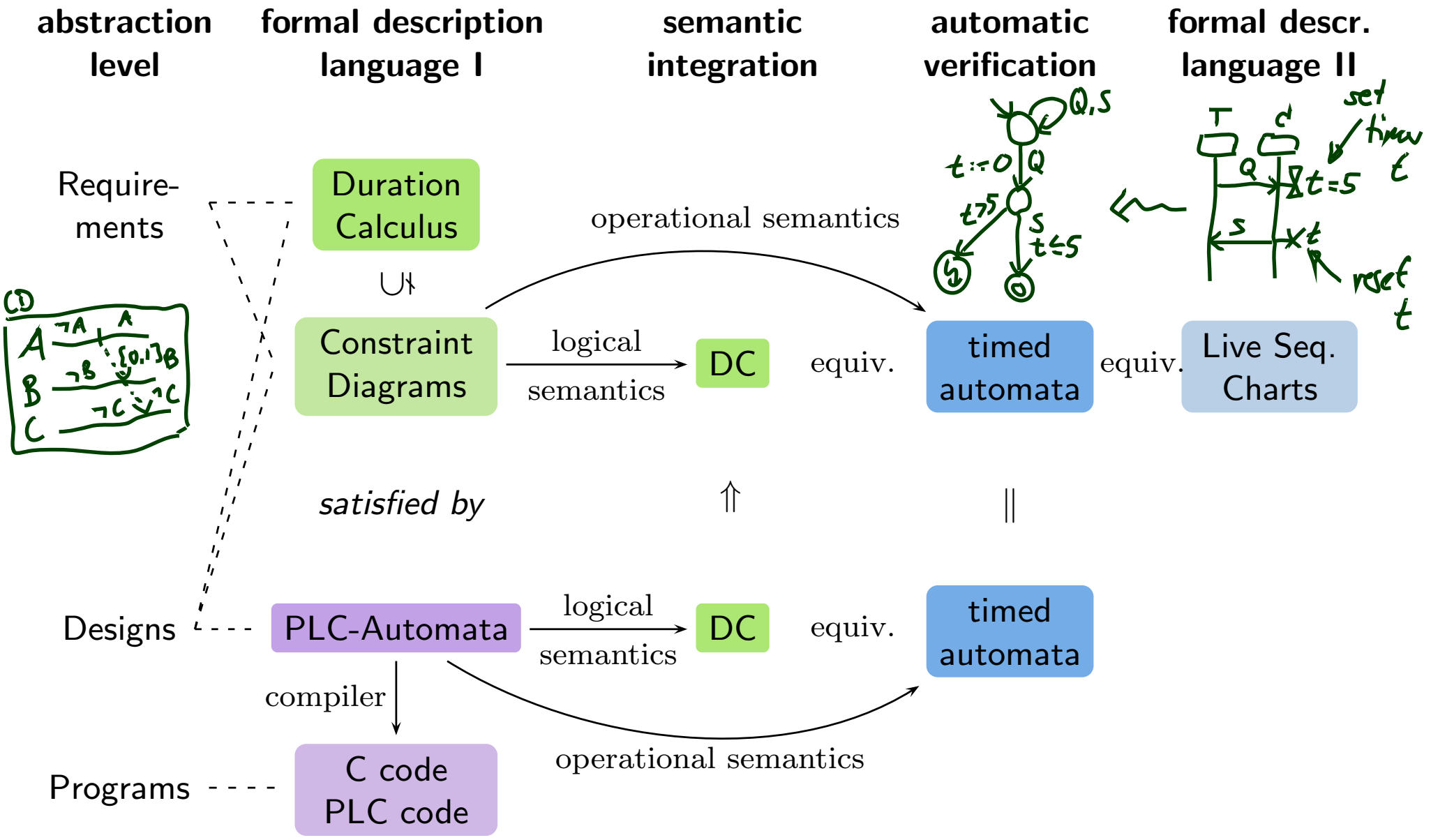
$obs : \text{Time} \to \mathscr{D}(obs)$

$\langle obs_0, \nu_0 \rangle, t_0 \xrightarrow{\lambda_0} \langle obs_1, \nu_1 \rangle, t_1 \ldots$

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

Recap

Tying It All Together



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- Lecture 02: Timed Behaviour
- Lecture 03: Duration Calculus I (Symbols, State Assertions)
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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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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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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?

PLC Automata

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?
  - DC-semantics of DC

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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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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

References

[Olderog and Dierks, 2008] Olderog, E.-R. and Dierks, H. (2008). *Real-Time Systems - Formal Specification and Automatic Verification*. Cambridge University Press.