Software Model Checking: Theory and Practice

Lecture: Specification Checking - Foundations

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Objectives

- To understand the goals and basic elements of every formal specification formalism
- To understand that a variety of different levels of abstraction and aspects of program behaviour that can be specified
- To understand the range of languages that can be used to express behavioural property specifications
Outline

- What is a specification?
- Why write specifications?
- What are the building blocks of specs?
- What aspects of behaviour can be captured in a formal specification?
- What are some of the different styles of specification?
What is a Specification?

- A detailed, exact statement of particulars, especially a statement prescribing materials, dimensions, and quality of work for something to be built, installed, or manufactured.
  
  American Heritage Dictionary 2000

- needs to be precise

- describes what is to be done
What is a Formal Specification?

- A *formal specification* is the expression, in some *formal language* and at some level of abstraction, of a *collection of properties* that some system should *satisfy*.


- *Formal language*
  - ensures precision
- *Properties ... system should satisfy*
  - is a prescription
Why Write Specifications?

- To drive the implementation of a system
  - Rare - usually driven from informal requirements
  - Expensive - would require a complete specification
- To provide a redundant description of intent so we can check an implementation against something
  - Generate tests
  - Perform rigorous inspections
  - Model check
A Spec for Spec Languages

Concise
- if the spec is as large and complex as the system, you’ve shifted the problem to the spec

Understandable
- spec needs to be right, so you must be able to read it

General
- want to be able to describe a wide range of system characteristics

Think Different
- Should force you to express properties differently than solutions
What’s a Good Spec?

**Consistent**
- no internal contradictions

**Complete**
- captures all of the essential aspects of the problem that are described elsewhere

**Unambiguous**
- has a unique meaning

**Minimal**
- doesn’t state irrelevant or implementation-specific properties
Essential Parts of a Specification

Components of the system that are related to the property $x$

Constraints define what is demanded, desired, or restricted of the components $x > 0$

Order describes how, if at all, the constrained-components related to one another

if $x > 0$ then after $x++$, $x > 0$
A Familiar Example

How would you describe a phone?

- Rotary or push button
- Wired or cell
- Coin operated or billed
- Handset or speaker
- Integrated phonebook
- Color, weight, materials, ...

We focus on functional behavior
Making a phone call

From a functional point of view:
What components of the phone are relevant?
What characteristics of those components do we care about?
How does the order in which components attain those characteristics influence the making of a phone call?
Variations in Specification Style

- **State-based**: a condition or mode of being
  - phone is off the hook
  - call is connected

- **Event-based**: something that happens at a given place and time
  - phone is lifted
  - number 3 is dialed
For You To Do

- Consider the property:
  
  *Dial 532-6350 to connect to CIS*

- Give a state-based specification

- Give an event-based specification

- Don’t forget to mention any implicit parts or constraints that are relevant
States and Events

- Changes in state are caused by events

  \[ x == 5 \quad \xrightarrow{x++} \quad x == 6 \]

- Not all events cause a change in state

  \[ x == 5 \quad \xrightarrow{x=x+0} \quad x == 5 \]
When the door is open and the key is not in the ignition, the alarm beeps.

\[
\text{door} == \text{open} \\
\text{ignitionKey} != \text{in} \\
\text{beep}
\]

Assigning \(x\) to 7 makes \(x\) greater than 0.

\[
\text{x} = 7 \\
\text{x} > 0
\]
Variations in Specification Style

- **Allowable behavior**: define what a correctly functioning system is able to do
  - offhook, number\(^7\), connected

- **Violations**: define what a correctly functioning system can never do
  - onhook, … anything but offhook …, connected
Specification Formalisms

- **Assertions**
  - Describe a condition in a *particular* system state

- **Invariants**
  - Describe a condition in *all* system states

- **State Machines**
  - Describe *sequences* of system states
  - Finite state automata vs. Buchi automata
  - Regular expressions vs. Linear Temporal Logic

- … lots more
Summary

- Specifications are an essential element of rigorous system analysis.
- A property specification usually focuses on a specific aspect of a system’s behaviour:
  - Only some of the system’s components are involved.
  - Only concerned with a limited view of those components.
- Specifications can be written in a variety of styles:
  - To suite the goals of the specifier.
  - To suite a particular property.
  - To enable a particular form of analysis.
- There are a large number of specification formalisms that one could apply to state properties of systems.