Model Checking in Uppaal

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http://ceres.hh.se/mediawiki/DIT085

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Dynamic Testing

Dynamic testing: invoking faults and detecting failures through execution of the program code on an actual execution platform

Pros:

- Quick and scalable techniques
- Natural extension of programming skills

Cons:

- No proof of correctness
- Gaps and redundancies

Alternatives to Dynamic Testing

Static Analysis / Abstract Interpretation

1. Approximating the program behavior into a mathematical structure
2. Using analysis techniques to detect a fixed category of faults
3. Refining the approximation by removing the false negatives

Model Checking

1. Translating program or specification into a behavioral model on an abstract machine
2. Correctness properties as logical formula
3. Checking whether behavior satisfies formula, producing counter-example if it does not

Static Analysis: Division by Zero

Input(x)
Input(y)
...
if x > 20 **then**
  x = x - 1 ;
end if
y = y/x

Static Analysis: Pros and

Pros

1. Scalable and efficient, often push button (integrated in IDEs)
2. Useful for common faults (e.g., division by zero, null pointer deref.)

Cons

1. Usually for a fixed property
2. Possibility of false negatives

Model Checking

Turing Award 2007 (abridged)

A program (i.e., model checker) can exhaustively construct every possible sequence of actions a system might perform, and for every action it could evaluate a property in logic. If the program found the property to be true for every possible sequence, the possible execution sequences form a model of the specified property.

Gossiping Girls: Specification

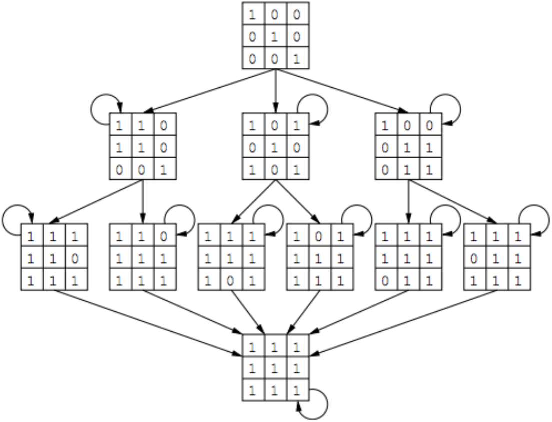
The Scene

1. n girls, each knowing a set of facts,
2. they call each other, and gossip so much that they know the same facts afterwards
3. continue until everyone knows everything

Gossiping Girls: Code Snippet

```
typedef int[1,3] girls;
bool knows[girls][girls];
void share (girls a, girls b) {
for (c : girls) {
   knows[a][c] := knows[a][c] or knows[b][c];
   knows[b][c] := knows[a][c];
}
```

Gossiping Girls: State Space



How about more girls, say 6? 6 trillion possible combinations!

Gossiping Girls: Property

Eventually every girl will know everything that every other girl knows.

Uppaal Tool

`http://www.uppaal.org`

- Developed at Uppsala and Aalborg (with contributions from other universities)
- Free for academic and private use
- Java-based implementation, socket-based server
- Toolsets for: simulation, verification, test case generation, optimization, statistical verification, and scheduling

Uppaal 101

System Descriptions : Networks of (Communicating) Timed Automata

Properties: Timed Computational Tree Logic (a sort of temporal logic)

Uppaal Templates

Timed Automata:

- Name
- Parameters
- Locations (nodes, states):
  - Name
  - Invariant
  - Initial
  - Urgent or Committed: time freezes, in case of committed state, one of the enabled committed states should be left next

Uppaal Templates

- Transitions (edges, vertices):
  - Select: choice of a parameter (to be read as "for some")
  - Guards: logical conditions on variables and clocks
  - Synchronizations: messages sent and received on channels (see the next slide)
  - Updates: change of variable values, resetting clocks

Uppaal Templates

- Channels:
  - Hand-shaking synchronization: receiving and sending synchronizations must be enabled
  - Broadcast: sender always succeeds, as many receiving synchronizations as possible synchronize

Timed Computational Tree Logic

- Expressions on variables and location names
- Usual logical connectives (`and`, `or`, `not`, `imply`)
- path quantifiers: `A` in every execution vs. `E` in some execution
- temporal operators: [] globally in every state vs. $<>$ eventually in some state,
  - `A`[] p invariantly (at every state of every execution) p holds
  - `E` $<>$ p possibly (there exists a state state in some execution) p holds
  - `A` $<>$ p inevitably (there exists a state state in every execution) p holds
  - $p --> q$ “leads to” is an acronym for `A`[] (p `imply` `A` $<>$ q)

Monitoring behavior

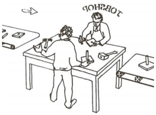
- To check for certain desired / forbidden sequence of state / transitions:
  - Define global variables to expose the state,
  - Make a monitor template that checks for a sequence of states / transitions using the global variables as guards,
  - Give the final state of the desired / forbidden order a name, e.g., “error”,
  - Create an instance of your monitor template with the rest of the system,
  - Check for reachability of “error”.

Jobshop

The Scene (simplified)

1. two workers at a jobshop, putting pegs into blocks,
2. one hammer and one mallet available
3. 2 types of jobs:
   - easy: requiring either hammer or mallet,
   - difficult: requiring both
4. finish after 3 jobs

Due to the late Robin Milner.



Acknowledgment

The material presented today is based on Frits Vaandrager's chapter on Uppaal; see the course page.

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