Towards Wise Computing:

An Initial Wise Development Environment for Behavioral Models

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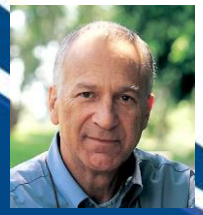
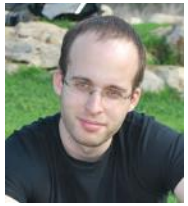

מכון ויצמן למדע
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Talk Based on

D. Harel, G. Katz, R. Marelly and A. Marron,

“An Initial Wise Development Environment for Behavioral Models”, In Proc. of Modelsward, 2016.

Agenda

- The Wise Computing Vision
- An Initial Wise Development Framework

A Nagging Question

- Situation & Assumptions
  - Software development is very hard
    - including some theoretical results
  - And it is likely to remain so even when all tools from industry and academia are mature and available to all
  - But we are and will be able to create reliable complex systems

- Question:
  - So what is this “magic” that the humans will (still) do?

- Answers:
  - Hard work on routine tasks that were not automated yet
  - Complex tasks that we don’t know yet how to automate.

The "*Wise Computing*" Vision Summary

Enable IDEs to perform "all" SE tasks

that are presently considered uniquely human-centric

and require

sophistication / intelligence / wisdom.

Harel et al, *" Wise Computing: Towards Endowing System Development with True Wisdom ", arXiv,* 2015

The “Added Value” of Humans in SE

- Broad knowledge and experience – SE, domain, user’s “world”
- Unbounded access to formal artifacts and informal information
- Ability to discover emergent properties
- Association-driven action / initiative / proactivity
- Ability to prioritize, skip, or interrupt activities
- Dedication (e.g., thinking about something “all the time”)
- Creativity / Invention / Innovation / ”Thinking-outside-the-box”
- . . .

The “Added Value” of Humans in SE (cont.)

- . . .
- Applying external knowledge to a particular situation
- Judging emergent properties and behaviors as “good”, “bad”, etc.
- Visualizing hypothetical situations
- Work and communicate in multiple and orthogonal ways/abstractions
- Ability to ask questions
- Formalizing informal statements (= *“programming”*)
- Ability to repair/modify defective/lacking programs
- . . .

Wise Computing

- **Goal:**

  create an interactive , proactive and knowledgeable development framework (WDS)

  - **Accompanies all phases of development**
  - **Analyzes the model without being told**
  - **Autonomously raises concerns, makes suggestions, repairs**

- **The WDS becomes a member of the dev. team**

- **A long-term goal**

Related Work

- The Programmer's Apprentice:
  Rich, Waters, Shrobe et al, 70′s to early 90′s
  - Teach the computer how to model/program
  - Based on clichés

- "Towards a Programmer's Apprentice (Again)"
  Shrobe, Katz, Davis, 2015.
  - From NL requirements to code

- "A Long Way to Have Come and Still to Go" ,
  Cerf , CACM, 12/2014

- A variety of focused tools

Why Now?

- **A lot has changed**
  - **Stronger machines**
  - **Formal analysis tools**
  - **Powerful HCI and NL methods**
  - **New programming / modeling approaches: closer to how people describe behavior**
  - **…**

Recent Results

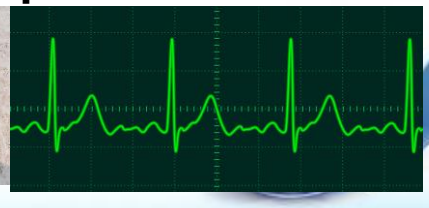
- An Initial Wise Development Suite (WDS)
- For Behavioral Models
  - Scenario-based programs in C++
  - System structure aligned with how people describe behavior
  - Amenable to incremental development and formal analysis

Components of an initial WDS: The three sisters

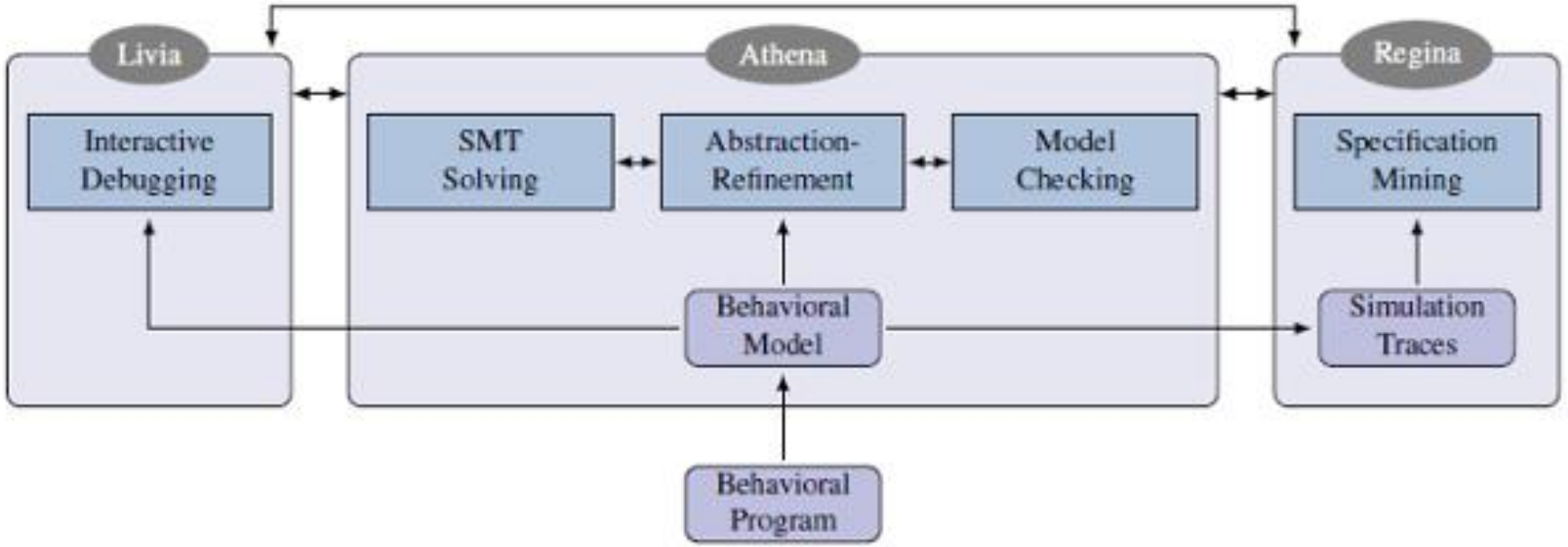
- **Athena:**
  - **Performs precise analysis of properties**
    - **General (e.g., deadlocks) and as suggested by Regina**
  - **Uses model-checking, SMT solving, abstraction-refinement…**

- **Regina:**
  - **Performs random/statistical simulations**
  - **Discovers emergent properties**
  - **Sends selected properties to Athena to validate**

- **Livia:**
  - **Performs live, run-time monitoring for desired properties**
  - **Run-time analysis, BMC**



An Initial WDS



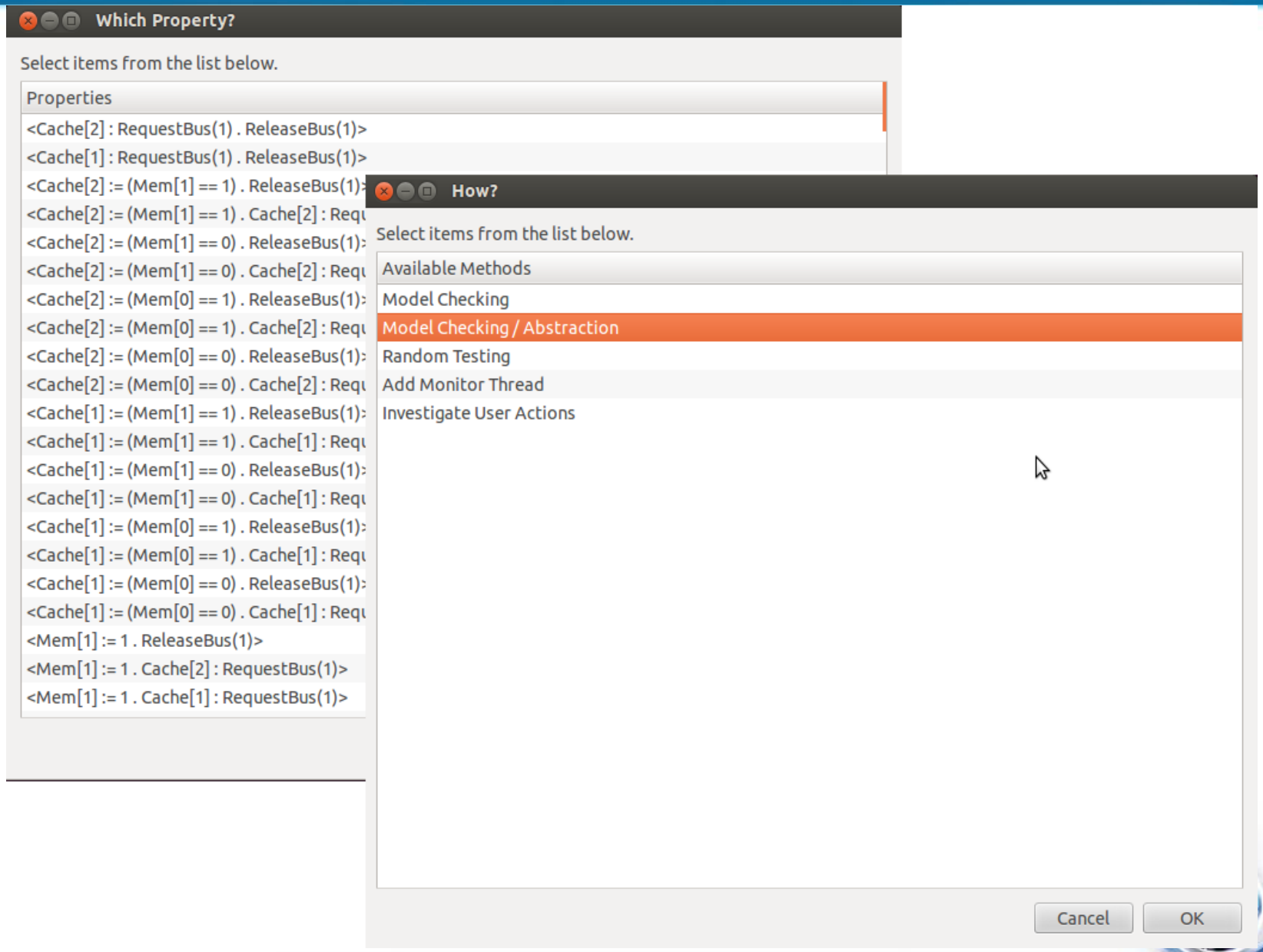
Development Workflow

- Constant analysis: interrupted and restarted with each compilation
  - Extract scenario models from code
  - Abstract the details and focus on inter-scenario comm.
  - Partition into modules – using patterns and “shared” events
  - Specification mining:
    - Run statiscal simulations on abstract model
    - Discover emergent properties: Bugs/Goals/Other?
  - Prioritize: heuristics / representatives / manual
  - Prove properties: MC, SMT, Abstraction-refinement, statistical testing
  - Throughout: interactively present results, explore deeper, repair

```
#ifndef __CacheOneReadHasBit_h__
#define __CacheOneReadHasBit_h__

#include "BThread.h"
#include "EventCodes.h"

class CacheOneReadHasBit : public BThread
{
public:
    CacheOneReadHasBit() : _getBitZero( *this, false )
    {
        _cacheOneReadEvents.insert( EventCodes::CACHE_ONE_EMPTY );
        _cacheOneReadEvents.insert( EventCodes::CACHE_ONE_BIT_0_IS_0 );
        _cacheOneReadEvents.insert( EventCodes::CACHE_ONE_BIT_0_IS_1 );
        _cacheOneReadEvents.insert(
        _cacheOneReadEvents.insert(
    }

    void entryPoint()
    {
        while ( true )
        {
            waitForRequests();

            if ( bitIsStored() )
            {
                reset();
                replyToRequest();
            }
            else
            {
                reset();
                waitForReply();
            }
        }
--:**-  CacheOneReadHasBit.h    Top
Beginning of buffer
```

Wise Framework Output

```
13:20:18        Selected property to check: ReleaseBus(1) <--> Cache[1] : RequestBus(1)
13:23:56        Model-checking based proof that property ReleaseBus(1) <--> Cache[1] : RequestBus(1) does not hold
13:23:56                Pc[1] : Write(Mem[1], 0)
13:23:56                Cache[1] == ?
13:23:56                pc[2] : Write(Mem[1], 0)
13:23:56                Cache[2] == ?
13:23:56                Cache[1] : RequestBus(1)
13:23:56                Mem[1] == 0
13:23:56                Cache[1] := (Mem[1] == 0)
13:23:56                ReleaseBus(1)
13:23:56                Cache[2] : RequestBus(1)
13:23:56                Mem[1] == 0
13:23:57                Cache[2] := (Mem[1] == 0)
13:23:57                ReleaseBus(1)
13:23:57                pc[2] : Success
13:23:57                pc[2] : Write(Mem[1], 0)
13:23:57                Cache[2] == (Mem[1] == 0)
13:23:57                pc[2] : Success
13:23:57                Pc[1] : Success
13:23:57                Pc[1] : Write(Mem[1], 0)
13:23:57                Cache[1] == (Mem[1] == 0)
13:23:57                pc[2] : Write(Mem[1], 0)
13:23:57                Cache[2] == (Mem[1] == 0)
13:23:57                pc[2] : Success
13:23:57                Pc[1] : Success
13:23:57                Pc[1] : Write(Mem[1], 0)
13:23:57                Cache[1] == (Mem[1] == 0)
13:23:57                pc[2] : Write(Mem[1], 0)
13:23:57                Cache[2] == (Mem[1] == 0)
13:23:57        Duration of model checking: 00:03:34
13:23:57
13:24:19        Selected property to check: Cache[2] : RequestBus(1) --> ReleaseBus(1)
13:26:46        Property Cache[2] : RequestBus(1) --> ReleaseBus(1) holds!
13:26:46        Duration of model checking: 00:02:23
13:26:46
```


Which Property?
Select items from the list below.
Properties
<Cache[2] : RequestBus(1) . ReleaseBus(1)>
<Cache[1] : RequestBus(1) . ReleaseBus(1)>
<Cache[2] := (Mem[1] == 1) . ReleaseBus(1)>
<Cache[2] := (Mem[1] == 1) . Cache[2] : Requ
<Cache[2] := (Mem[1] == 0) . ReleaseBus(1)>
<Cache[2] := (Mem[1] == 0) . Cache[2] : Requ
<Cache[2] := (Mem[0] == 1) . ReleaseBus(1)>
<Cache[2] := (Mem[0] == 1) . Cache[2] : Requ
<Cache[2] := (Mem[0] == 0) . ReleaseBus(1)>
<Cache[2] := (Mem[0] == 0) . Cache[2] : Requ
<Cache[1] := (Mem[1] == 1) . ReleaseBus(1)>
<Cache[1] := (Mem[1] == 1) . Cache[1] : Requ
<Cache[1] := (Mem[1] == 0) . ReleaseBus(1)>
<Cache[1] := (Mem[1] == 0) . Cache[1] : Requ
<Cache[1] := (Mem[0] == 1) . ReleaseBus(1)>
<Cache[1] := (Mem[0] == 1) . Cache[1] : Requ
<Cache[1] := (Mem[0] == 0) . ReleaseBus(1)>
<Cache[1] := (Mem[0] == 0) . Cache[1] : Requ
<Mem[1] := 1 . ReleaseBus(1)>
<Mem[1] := 1 . Cache[2] : RequestBus(1)>
<Mem[1] := 1 . Cache[1] : RequestBus(1)>
How?
Select items from the list below.
Available Methods
Model Checking
Model Checking / Abstraction
Random Testing
Add Monitor Thread
Investigate User Actions
Cancel
OK

A Case Study

- Modeled a cache coherence protocol
- Used the wise framework throughout development
- Wanted to answer:
  - Is the idea scalable?
  - Can we reach interesting conclusions on a larger program?
  - Is this type of development enjoyable?
- In our experience: yes, yes and a subjective yes
- Video available online (link in paper)

Example: An Emergent Property

- **"Cache 3 cannot acquire bus 2 twice without first releasing it"**
  - **Prioritized because it is a mutual exclusion property**
- **Framework abstracts away code relating to bus 1**
- **Accelerated verification due to abstraction:**
  - 21,000 **states instead of** 972,233
  - 30 **seconds instead of** 1620
- **Process completely autonomous**

Case-Study Conclusions

Showed useful proactive analysis as part of development flow

General Challenges in Wise Computing

- **Modeling and representation**
- **Analysis and synthesis techniques**
- **Human-computer discourse**

Thank You!