Runtime Assurance Based on Formal Specifications

and

Purify

Administrivia

- Homework 2
  - due next Thursday (Feb 12)
- Blog – ok?
- Presentations
  - first presentation is today
  - let me know if there's a particular area or paper you'd like to present
  - I'm putting a list of additional possibilities on the course web page

Administrivia - calendar

- CMPS 280G Thurs 2-3:45pm, Crown 105
  - Feb 12: Arnaud Venet and Guillaume Brat
    - NASA's C Global Surveyor
  - Feb 19: Willem Visser
    - Java PathFinder model checker
  - Feb 26: Klaus Havelund from NASA Ames
- Interview candidates
  - Monday March 1st: Benjamin Pierce
    - distributed debugging
  - Thursday March 4th: Ranjit Jhala
    - BLAST model checker for Linux device drivers

Big Picture of *Runtime Assurance ...*

- Real time systems have intended behaviors
  - really, specifications
- Check dynamically for violations of safety specification
  - e.g. fail-stop, or to alert human operator
- Could write code for this
  - in a regular language
  - in a domain-specific language (this paper)

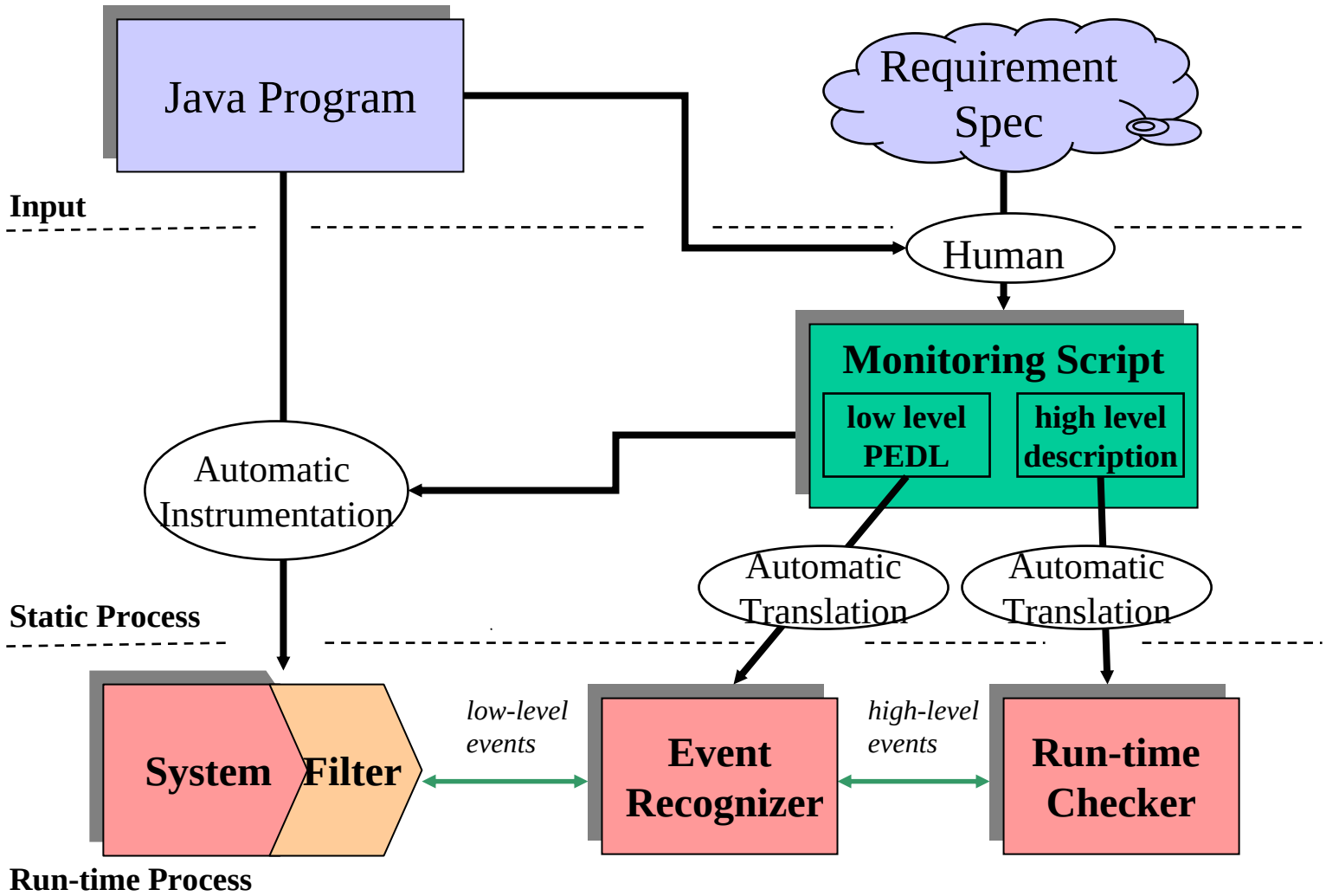
Design

- Two pieces
- Recognize *primitive events*
  - Interesting things that happen in the program
  - Specified by a PEDL script
    - *Primitive Event Definition Language*
- Check requirements
  - Specified by a MEDL specification
    - *Meta-Event Definition Language*

Why Two Languages?

- Convenient to write low-level predicates in the target programming language
- But higher-level specifications will need to be in some kind of logic
- Separating the two makes the system more portable

Monitoring and Checking (MaC) Framework



Primitives

- Examples

  TooFast = Train.calculatePosition().trainspeed > 100

  InMethod(f)

  MethodEnter(f)

  MethodExit(f)

Conditions and Events

- Examples

  TooFast = Train.calculatePosition().trainspeed > 100

  InMethod(f)

  MethodEnter(f)

  MethodExit(f)

- An *event* happens at a moment in time

Conditions and Events

- Examples

  TooFast = Train.calculatePosition().trainspeed > 100

  InMethod(f)

  MethodEnter(f)

  MethodExit(f)

- A *condition* is true for intervals of time

Conditions and Events

- Examples

  TooFast = Train.calculatePosition().trainspeed > 100

  InMethod(f)

  MethodEnter(f)

  MethodExit(f)

- Two events characterize every condition
  - When the condition first becomes true
  - When the event first becomes false

Definitions

- Examples

  TooFast = Train.calculatePosition().trainspeed > 100

  InMethod(f)

  MethodEnter(f)

  MethodExit(f)

- Primitives can be named
  - For use in MEDL specifications

Time

- Examples

  TooFast = Train.calculatePosition().trainspeed > 100

  InMethod(f)

  MethodEnter(f)

  MethodExit(f)

- Every primitive event comes with a timestamp
  - To enable checking of real-time properties

Undefined Conditions

- Examples

  TooFast = Train.calculatePosition().trainspeed > 100

  InMethod(f)

  MethodEnter(f)

  MethodExit(f)

- Conditions may not be true or false
  - Because of uninitialized data
  - Add explicit "undefined" value
  - Add primitive condition undefined(c)

MEDL

- Primitive events & conditions can be combined
  - Note no negation for events

e ::=	e_p	c ::=	c_p
	start(c)		defined(c)
	end(c)		[e, e)
	e && e		! c
	e || e		c && c
	e when c		c || c
			c ‡ c

Semantics

- Primitive events/conditions are tested at specified points
  - Part of PEDL script
  - Designed to be cheap
    - Primitives depend only on current state
- MEDL semantics is 3-valued logic
  - true, false, undefined (for conditions)

Auxiliary Variables

- Sometimes need stateful monitoring
  - E.g., a count of certain events
- MEDL allows definition of auxiliary variables

$$e_1 \ , \quad count_{e1} := count_{e1} + 1$$

- A bit ugly
  - Auxiliary variables/computations in MEDL expressed in host programming language

Example: A Train Crossing Controller

```
/* export to MEDL */
Export event OpentGate, CloseGate
Expert condition GateDown

/* monitoring only at these points */
Monitored Entities:
   void GateController.open();
   void GateController.close();
   int GateController.gatePosition;
```

Example: A Train Crossing Controller (Cont.)

```
/* define a condition */
CondDef:
   Cond GateDown = (GateCotroller.gatePosition ==
                          GateController.GATE_DOWN)

/* define events */
EventDef:
   Event OpenGate = MethodEnter(GateController.open());
   Event CloseGate = MethodEnter(GateController.close());
```

Example: A Train Crossing Controller (Cont.)

```
/* MEDL spec */
Import event OpenGate, CloseGate;
Import condition GateDown;
AuxVarDecl: float startClose, currentTime;

Cond GateClosing =
[ CloseGate when !GateDown, OpenGate || start(GateDown))
    ‡
    startClose + 30 > currentTime
```

Opinions

- Could write monitoring code directly in Java
  - but would complicate (+ break?) monitored code
  - and Java monitors might be awkward to write/read
- A runtime monitoring toolkit is a good idea
  - separates code from specification
  - clearer, readable specification
  - leads to programmers writing specifications ?
- This paper represents a start
  - Need more expressiveness and applications

Purify

Purify

- Purify detects
  - reads of uninitialized memory
  - accesses to deallocated memory
  - accesses out of bounds
- Memory instrumentation via memory map
  - 2 bits per byte of memory
    - unallocated, uninitialized, initialized
    - "red zone"
  - Purify substitutes its own malloc
- Each load/store instrumented to test/set bits

Click **Run** to begin

Color-coded icons show message severity:

informational warning error

Acronyms like ABW identify message type

For a description of a message, right-click the message, then select **Describe**

Purify Main Window

```
Starting Purify'd stockvc6.exe at 08/13/98 16:36:00
Starting main
ABW: Array bounds write in CStockApp:
ODS: Warning: no shared menu for docu
ODS: Warning: no shared menu for docu
UMR: Uninitialized memory read in Set
UMR: Uninitialized memory read in str
PAR: Overlapping block copy may produ
ABW: Array bounds write in sprintf (3
ABR: Array bounds read in lstrlenA (7
PAR: Overlapping block copy may produ
ABW: Array bounds write in sprintf (3
HAN: Handle 0x00000001 is invalid in
HAN: Handle 0xffffffff is invalid in
Searching for new memory leaks...
Leak search complete
Exiting with code 0 (0x00000000)
Program terminated at 08/13/98 16:36:55
```

Describe ABW: Array Bounds Write
Copy
Submit ClearQuest Defect
Expand
Expand Branch
Collapse
QuickFilter
Create Filter...
View Source File
Select Source File