

Automated Test Case Generation for an Autopilot Requirement Prototype

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motivation

- need for Human – Automation Interaction (HAI) test support in the aircraft certification and approval process
- existing formal method algorithms and framework might help
- but any results must be transparent and usable by evaluator

automated test-case generation through
symbolic execution



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why symbolic execution?

```
@Symbolic("true")
int x;
@Symbolic("true")
int y;

void testX() {
    if (x > 0)
        y = y + x;
    else
        y = y - x;
}
```

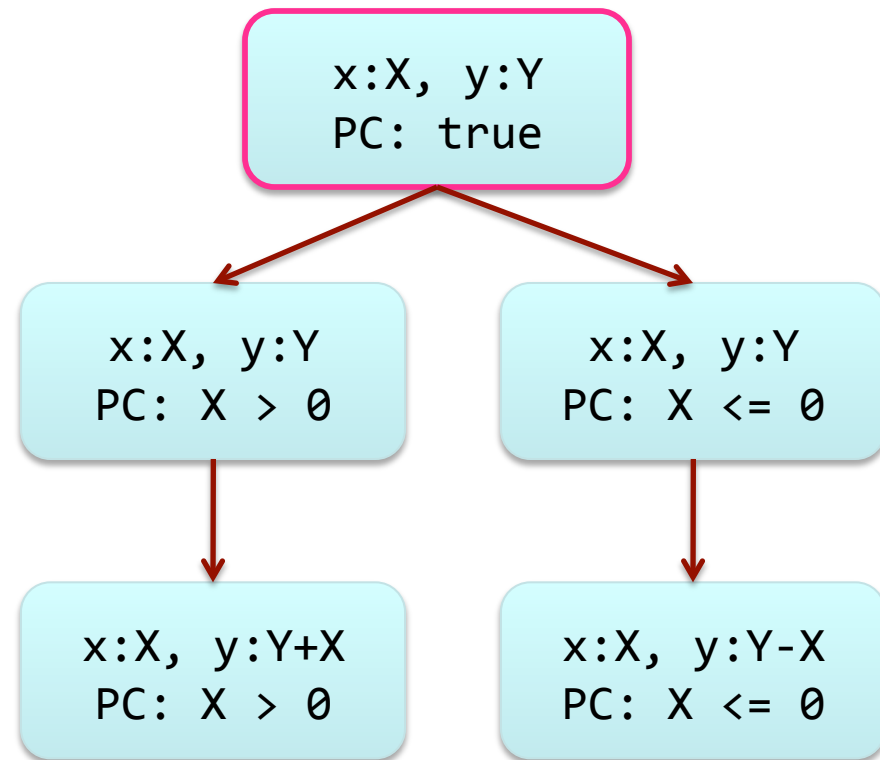


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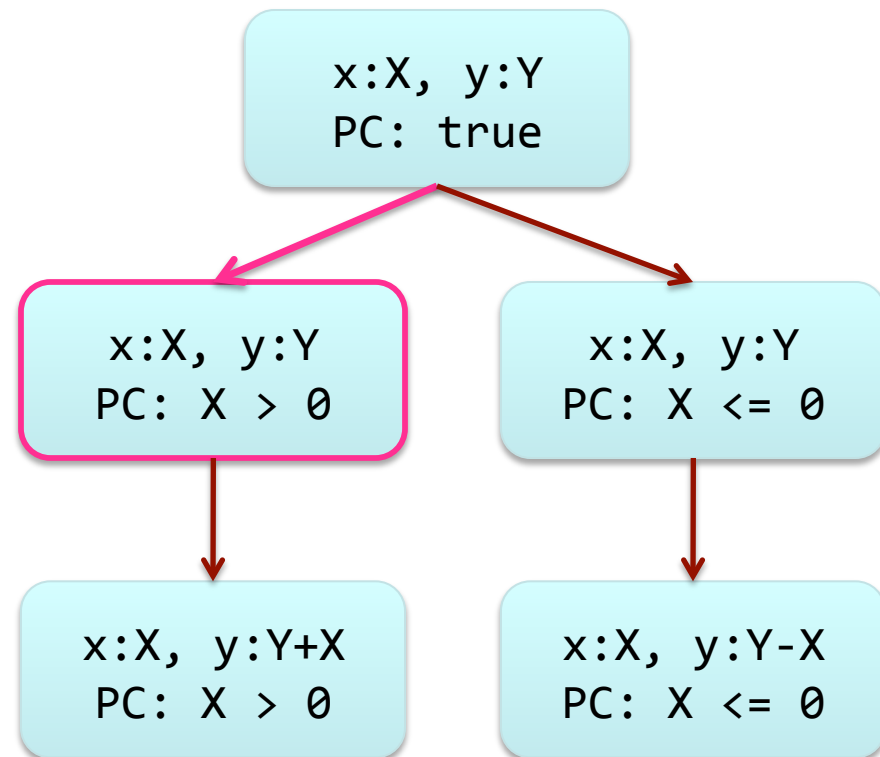


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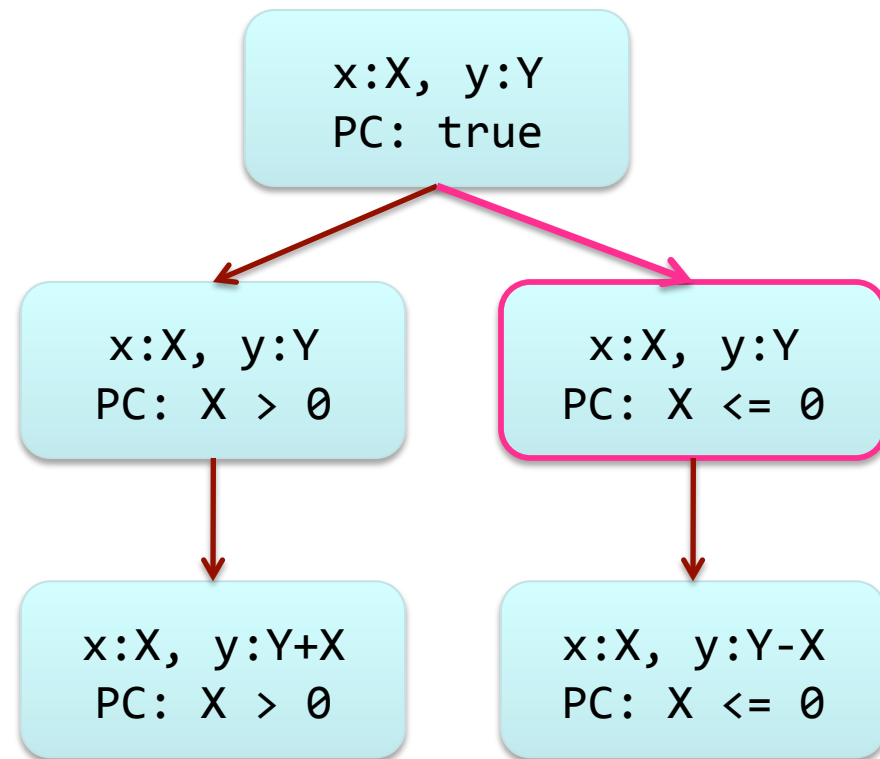


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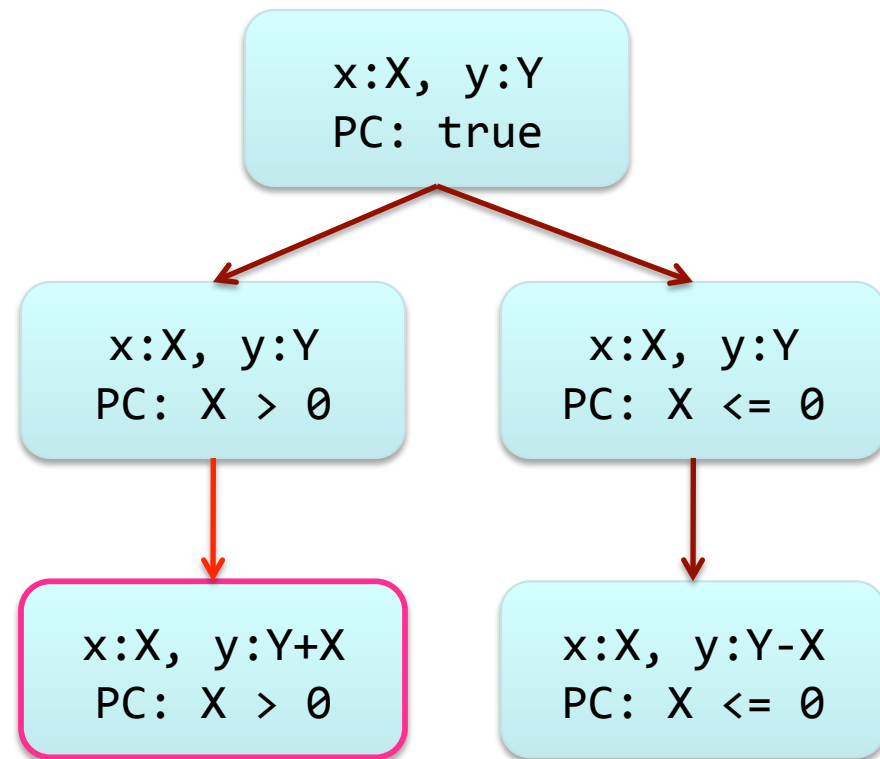


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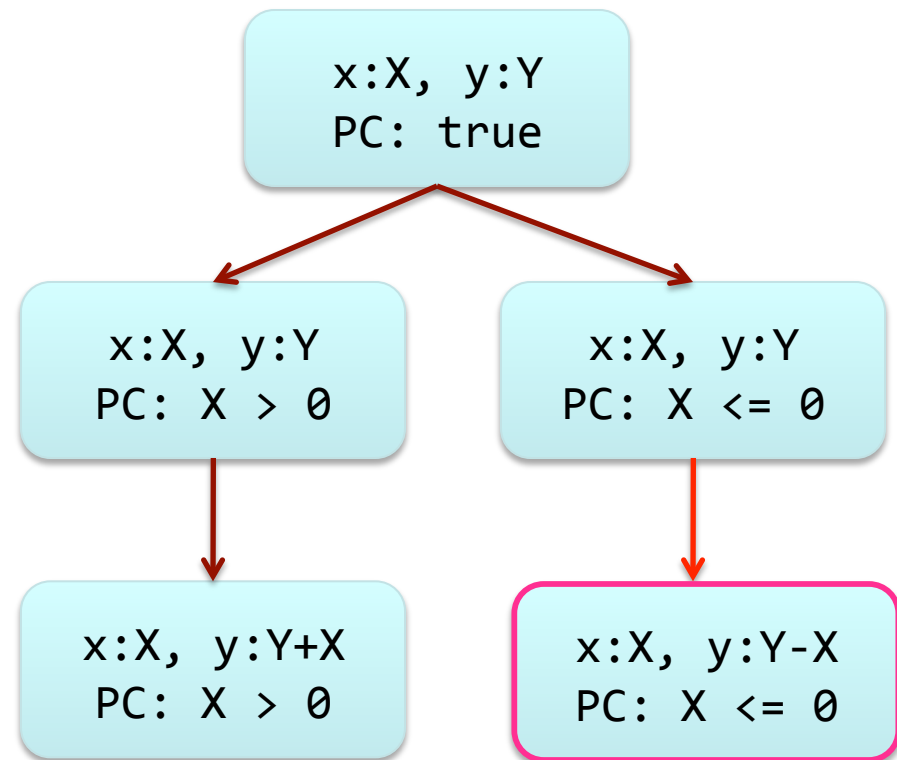


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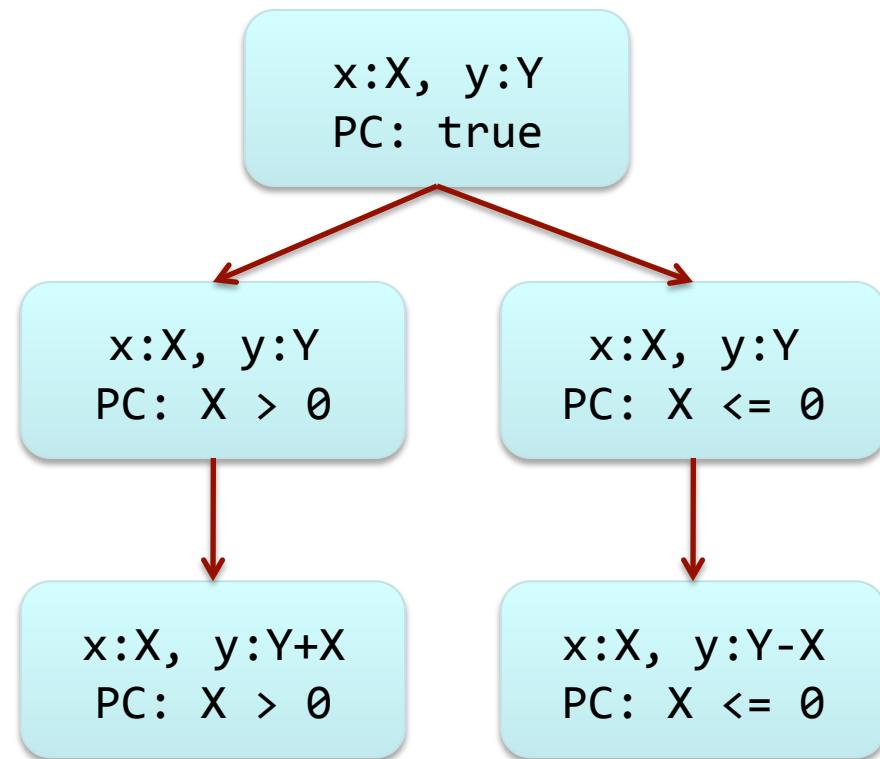


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Test Input Generation

$X = 1$

$X = 0$



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...when successful, automated test case generation automatically generates high quality test suites for full path coverage

Step 1: ADEPT to Java

Autopilot Example

The screenshot displays a software development environment for an autopilot system, divided into three main panels:

- System Browser (Left):** Lists system components such as `lateralTargetError`, `lateralTarget`, and `lateralSystemTable`.
- Data Table (Middle):** A table with columns 0-6 and rows for **INPUTS** and **OUTPUTS**.

	0	1	2	3	4	5	6
INPUTS							
<input checked="" type="checkbox"/> simulationStatus							
paused		•					
running			•	•	•		
OUTPUTS							
<input checked="" type="checkbox"/> lateralSystem....outputState							
no action		•	•	•			
user presses...elector knob					•	•	•
user presses...HOLD button						•	•
user presses LNAV button							•
OUTPUTS							
<input checked="" type="checkbox"/> lateralSystem....outputState							
Capture and ...eral Target		•		•			
Hold Selected Lateral Target			•	•	•		
Capture and ...plan Target				•	•	•	
<input checked="" type="checkbox"/> selectedLateralTargetError							
>179							•
<=179 && s...rrol>=-179							•
>-179							•
- User Interface Editor (Right):** Shows a cockpit display with various gauges and controls. The top section includes mode selectors (IAS, HDG, V/S, ALTITUDE) and a central control knob. The bottom section features a speedometer (IAS 250), altimeter (5000), and a central heading indicator.

	0	1	2	3	4	5	6	7	8	9
lateralSystemTable										
Behavior										
isNominal										
True		•	•	•	•	•				•
False								•	•	•
Inputs										
simulationStatus										
paused	•									
running		•	•	•						
lateral Interface Action OutputState										
noAction	•	•	•	•						
user presses Lateral Target knob					•	•	•	•		
user presses Lateral Hold button									•	
user presses LNAV button										•
lateral system table output state										
capture and maintain selected lateral target	•				•					
hold selected lateral target			•			•	•	•		
capture and maintain lateral flight plan				•		•	•	•		
selected lateral target error										
> 179								•		
<= 179 && >= -179						•				
< -179									•	
Outputs										
lateral system table output state										
capture and maintain selected lateral target					•	•	•	•		
hold selected lateral target									•	
capture and maintain lateral flight plan										•
selected lateral target error										
- = 360							•			
+ = 360								•		
0									•	
preselected lateral target										
lateral direction										•
selected lateral Target										
preselected lateral target					•	•	•	•		
lateral direction										•
lateral target										
selected lateral target		•			•	•	•	•		
lateral direction			•							•
lateral flight plan target										
lateral flight plan target				•						•
lateral target error										
selected lateral target error						•	•	•		
lateral flight plan target error										•
0										•

```

. . . . .
if(!isNominal && ((outputState == 1) ||
(outputState == 2)) &&
selectedLateralTargetError > 179 &&
(userPressesLateralTargetButton == true &&
userPressesLateralHoldButton == false &&
userPressesLNAVbutton == false)){
    applyRule06();
}
if(!isNominal && ((outputState == 1) ||
(outputState == 2)) &&
selectedLateralTargetError < -179 &&
(userPressesLateralTargetButton == true &&
userPressesLateralHoldButton == false &&
userPressesLNAVbutton == false)){
    applyRule07();
}
. . . . .

public void applyRule06() {
    outputState = 0;
    selectedLateralTargetError -= 360;
    selectedLateralTarget =
        preSelectedLateralTarget;
    lateralTarget = selectedLateralTarget;
    lateralTargetError =
        selectedLateralTargetError;
}

public void applyRule07() {
    outputState = 0;
    selectedLateralTargetError += 360;
    selectedLateralTarget =
        preSelectedLateralTarget;
    lateralTarget = selectedLateralTarget;
    lateralTargetError =
        selectedLateralTargetError; }

```

isNominal[0] == false
outputState[2] == CONS
selectedLateralTargetE
userPressesLateralTarg
userPressesLateralHold
userPressesLNAVbutton_

outputState = 0;
selectedLateralTargete
selectedLateralTargete
lateralTarget = sele
lateralTargetError =

isNominal[0] == false
outputState[2] == CONS
selectedLateralTarget
userPressesLateralTarg
userPressesLateralHold
userPressesLNAVbutton_
outputState[2] != CONS
outputState[2] == CONS
selectedLateralTarget
userPressesLateralTarg
userPressesLateralHo
userPressesLNAVbutton_

outputState = 0;
selectedLateralTargete
selectedLateralTargete
lateralTarget = sele
lateralTargetError s

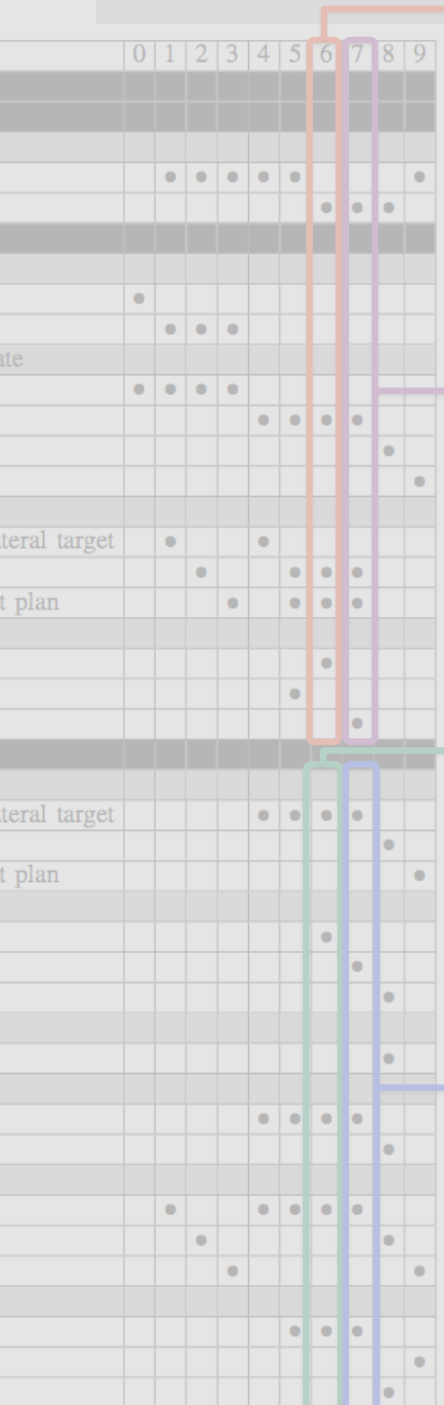
Step 2: Symbolic Execution

what do we execute symbolically?

- method **execute** – parameters are user inputs (eg button presses) and are symbolic
- other (not user input) variables in the table that appear in rule conditions are eligible to be treated as symbolic; this allows us to explore different initial values that may lead us to different paths
- the **main** method calls method **execute** n times (n can be selected); each time, fresh values are picked for the symbolic parameters since each time the user input actions may vary



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```

. . . . .
if(!isNominal && ((outputState == 1) ||
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selectedLateralTargetError > 179 &&
(userPressesLateralTargetButton == true &&
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    applyRule06();
}
if(!isNominal && ((outputState == 1) ||
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(userPressesLateralTargetButton == true &&
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    applyRule07();
}
. . . . .

```

```

public void applyRule06() {
    outputState = 0;
    selectedLateralTargetError -= 360;
    selectedLateralTarget =
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    lateralTarget = selectedLateralTarget;
    lateralTargetError =
        selectedLateralTargetError;
}

```

```

public void applyRule07() {
    outputState = 0;
    selectedLateralTargetError += 360;
    selectedLateralTarget =
        preSelectedLateralTarget;
    lateralTarget = selectedLateralTarget;
    lateralTargetError =
        selectedLateralTargetError; }

```

isNominal[0] == false && outputState[2] != CONST_1 && outputState[2] == CONST_2 && selectedLateralTargetError[180] > CONST_179 && userPressesLateralTargetButton_s1_1[1] == true && userPressesLateralHoldButton_s2_0[0] == false && userPressesLNAVbutton_s3_0[0] == false

outputState = 0; selectedLateralTargetError += 360; selectedLateralTarget = preSelectedLateralTarget; lateralTarget = selectedLateralTarget; lateralTargetError = selectedLateralTargetError;

isNominal[0] == false && outputState[2] != CONST_1 && outputState[2] == CONST_2 && selectedLateralTargetError[180] > CONST_179 && userPressesLateralTargetButton_s1_1[1] == true && userPressesLateralHoldButton_s2_0[0] == false && userPressesLNAVbutton_s3_0[0] == false && outputState[2] != CONST_1 && outputState[2] == CONST_2 && selectedLateralTargetError[180] > CONST_179 && userPressesLateralTargetButton_s4_1[1] == CONST_1 && userPressesLateralHoldButton_5_0[0] == CONST_0 && userPressesLNAVbutton_6_0[0] == CONST_0 &&

outputState = 0; selectedLateralTargetError += 360; selectedLateralTarget = preSelectedLateralTarget; lateralTarget = selectedLateralTarget; lateralTargetError selectedLateralTargetError;

results and challenges

- automatically generated 16 test cases for $n=1$
- discovered through unsatisfiable path constraints that some rules disable each other
- (HAI challenge) provide support for modeling semantics of user interface components such momentary vs. toggle switch
- (HAI challenge) define coverage criteria – for example related to covering modes; also what values should we pick for n (what length of user inputs)?
- (generic challenge) scalability of symbolic execution



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- Generic

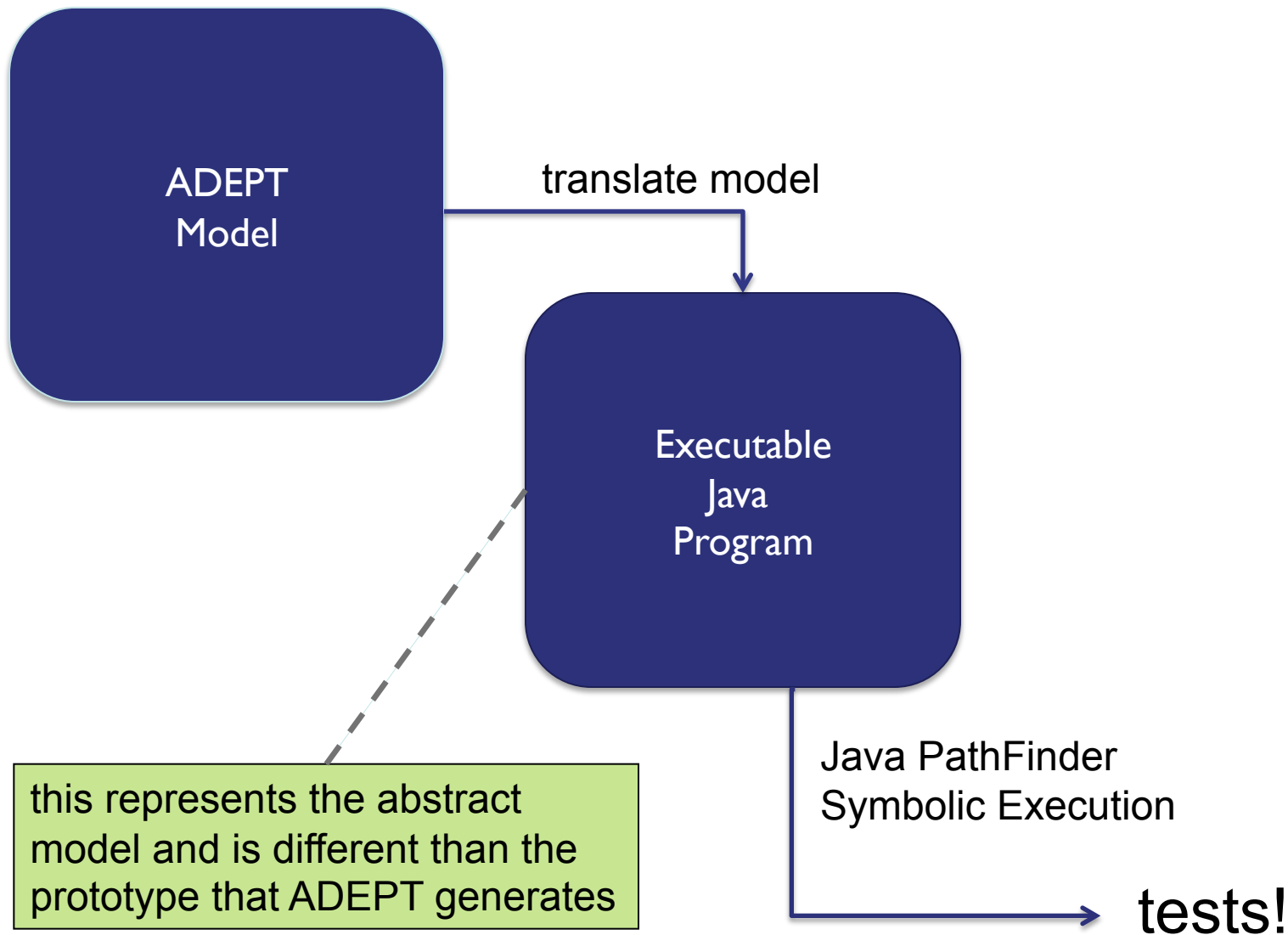
thank you!

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michael.s.feary@nasa.gov

symbolic execution for ADEPT HAI models



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