Automated Test Case Generation for an Autopilot Requirement Prototype

Dimitra Giannakopoulou, Neha Rungta, and Michael Feary
NASA Ames Research Center
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
source code (main method)

symbolic execution to derive execution paths

Usability Test
why symbolic execution?

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

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

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

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

![Diagram showing symbolic execution flow](image-url)
why symbolic execution?

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

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

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

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

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

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

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

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

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

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

Test Input Generation

<table>
<thead>
<tr>
<th>X</th>
<th>Test Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>x:X, y:Y+X, PC: X &gt; 0</td>
</tr>
<tr>
<td>0</td>
<td>x:X, y:Y-X, PC: X &lt;= 0</td>
</tr>
</tbody>
</table>
...when successful, automated test case generation automatically generates high quality test suites for full path coverage
Step 1: ADEPT to Java
Autopilot Example
### Lateral System Table

<table>
<thead>
<tr>
<th>Behavior</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>isNominal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>True</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>False</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Inputs

<table>
<thead>
<tr>
<th>simulationStatus</th>
<th>paused</th>
<th>running</th>
</tr>
</thead>
<tbody>
<tr>
<td>NoAction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>User presses Lateral Target knob</td>
<td></td>
<td></td>
</tr>
<tr>
<td>User presses Lateral Hold button</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lateral system table output state</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hold selected lateral target</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capture and maintain lateral flight plan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selected lateral target error</td>
<td>&gt;= 179</td>
<td>&lt;= -179</td>
</tr>
</tbody>
</table>

#### Outputs

<table>
<thead>
<tr>
<th>lateral system table output state</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Capture and maintain selected lateral target</td>
<td></td>
</tr>
<tr>
<td>Hold selected lateral target</td>
<td></td>
</tr>
<tr>
<td>Capture and maintain lateral flight plan</td>
<td></td>
</tr>
<tr>
<td>Selected lateral target error</td>
<td>= 360</td>
</tr>
</tbody>
</table>

```java
if(!isNominal & ((outputState == 1) || (outputState == 2)) && selectedLateralTargetError > 179 && (userPressesLateralTargetButton == true && userPressesLateralHoldButton == false && userPressesLNAVbutton == false)){
    applyRule06();
}
```

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

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

```java
public void applyRule07() {
    outputState = 0;
    selectedLateralTargetError += 360;
    selectedLateralTarget = preSelectedLateralTarget;
    lateralTarget = selectedLateralTarget;
    lateralTargetError = selectedLateralTargetError;
}
```
Step 2: Symbolic Execution
what do we execute symbolically?

- method `execute` – parameters are user inputs (e.g., 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
if(!isNominal && ((outputState == 1) ||
(outputState == 2)) &&
    selectedLateralTargetError > 179 &&
(userPressesLateralTargetButton == true &&
userPressesLateralHoldButton == false &&
userPressesNAVbutton == false)){
    applyRule06();
}
if(!isNominal &&((outputState == 1) ||
(outputState == 2)) &&
    selectedLateralTargetError < -179 &&
(userPressesLateralTargetButton == true &&
userPressesLateralHoldButton == false &&
userPressesNAVbutton == 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;
}
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
thank you!

dimitra.giannakopoulou@nasa.gov
neha.s.rungta@nasa.gov
michael.s.feary@nasa.gov
symbolic execution for ADEPT HAI models

ADEPT Model

translate model

Executable Java Program

this represents the abstract model and is different than the prototype that ADEPT generates

Java PathFinder Symbolic Execution

tests!