Test-Case Generation for Runtime Analysis and Vice-Versa: Verification of Aircraft Separation Assurance

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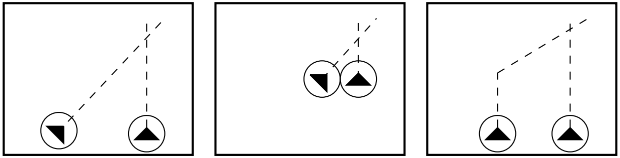
Goals

- Propose verification properties for aircraft separation assurance software
- Verify properties at runtime

AutoResolver

- Part of US federal government's NextGen project
- Developed at NASA Ames Research Center
- Software system for aircraft separation assurance
- 65K lines of Java code
- Its environment's core: 450K lines of code

Conflict, Loss of Separation, Separation Assurance



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Resolution Monitor

- M_1 For each conflict, report its resolution type and how it changes over time.

Wrapper

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- Environment stubbing
- Light-weight testing with different kinds of input than trajectories
  - E.g. airspeed, initial heading, climb rate, heading change, trajectory time, destination coordinates

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Purpose

- Test-case generation
- Property verification at runtime

Wrapper — Aspect-Oriented Programming

- Avoid usual way: instrumentation for verification
- Leave AutoResolver's source code intact

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- Java language extension
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In-house verification

- No external verification tool used (SMT solvers, MOP tools)

Wrapper — Properties

Properties as AspectJ aspects

- 1 property = 1 aspect
- 1 aspect = multiple pointcuts and advices

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Pointcuts

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Advices

- Actions to be taken at pointcuts

AspectJ Example

```
pointcut callAR(AacTestWrapper wrapper):
  call(public ArrayList conflictDetectResolve()) &&
  target(wrapper) &&
  !cflow(myAspect()) &&
  !cflow(callFlyForMethod(*, *)) &&
  if(isEnabled);

after(AacTestWrapper wrapper): callAR(wrapper) {
  for (t = 60.0; t <= 480.0; t += 60.0) {
    AacTestWrapper w = wrapper.flyFor(t);
    w.conflictDetectResolve();
  }
}
```

Runtime Verification

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- Need for good runtime drivers
    - Test cases

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"Testing shows the presence,
not the absence of bugs." — Dijkstra

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- Secondary conflicts — challenging to create
- Time dimension added at runtime

Generating Secondary Conflicts

- Secondary conflicts: created along a resolution trajectory

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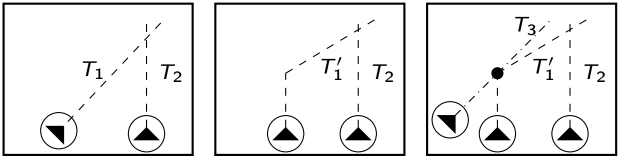

Test Case — Example

```
public void test0() throws Throwable {

    AacTestWrapper wrapper = new AacTestWrapper();

    wrapper.setUpCR(CR_parameters1);
    wrapper.setUpCL(CL_parameters2);
    wrapper.setUpCR(CR_parameters3);

    wrapper.conflictDetectResolve();
}
```

Evaluation

- Test suite of 3.5 million test cases
  - Each test case with about 5 conflicts
- Every test case executed at 9 different time points
  - Fly all aircraft for some time and then call AutoResolver
  - Effectively: 3.5 million $\cdot$ 9 $=$ 31.5 million test cases
- Check if every requirement is exercised
  - Second-level monitors

Results — Property P_1

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- It does not hold, but this is not a bug
- AutoResolver does not resolve conflicts that:
  - involve aircraft already in violation
  - happen earlier than a predetermined time limit (1 minute)
  - happen later than a predetermined time limit (8 minutes)
  - "Neither plane able to maneuver/neither plane able to be unfrozen" (current resolution round)

Results — Property P_2

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Initial conflicts are resolved in the non-decreasing order of their first time to loss of separation.

- No violation found

Results — Property P_3

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Results — Property P_3

New conflicts arising as a result of conflict resolution should be inserted into the list of conflicts according to their first loss of separation time.

- No violation found
- No test case that exercises respective parts of code
    - Second-level monitor
- Need support for weather conflict type

Results — Property P_4

No picked resolution is allowed to cause a more imminent secondary conflict.

Results — Property P_4

No picked resolution is allowed to cause a more imminent secondary conflict.

- No violation found
  - Several test cases used to indicate violation (bug found in wrapper)

Results — Resolution Monitor M_1

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ttlos [s]	Delay time [s]	Res type
430.0	0.0	26
370.0	60.0	26
310.0	120.0	26
250.0	180.0	26
190.0	240.0	26
130.0	300.0	13
70.0	360.0	13
10.0	420.0	not resolved
0.0	480.0	not resolved

Results — Resolution Monitor M_1 — Continued

No-conflict window?

ttlos [s]	Delay time [s]	Res type
445.0	0.0	3
—	60.0	—
—	120.0	—
265.0	180.0	3
205.0	240.0	3
145.0	300.0	3
85.0	360.0	3
25.0	420.0	not resolved
0.0	480.0	not resolved

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- Runtime verification for test-case generation
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Credits

- Crossroads — Umberto Nicoletti
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