# Program Analysis

# Symbolic and Concolic Execution (Part 2)

**Prof. Dr. Michael Pradel**

**Software Lab, University of Stuttgart**

**Winter 2020/2021**

# Overview

1. Classical Symbolic Execution
2. Challenges of Symbolic Execution 
3. Concolic Testing
4. Large-Scale Application in Practice

Mostly based on these papers:

- *DART: directed automated random testing*, Godefroid et al., PLDI'05
- *KLEE: Unassisted and Automatic Generation of High-Coverage Tests for Complex Systems Programs*, Cadar et al., OSDI'08
- *Automated Whitebox Fuzz Testing*, Godefroid et al., NDSS'08

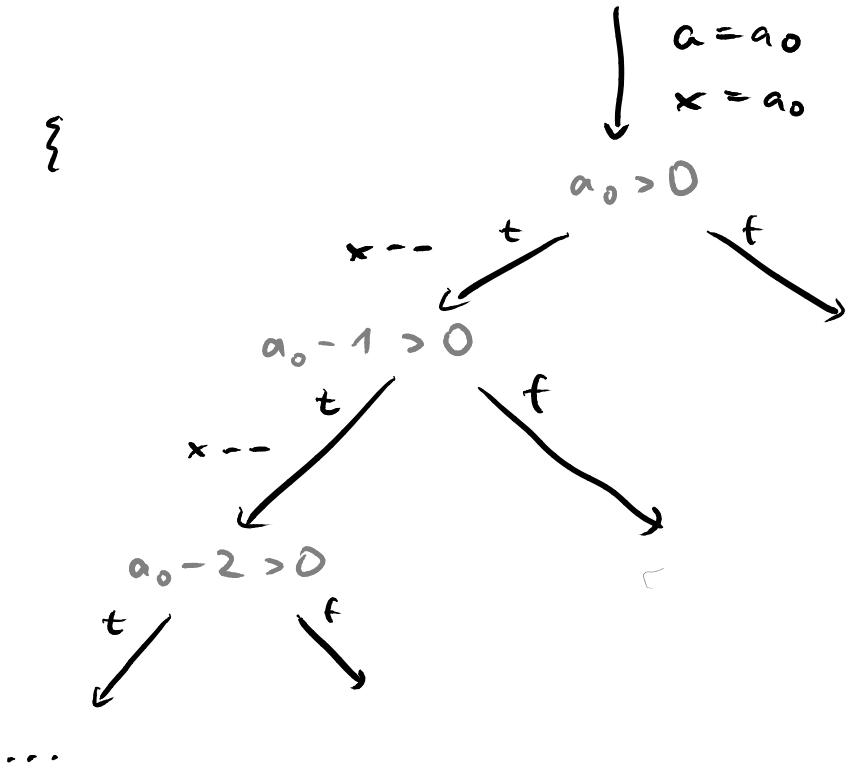
# Problems of Symbolic Execution

- Loops and recursion: Infinite execution trees
- Path explosion: Number of paths is exponential in the number of conditionals
- Environment modeling: Dealing with native/system/library calls
- Solver limitations: Dealing with complex path conditions
- Heap modeling: Symbolic representation of data structures and pointers

# Problems of Symbolic Execution

- Loops and recursion: Infinite execution trees
- Path explosion: Number of paths is exponential in the number of conditionals
- Environment modeling: Dealing with native/system/library calls
- Solver limitations: Dealing with complex path conditions
- Heap modeling: Symbolic representation of data structures and pointers

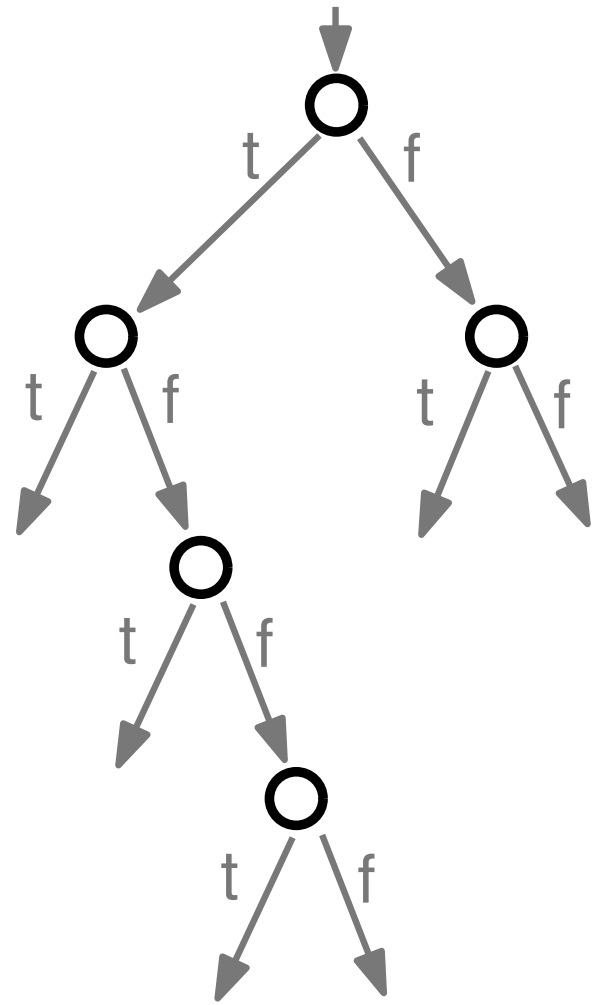
```
function f(a) {
    var x = a;
    while (x > 0) {
        x--;
    }
}
```



# Dealing with Large Execution Trees

**Heuristically select which branch to explore next**

- Select at random
- Select based on coverage
- Prioritize based on distance to ”interesting” program locations
- Interleaving symbolic execution with random testing



# Problems of Symbolic Execution

- Loops and recursion: Infinite execution trees
- Path explosion: Number of paths is exponential in the number of conditionals
- Environment modeling: Dealing with native/system/library calls
- Solver limitations: Dealing with complex path conditions
- Heap modeling: Symbolic representation of data structures and pointers

# Problems of Symbolic Execution

- Loops and recursion: Infinite execution trees
- Path explosion: Number of paths is exponential in the number of conditionals
- Environment modeling: Dealing with native/system/library calls
- Solver limitations: Dealing with complex path conditions
- Heap modeling: Symbolic representation of data structures and pointers

# Modeling the Environment

- Program behavior may depend on parts of system not analyzed by symbolic execution
- E.g., native APIs, interaction with network, file system accesses

```
var fs = require("fs");
var content = fs.readFileSync("/tmp/foo.txt");
if (content === "bar") {
  ...
}
```

# Modeling the Environment (2)

## Solution implemented by KLEE

- If all arguments are concrete, forward to OS
- Otherwise, provide models that can handle symbolic files
  - Goal: Explore all possible legal interactions with the environment

```
var fs = {
  readFileSync: function(file) {
    // doesn't read actual file system, but
    // models its effects for symbolic file nam
  }
}
```

# Problems of Symbolic Execution

- Loops and recursion: Infinite execution trees
- Path explosion: Number of paths is exponential in the number of conditionals
- Environment modeling: Dealing with native/system/library calls
- Solver limitations: Dealing with complex path conditions
- Heap modeling: Symbolic representation of data structures and pointers

# Problems of Symbolic Execution

- Loops and recursion: Infinite execution trees
- Path explosion: Number of paths is exponential in the number of conditionals
- Environment modeling: Dealing with native/system/library calls
- Solver limitations: Dealing with complex path conditions
- Heap modeling: Symbolic representation of data structures and pointers

**One approach: Mix symbolic with concrete execution**