CSE 403: Software Engineering, Fall 2016

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Symbolic Execution

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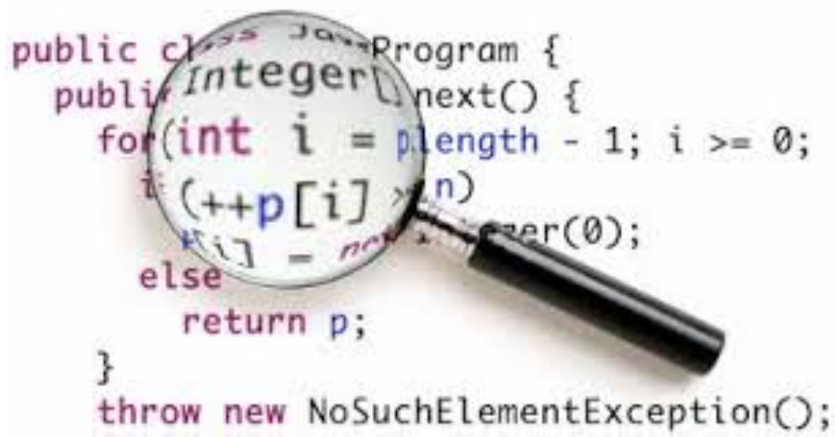
Outline

- What is symbolic execution?
- How does it work?
- State-of-the-art tools



a brief introduction to symbolic execution

what

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    - Can prove absence of many classes of important errors (such as runtime errors in safety critical systems)
    - High-quality commercial and open-source tools available

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- Sound static analysis tools are great!
    - Can prove absence of many classes of important errors (such as runtime errors in safety critical systems)
    - High-quality commercial and open-source tools available
- But they are can be difficult to use unless you are an expert in static analysis …
    - They can produce many false positives on large and/or unusual code bases
    - For a sophisticated static analysis, telling a false positive from a real bug can be hard

Symbolic execution

Symbolic execution

- A bug finding technique that is easy to use!
    - No false positives
    - Produces a *concrete* input (a test case) on which the program will fail to meet the specification
    - But it cannot, in general, prove the absence of errors

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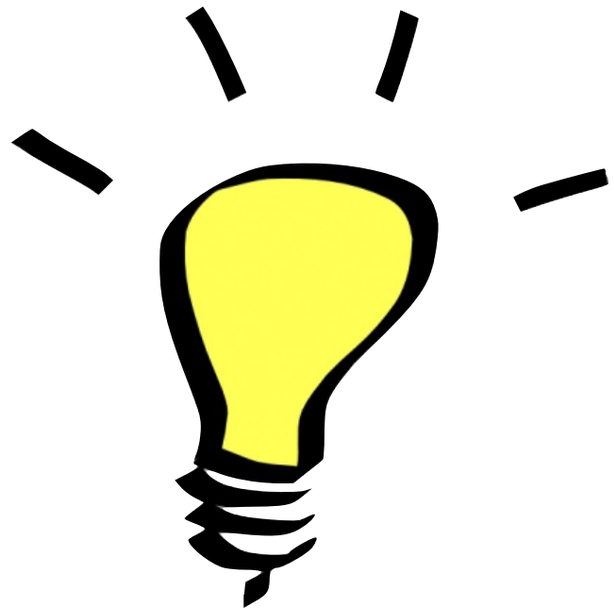
- Key idea
  - Evaluate the program on *symbolic* input values
  - Use an automated theorem prover to check whether there are corresponding *concrete* input values that make the program fail.



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Demo!

Some history ...

1976: *A system to generate test data and symbolically execute programs* (Lori Clarke)

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2005-present: practical symbolic execution

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2005-present: practical symbolic execution

- Moore's Law
- Better theorem provers (SAT / SMT solvers)
- Heuristics to control exponential explosion
- Heap / environment modeling techniques, ….

symbolic execution by example

Symbolic execution: basic idea

```
def f (x, y):
  if (x > y):
    x = x + y
    y = x - y
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$x \mapsto A$

$y \mapsto B$

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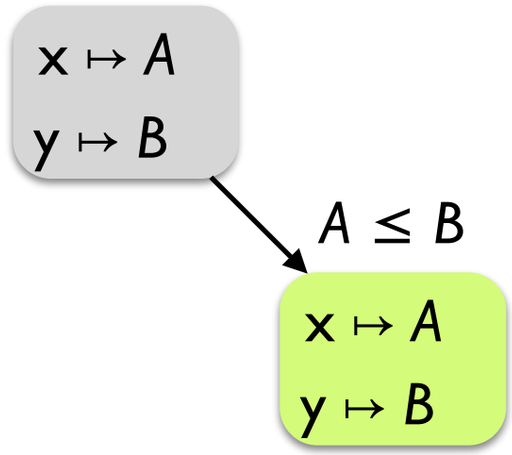

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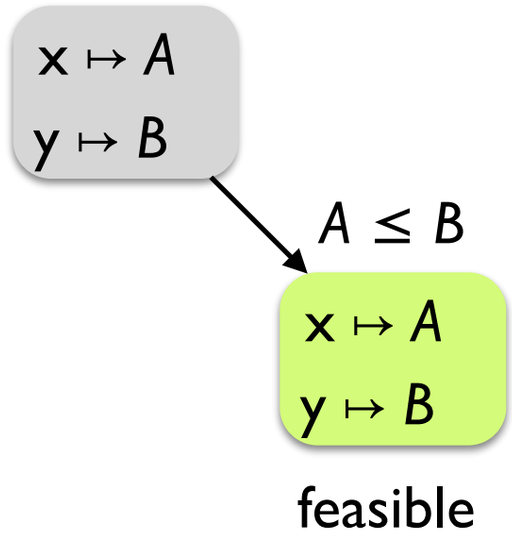

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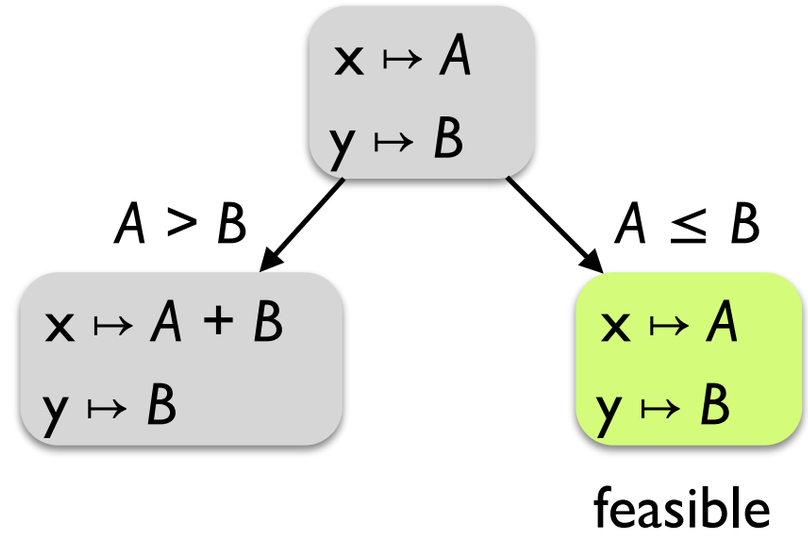

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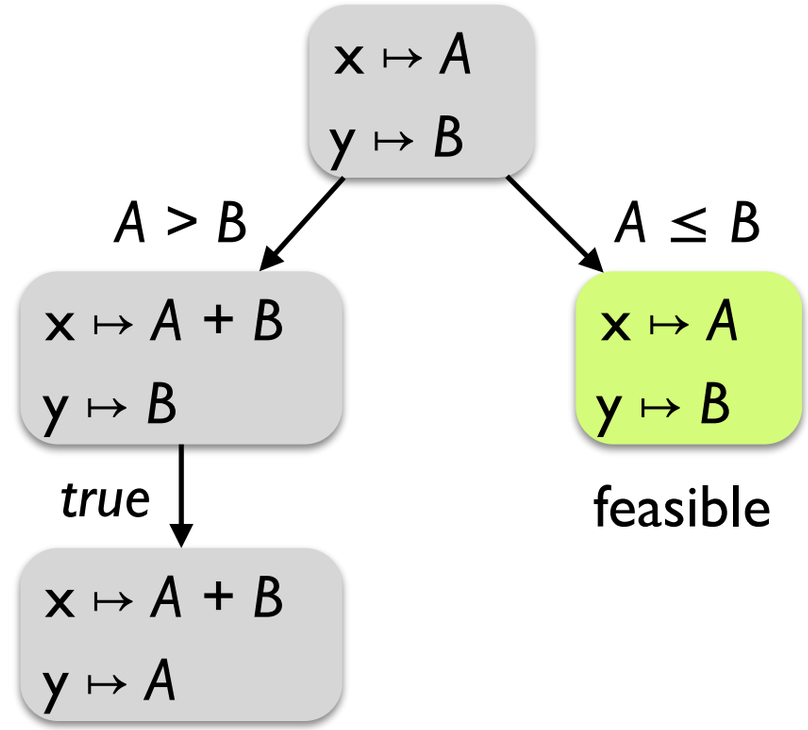

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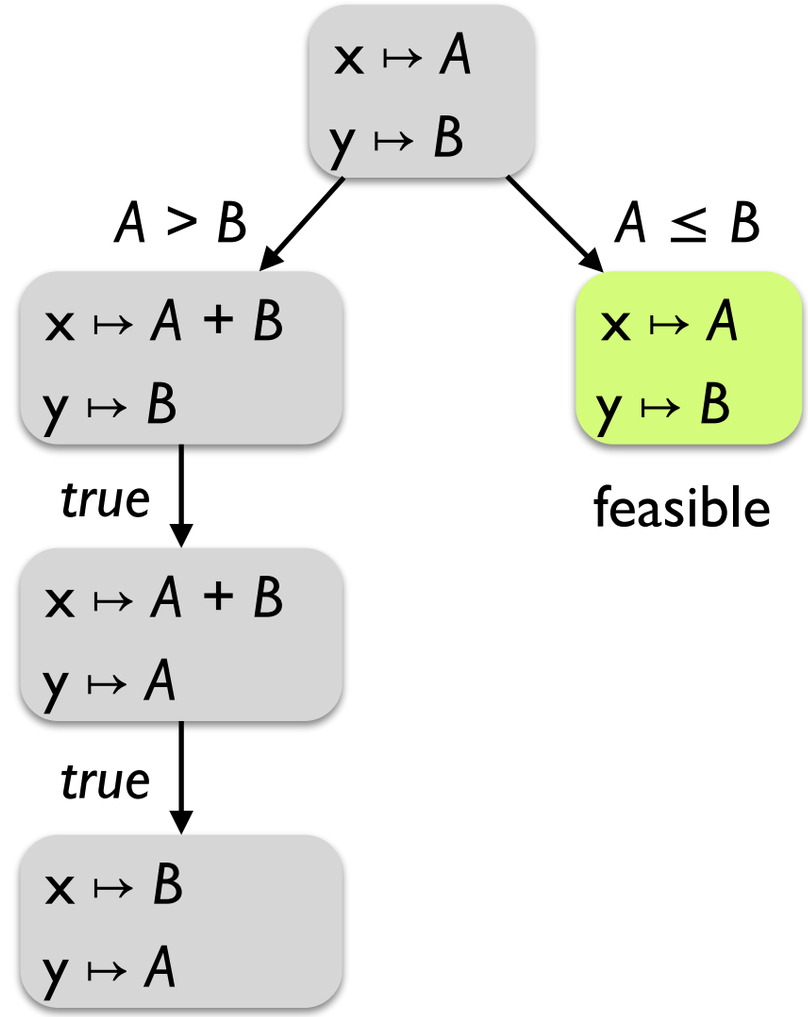

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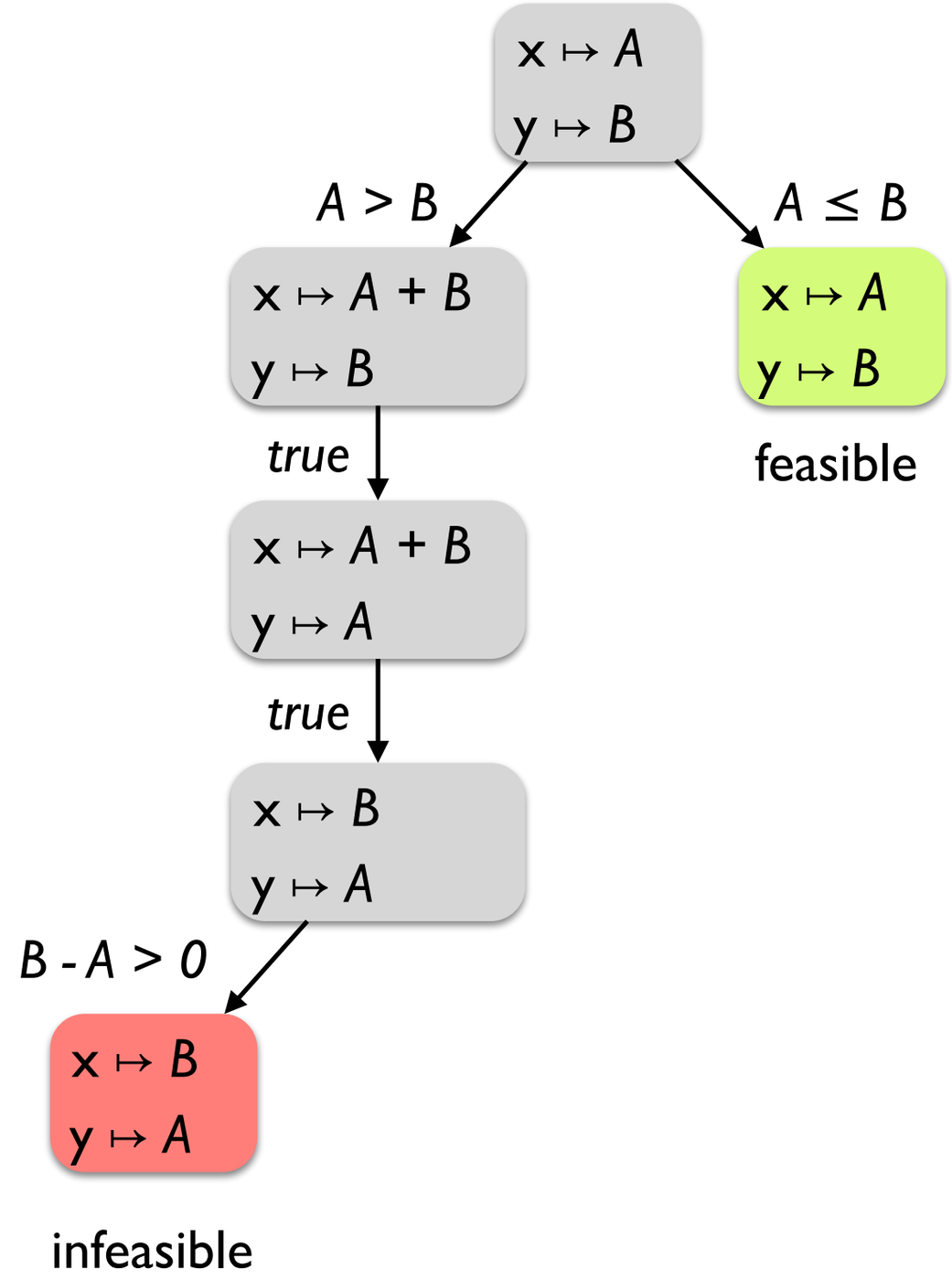

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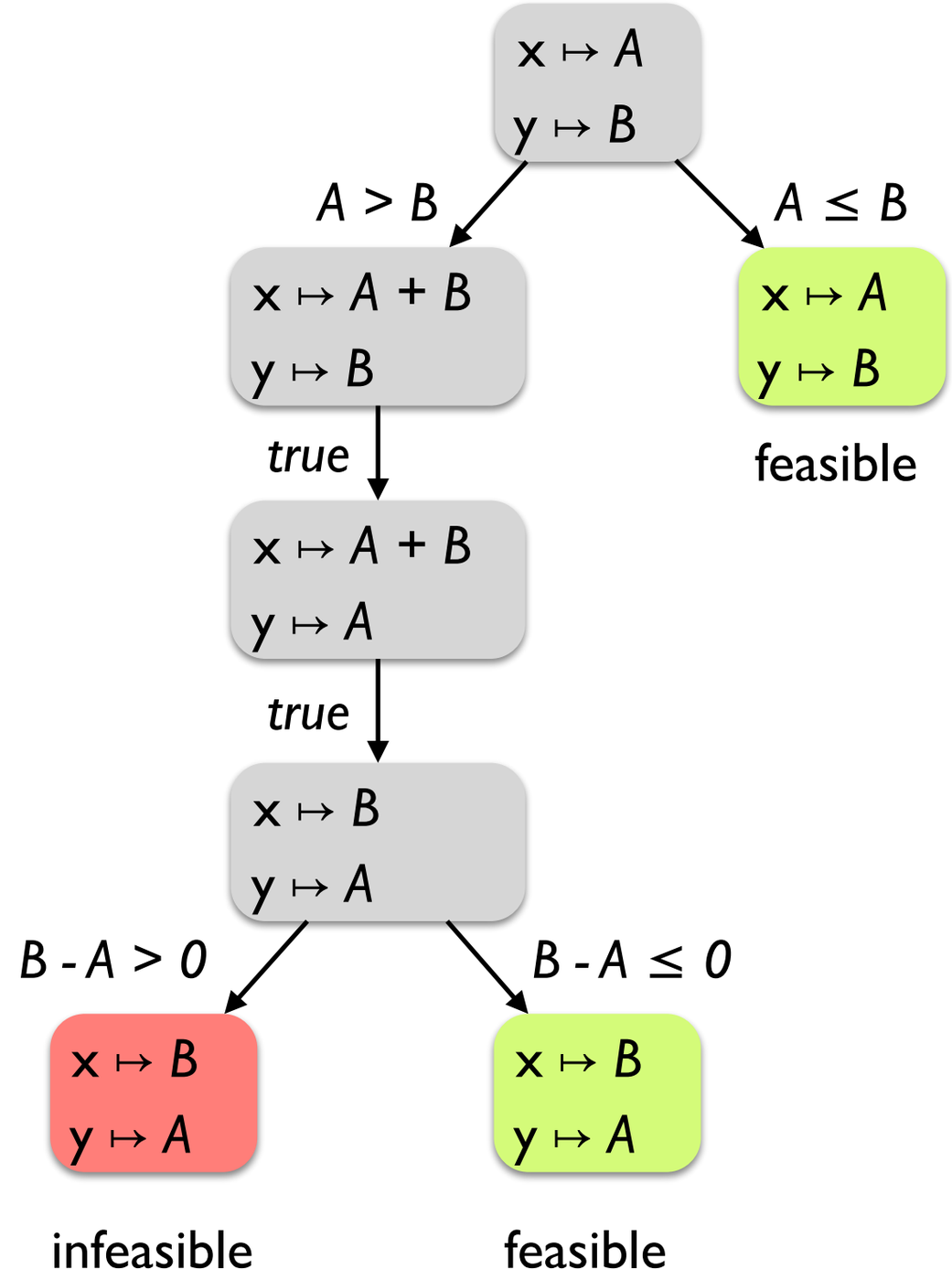

Symbolic execution: practical issues

Loops and recursion: infinite execution trees

Path explosion: exponentially many paths

Heap modeling: symbolic data structures and pointers

Solver limitations: dealing with complex PCs

Environment modeling: dealing with native / system / library calls

symbolic execution tools

Some state-of-the-art symbolic execution tools

- KLEE (symbolic execution for C, built on LLVM)
- SAGE (symbolic execution for x86)
- Jalangi (symbolic execution for JavaScript)
- Many, many others

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- SAGE (symbolic execution for x86)
  - Internal Microsoft tool
  - A huge cluster continuously running SAGE (**500+ machine years**)
    - 1/3 Windows 7 security bugs found by SAGE!
- Jalangi (symbolic execution for JavaScript)
- Many, many others

Summary

- Symbolic execution is a bug finding technique based on automated theorem proving:
  - Evaluates the program on symbolic inputs, and a solver finds concrete values for those inputs that lead to errors.
- Many success stories in the open-source community and industry.