CMPT 473
Software Testing, Reliability and Security

Symbolic Execution

Nick Sumner
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Symbolic Execution

- As we have seen, building constraints that model code can be useful

CBMC was able to prove
certain errors couldn’t exist!

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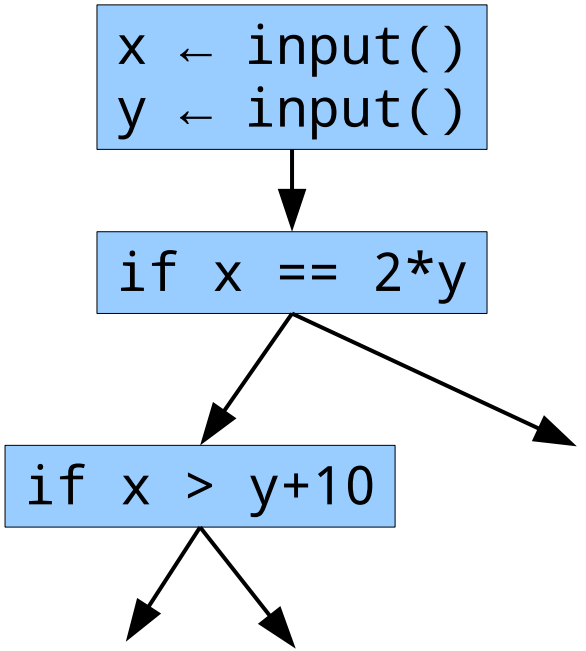
- As we have seen, building constraints that model code can be useful
- With care, we can even use constraints to generate all inputs that are "interesting"
- Techniques for supporting this are known as ***symbolic execution***
  - (SymEx)

Symbolic Execution

- An approach for generating test inputs.

[Cadar & Sen, 2013]



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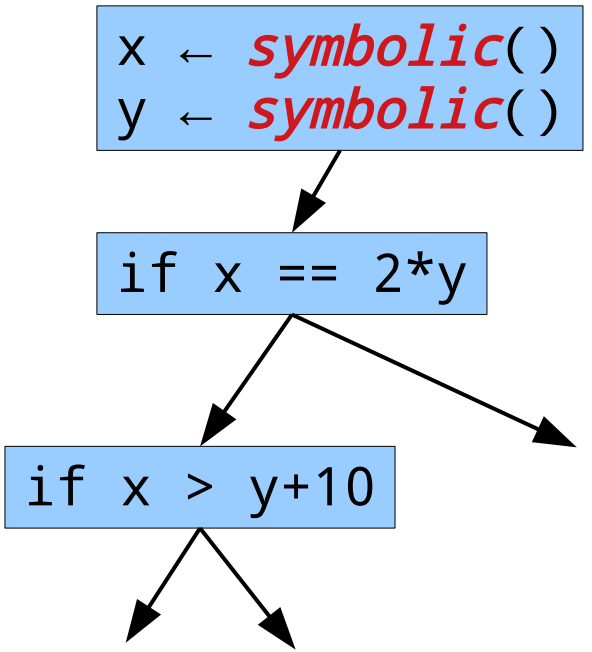

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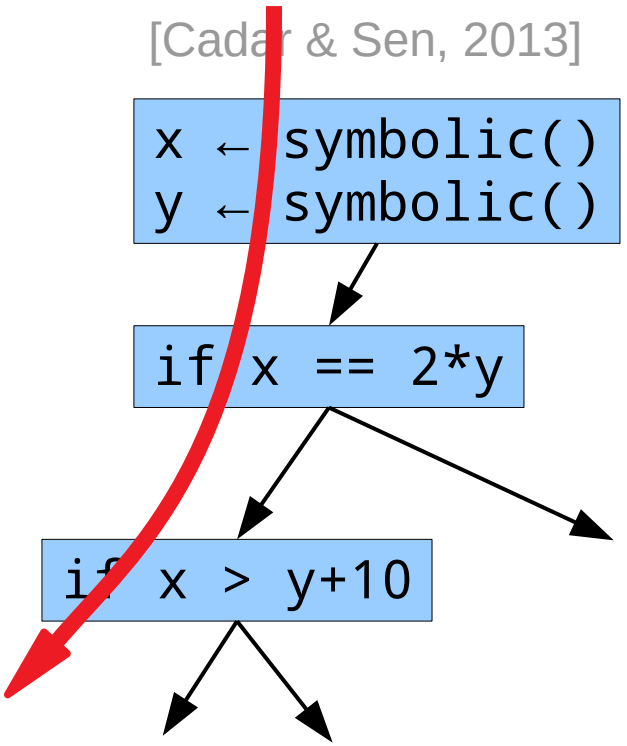

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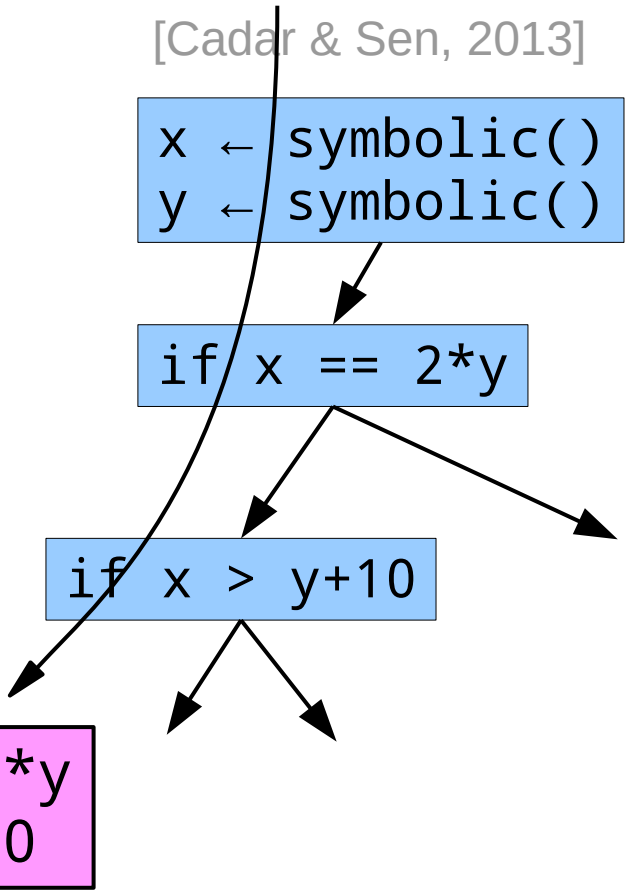

Path Constraint

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A path constraint represents all executions along that path

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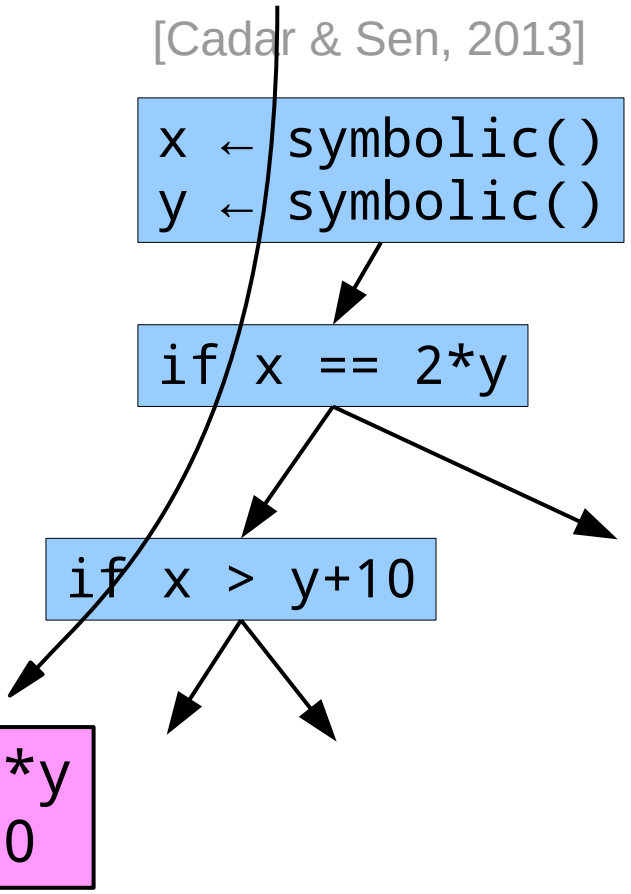

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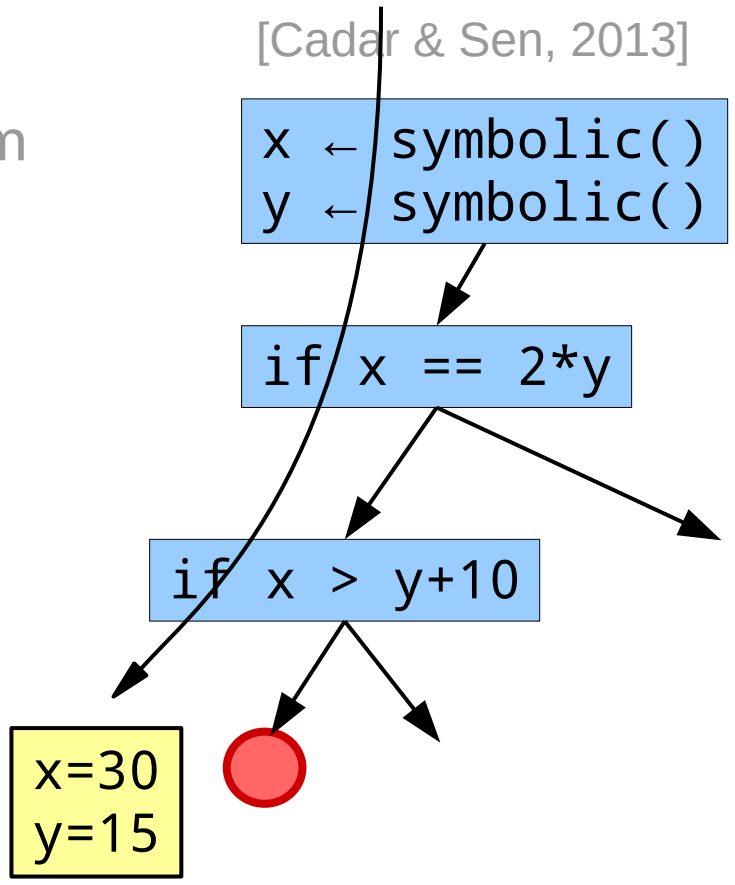

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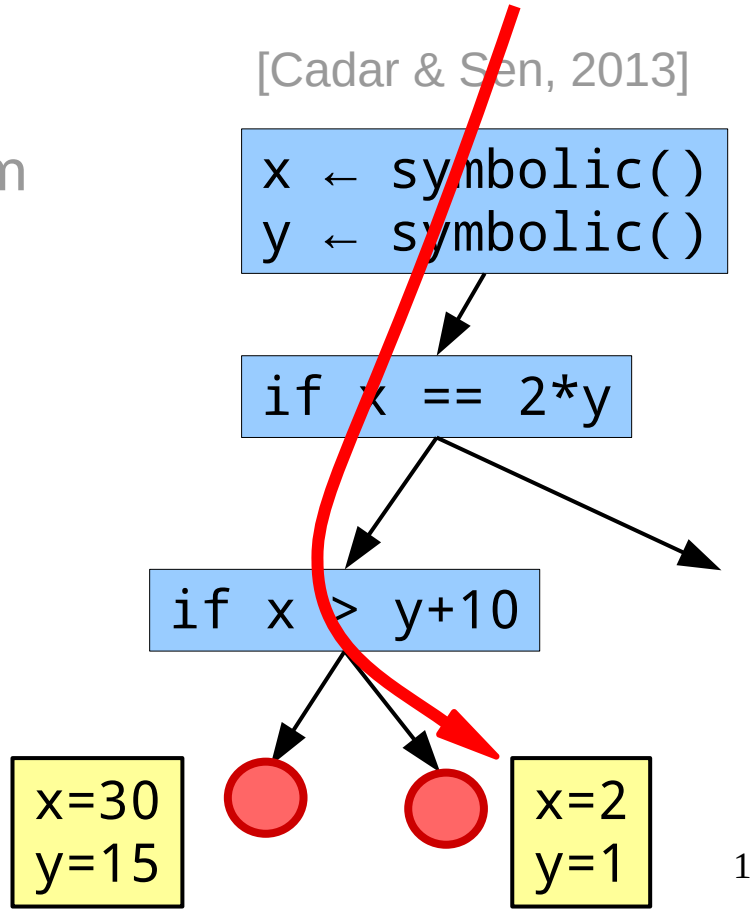

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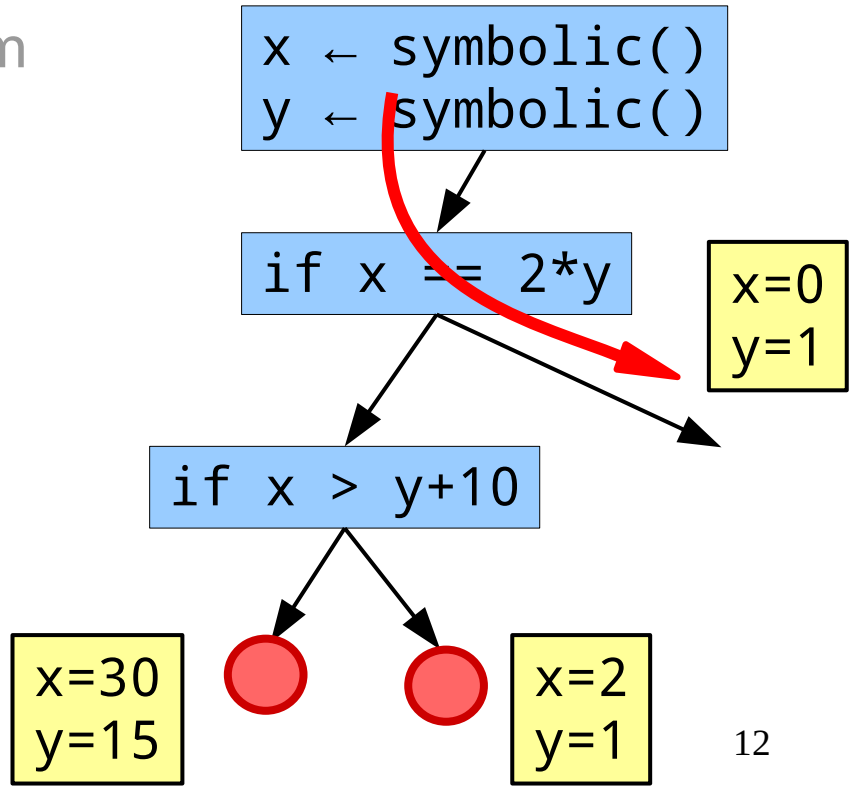

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What is $wp(\varphi_1) \wedge \neg wp(\varphi_2)$?

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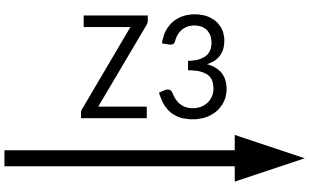


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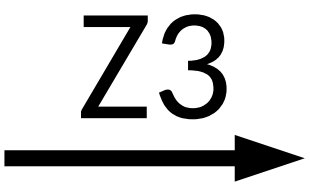


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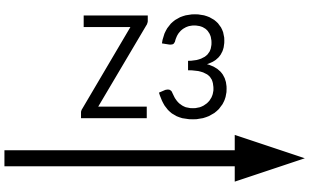


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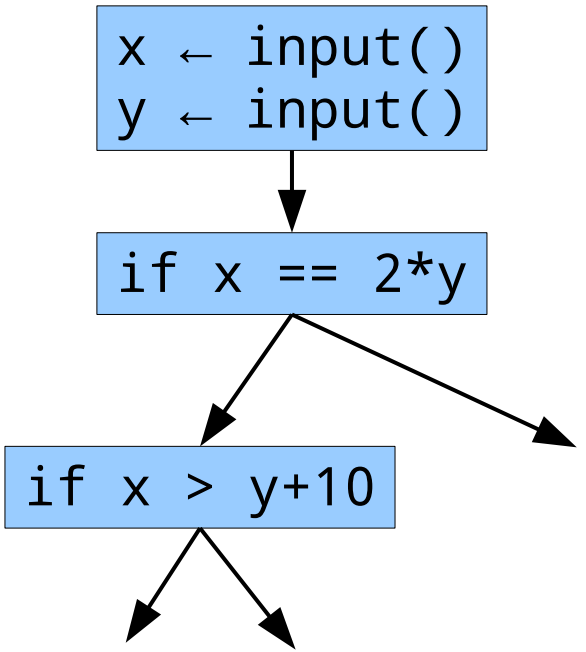
Try it online:
http://www.rise4fun.com/Z3/tutorial/

Exploring the Execution Tree

- The possible paths of a program form an ***execution tree***.

[Cadar & Sen, 2013]



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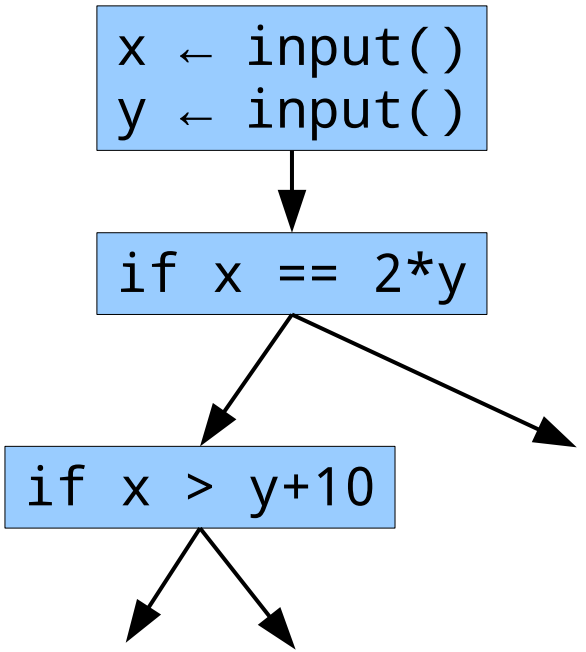

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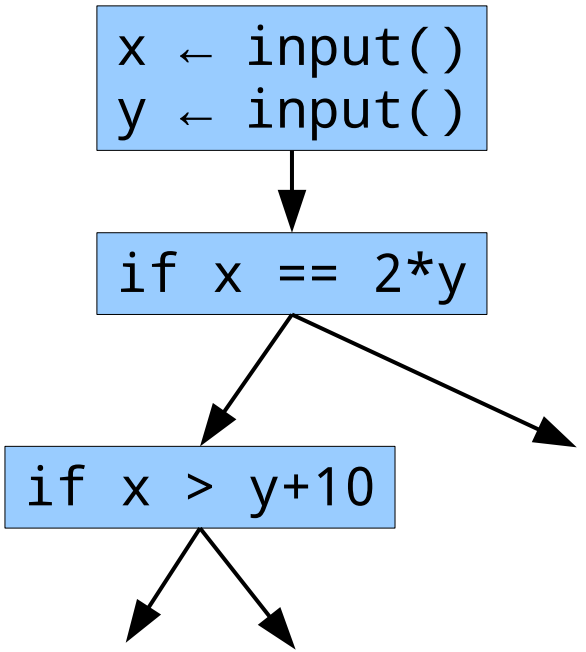

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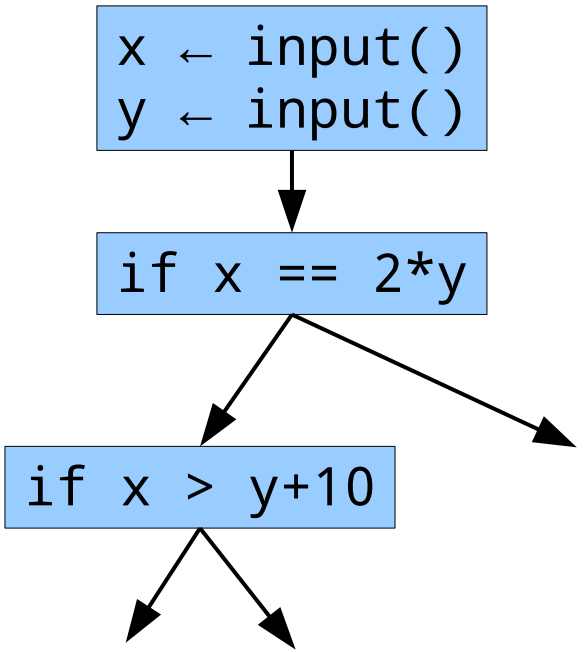

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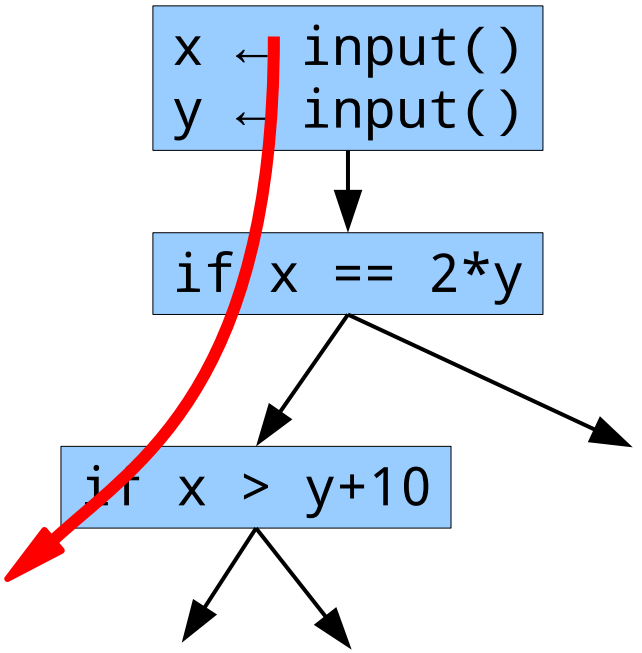

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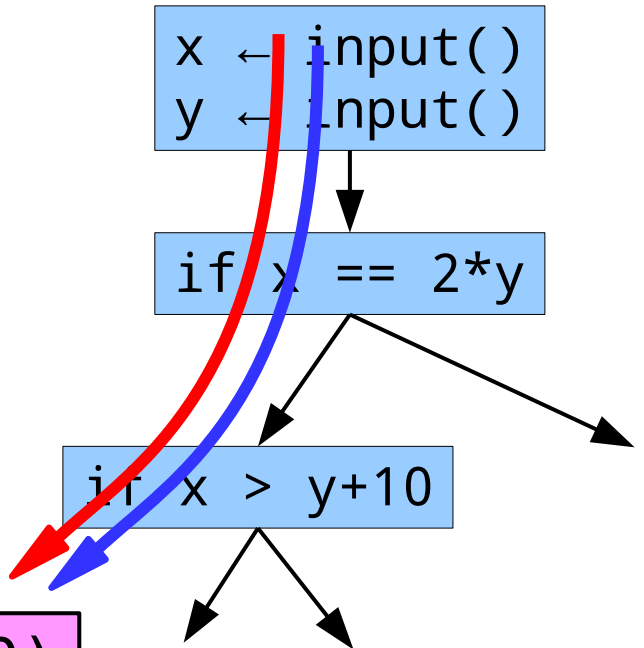

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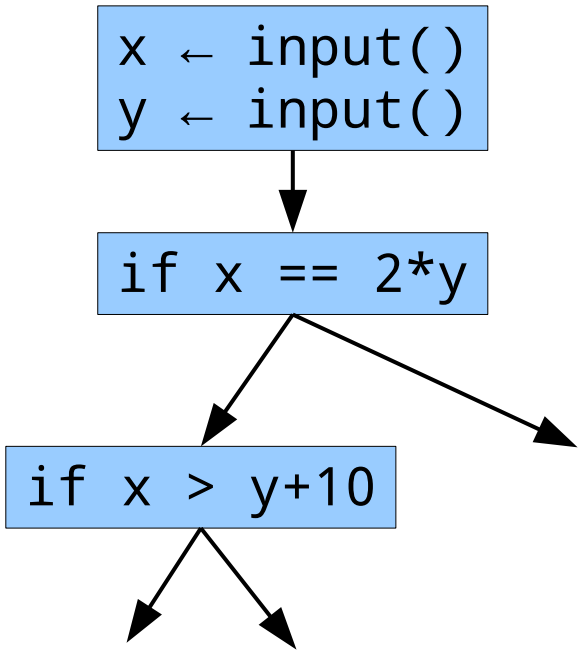

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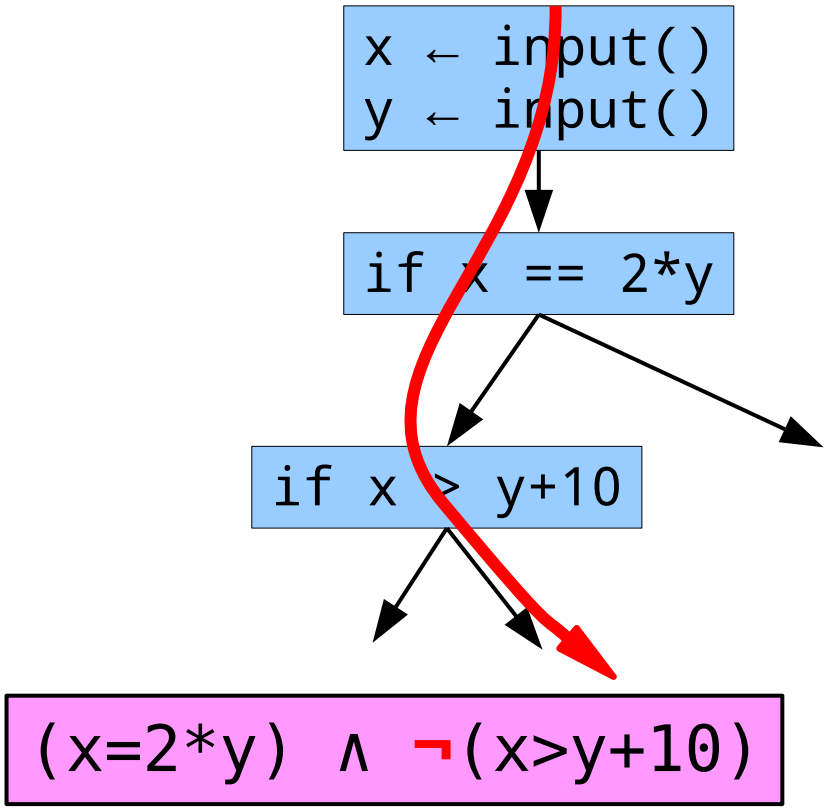

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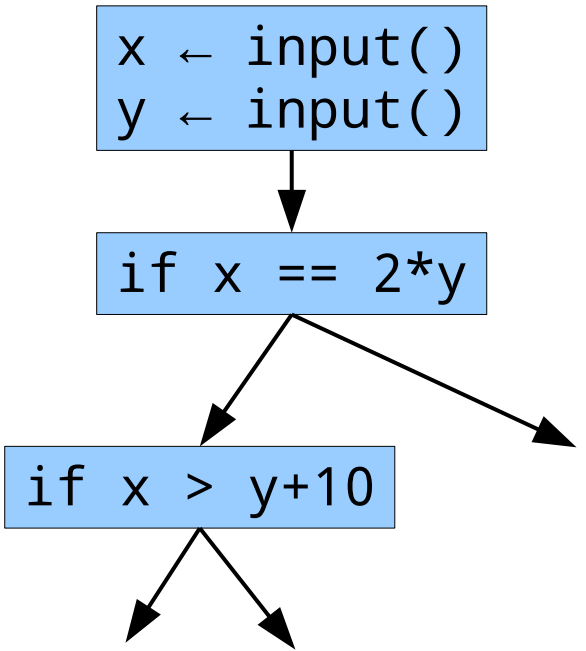

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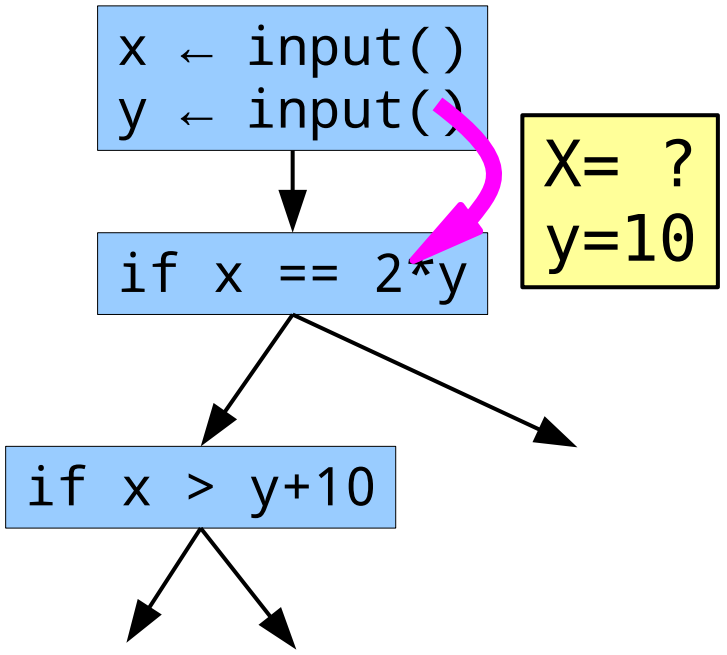

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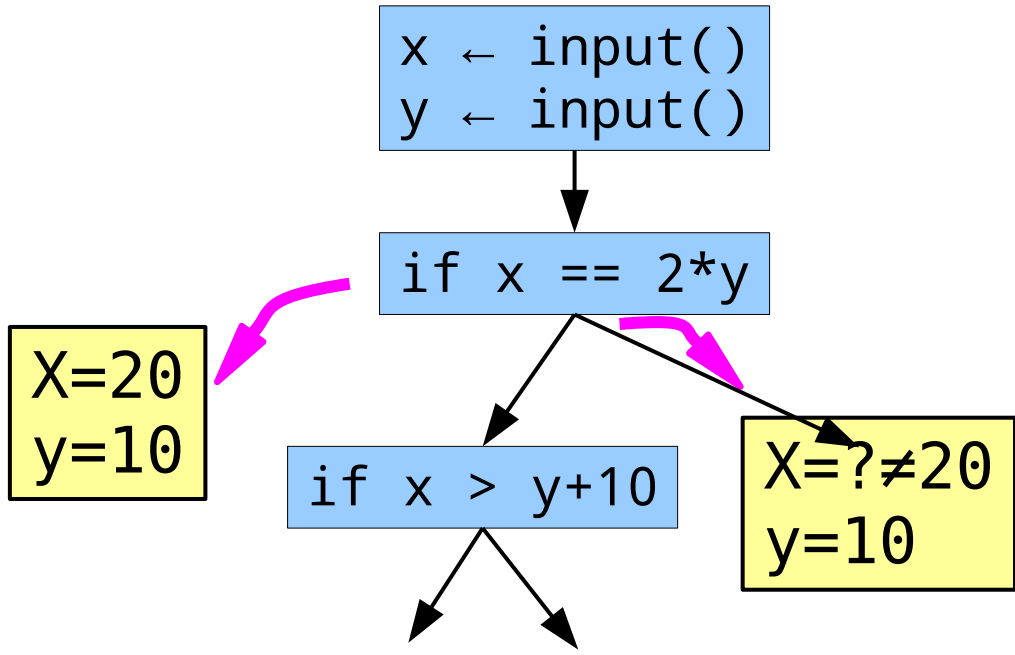

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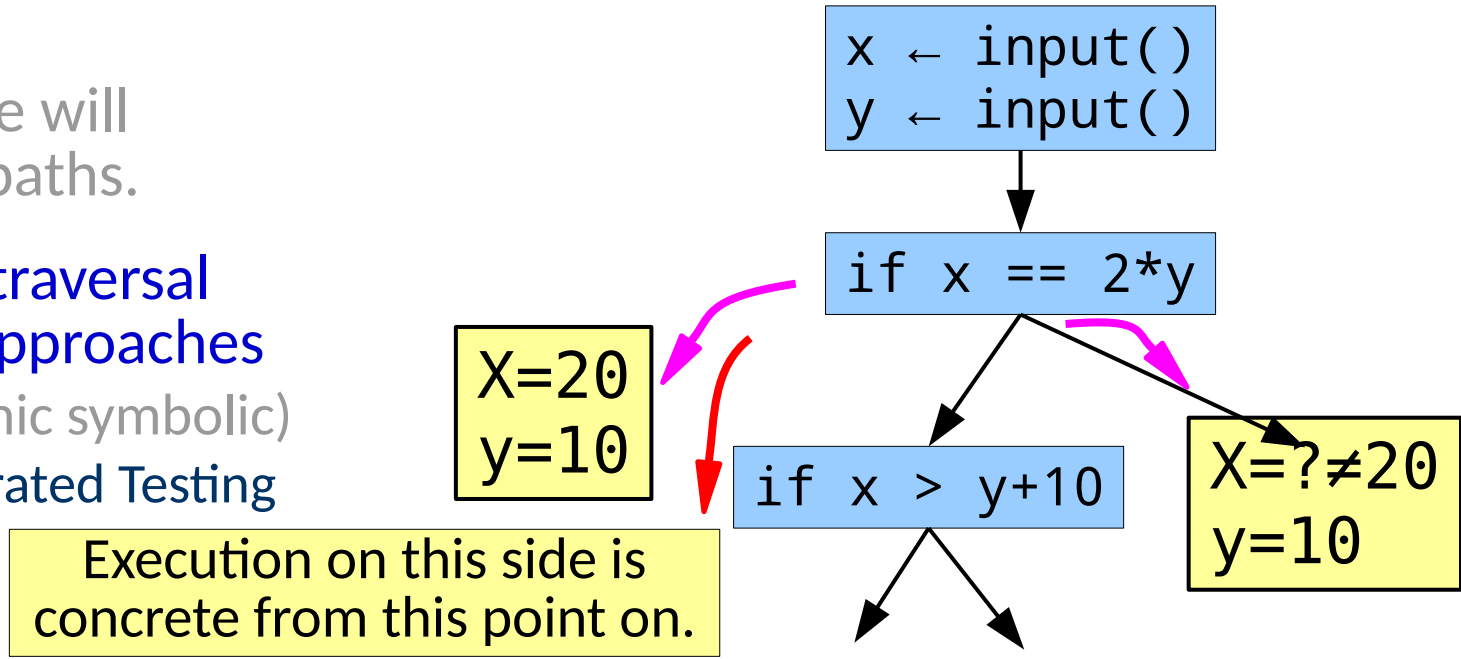

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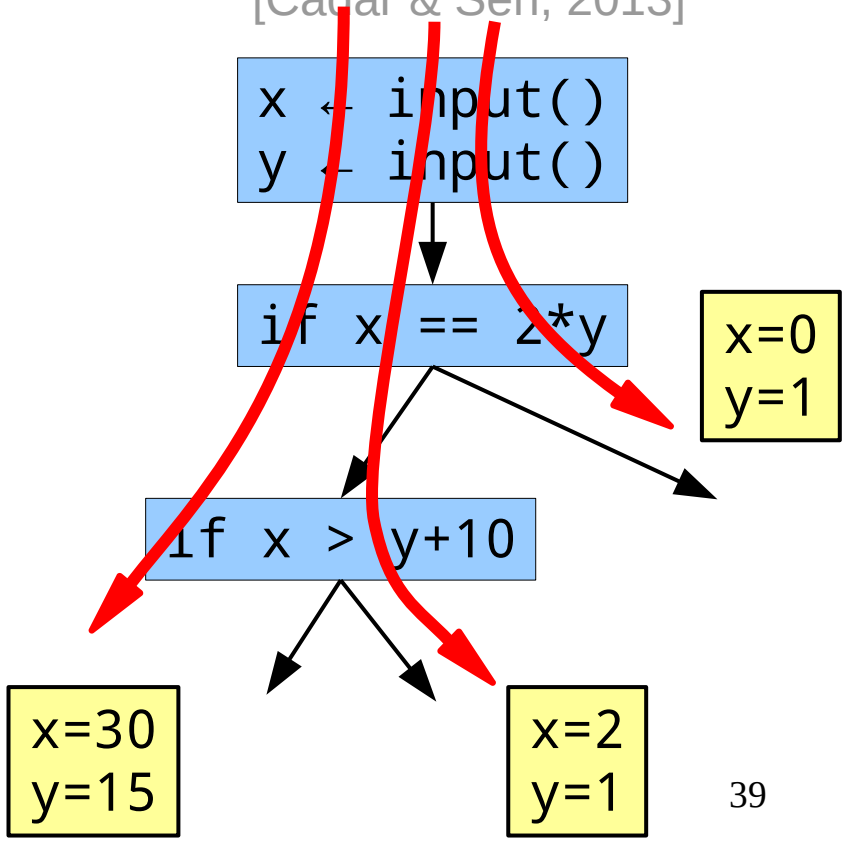

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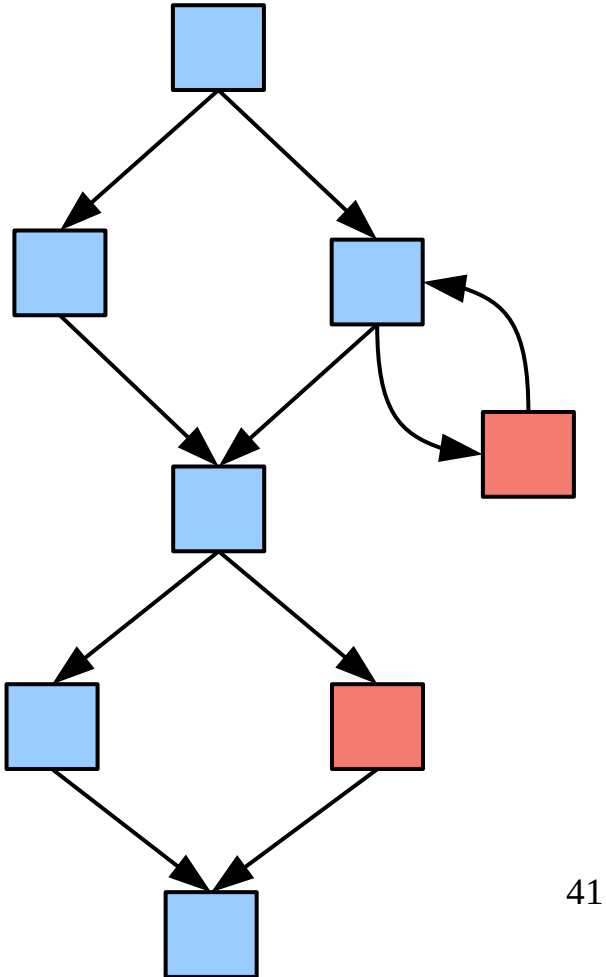

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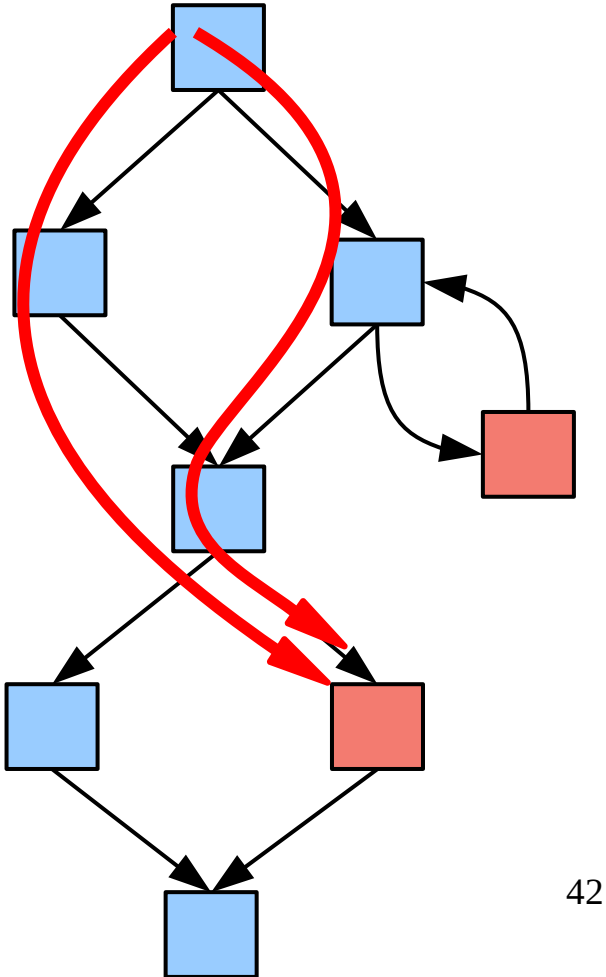

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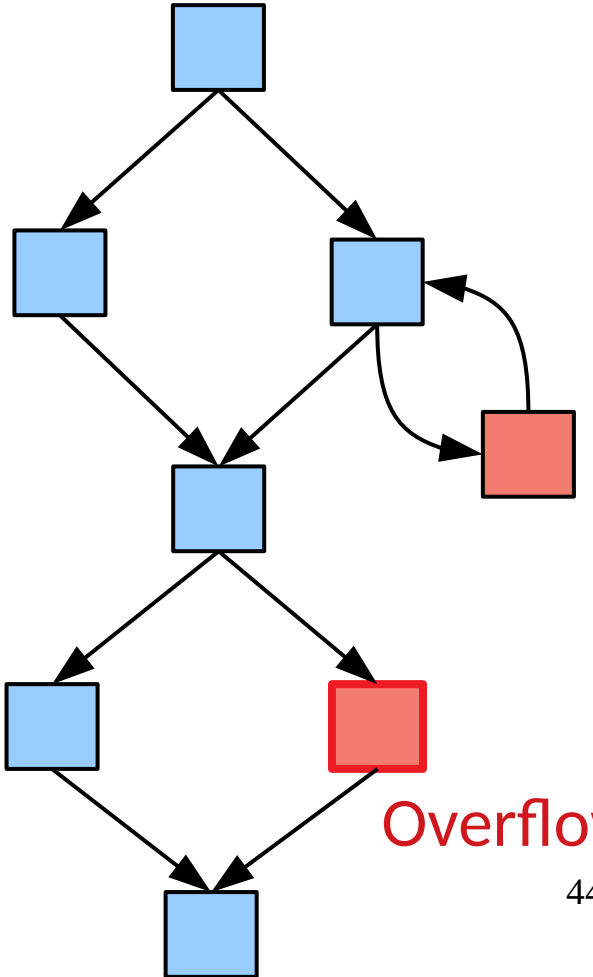

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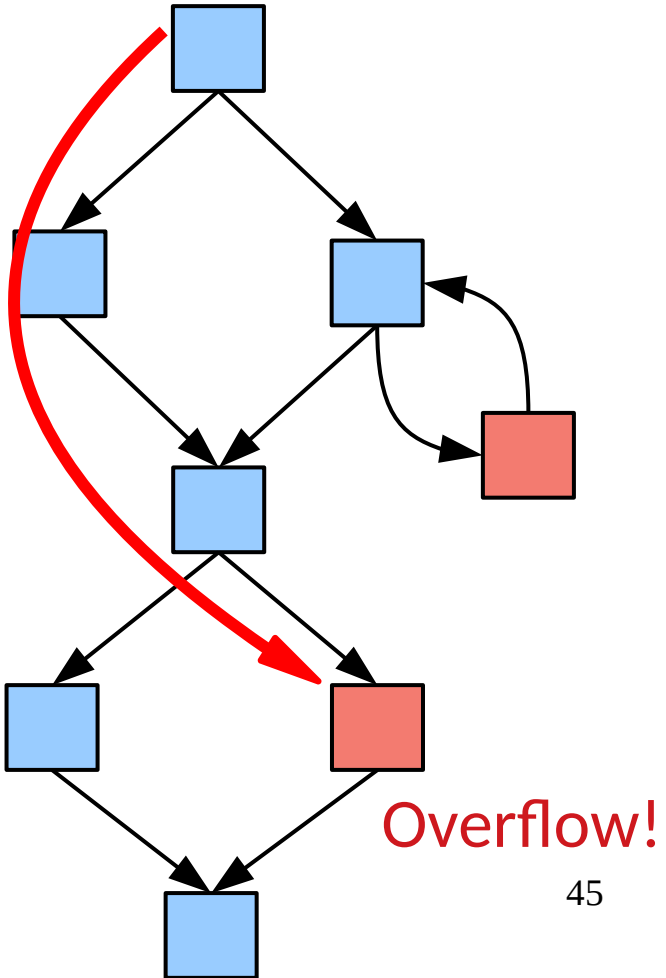

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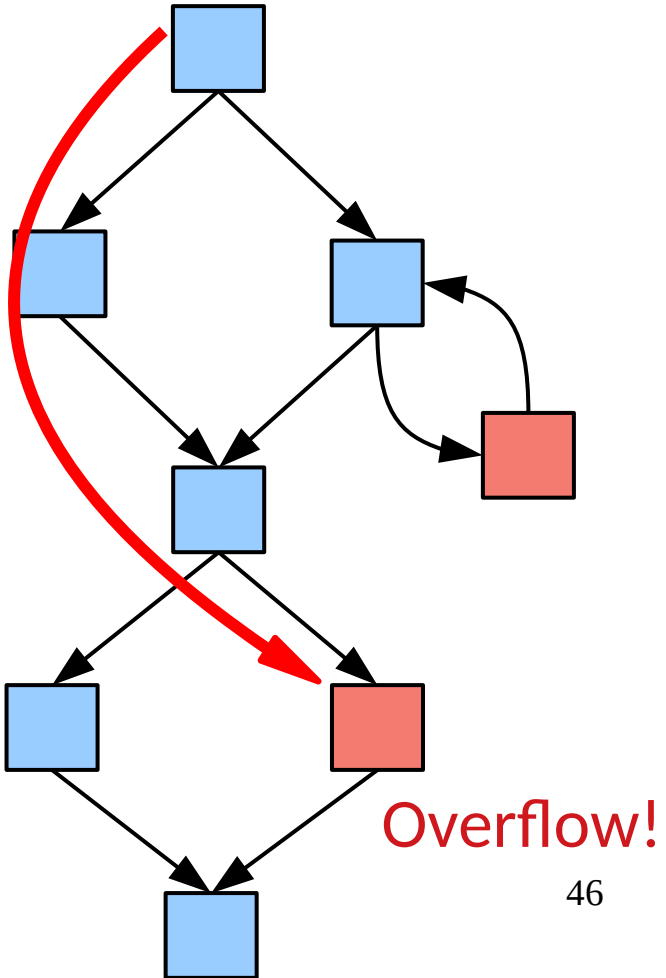
Input ⊢ Overflow ^ StartsShellcode

This is the core process for
Darpa Cybersecurity Grand Challenge entries!



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The latest testing & verification services from MS are built around these techniques.

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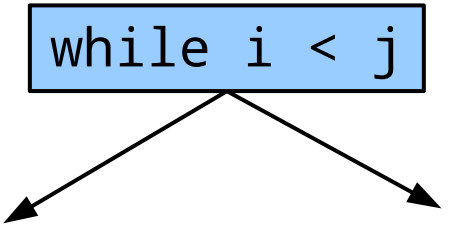
Let’s revisit a familiar example…

Challenges

- Path Explosion
- Challenging constraints
- Constraint representations & domain knowledge

Path Explosion

- Loops



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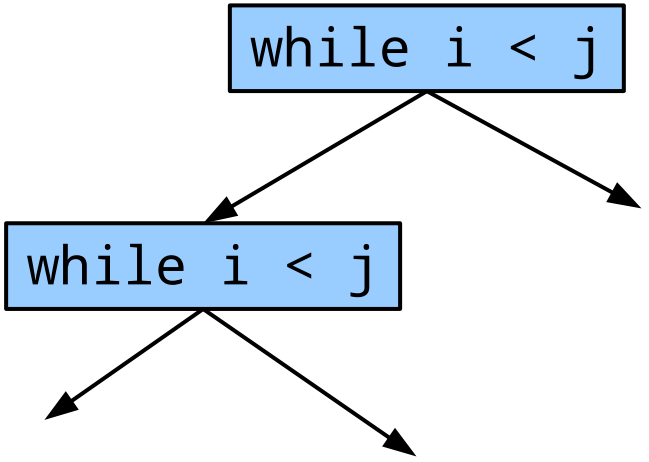

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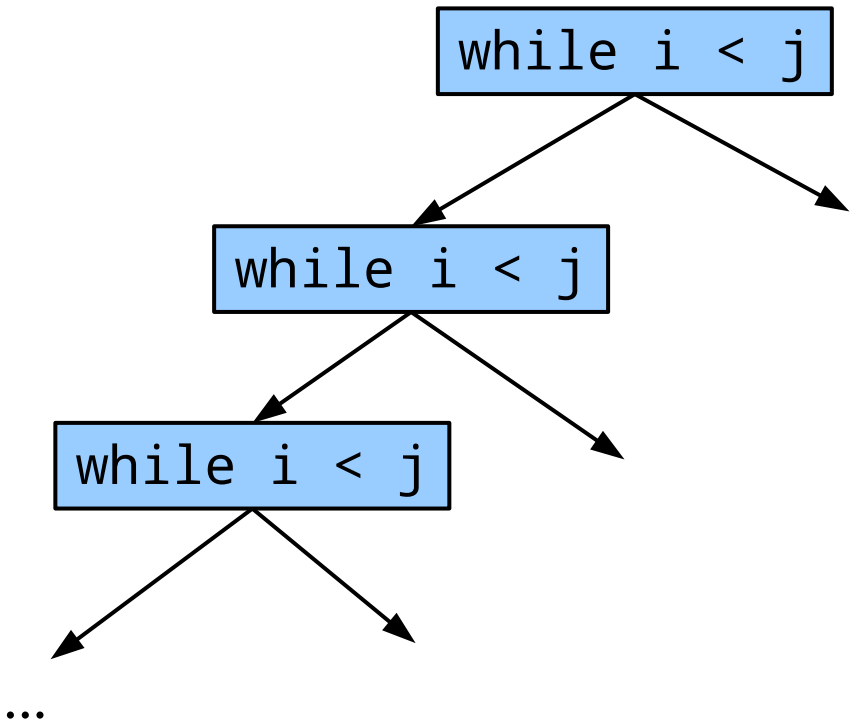

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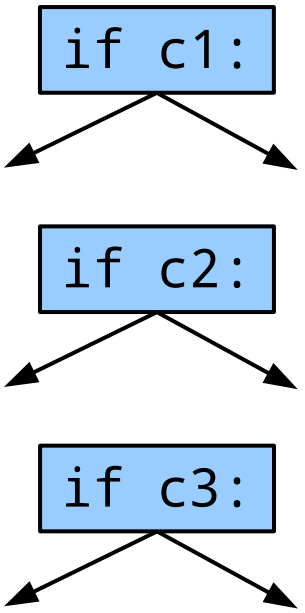
- Loops
- Combinatorial Explosion



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State of the art techniques carefully use summarization & representations to minimize these

Path Explosion

- Loops
- Combinatorial Explosion
- Strategies
  - Search heuristics
  - Memoization

Challenging Constraints

- Intuitively, we cannot solve all constraints

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  print(“how odd”)
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What would it imply if we could?

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How do these affect our ability to explore the execution tree?

Domain Knowledge

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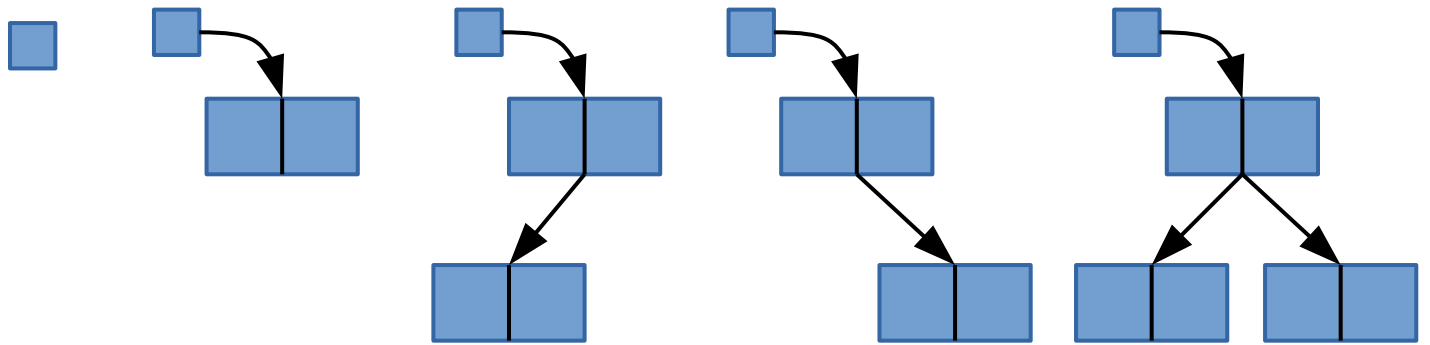
- Can we carefully explore interesting structures?
  - Korat style enumeration



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Try it out:
1) https://github.com/klee/klee
2) Symbolic PathFinder
3) http://research.microsoft.com/Pex/
4) http://angr.io/