Karlsruhe Institute of Technology

Static Program Checking

Introduction

Automated Software Analysis Group, Institute of Theoretical Informatics

Jun.-prof. Dr. Mana Taghdiri

Thursday – April 24, 2014

Administrative notes

- Lecturer
  - Mana (mana.taghdiri@kit.edu, Geb. 50.34, Room 229)
  - Office hours by appointment
- Class material
  - Recent research papers
  - Will practice with the tools whenever possible (bring your laptops)
  - Exchange of ideas (the more interactive, the better)
- Exam
  - Part of the ‘formal methods’ module
  - Oral exam

Contents Overview

- Class focuses on systematic bug-finding techniques
  - Emphasis on cost, practicality, and automation
  - Push-button techniques
  - In contrast to verification approaches
    - E.g. theorem proving

- Announced topics
  - Finding bugs in OO programs statically
    - As opposed to testing
  - Inferring what programs do
    - Summaries
      - Static techniques
    - Invariants
      - Static and dynamic techniques
  - Iterative analysis via feedback loops

Approach

- Flexible about the topics
  - Will adjust based on your feedback

- If interested in such topics
  - Diploma/masters thesis
  - student work
  - Discussions

- Check out the website regularly
  - http://asa.iti.uka.de/
  - For the list of references, schedule, and slides

Traditional testing is not cost-effective

- Zero-tolerance for bugs in safety-critical software
  - Air-traffic controllers, medical equipments, automotive industry, etc.
- Pressure to reduce time-to-market

- Testing is easy
  - Few first tests reveal many quick bugs
  - Tests are usually run automatically and repeatedly
- Testing is incomplete
  - Requires domain experts to pinpoint troubling scenarios
- Testing is costly
  - Consumes half the total cost of software development
  - Microsoft hires one tester for every developer

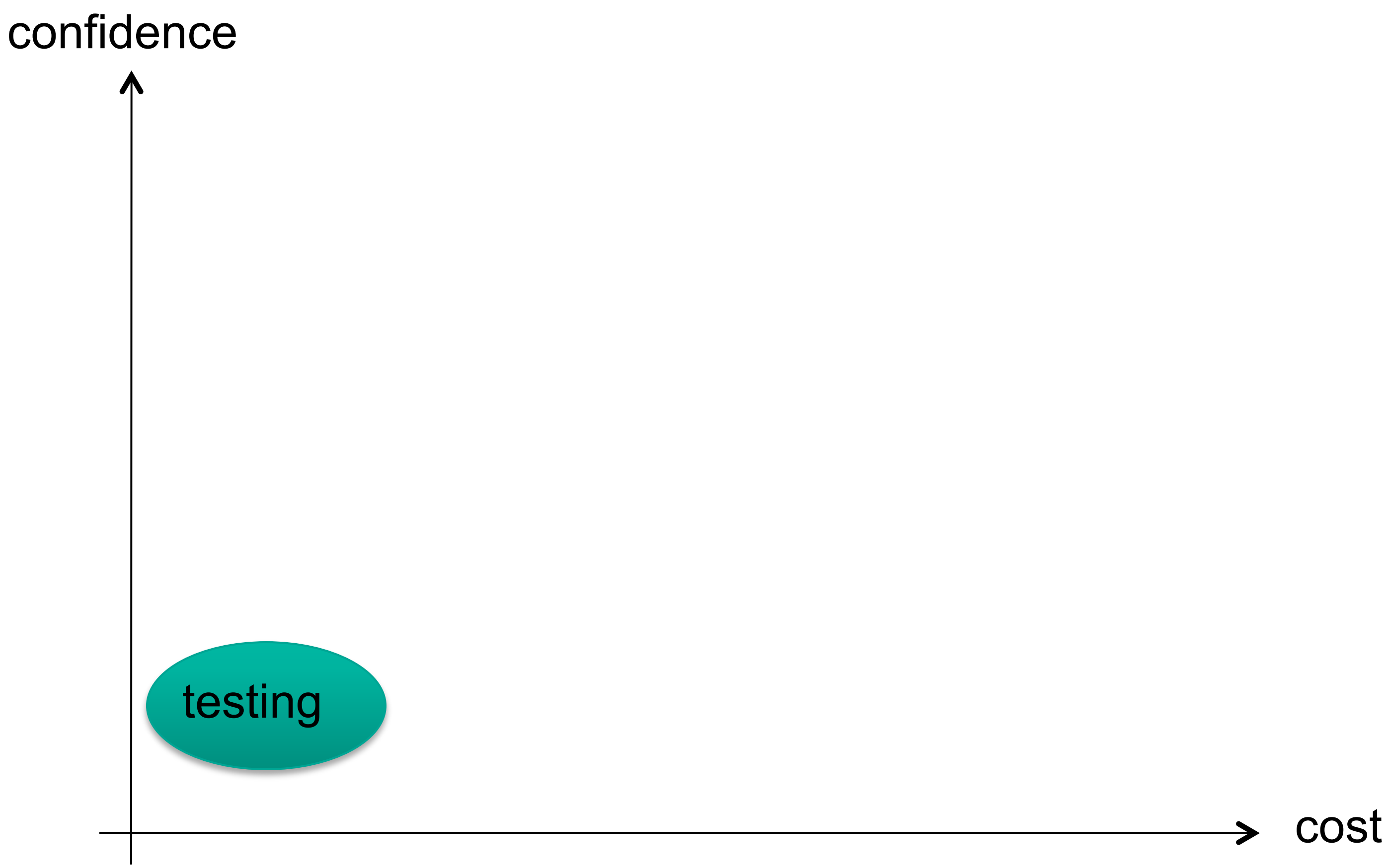
Automatic test-case generation

- Exhaustive generation
  - Test cases generated for a method based on its pre-condition
  - All non-isomorphic test cases up to a certain size
  - Runs the code on generated tests and compares against the post-condition
  - Either declarative (based on Alloy) or imperative algorithm

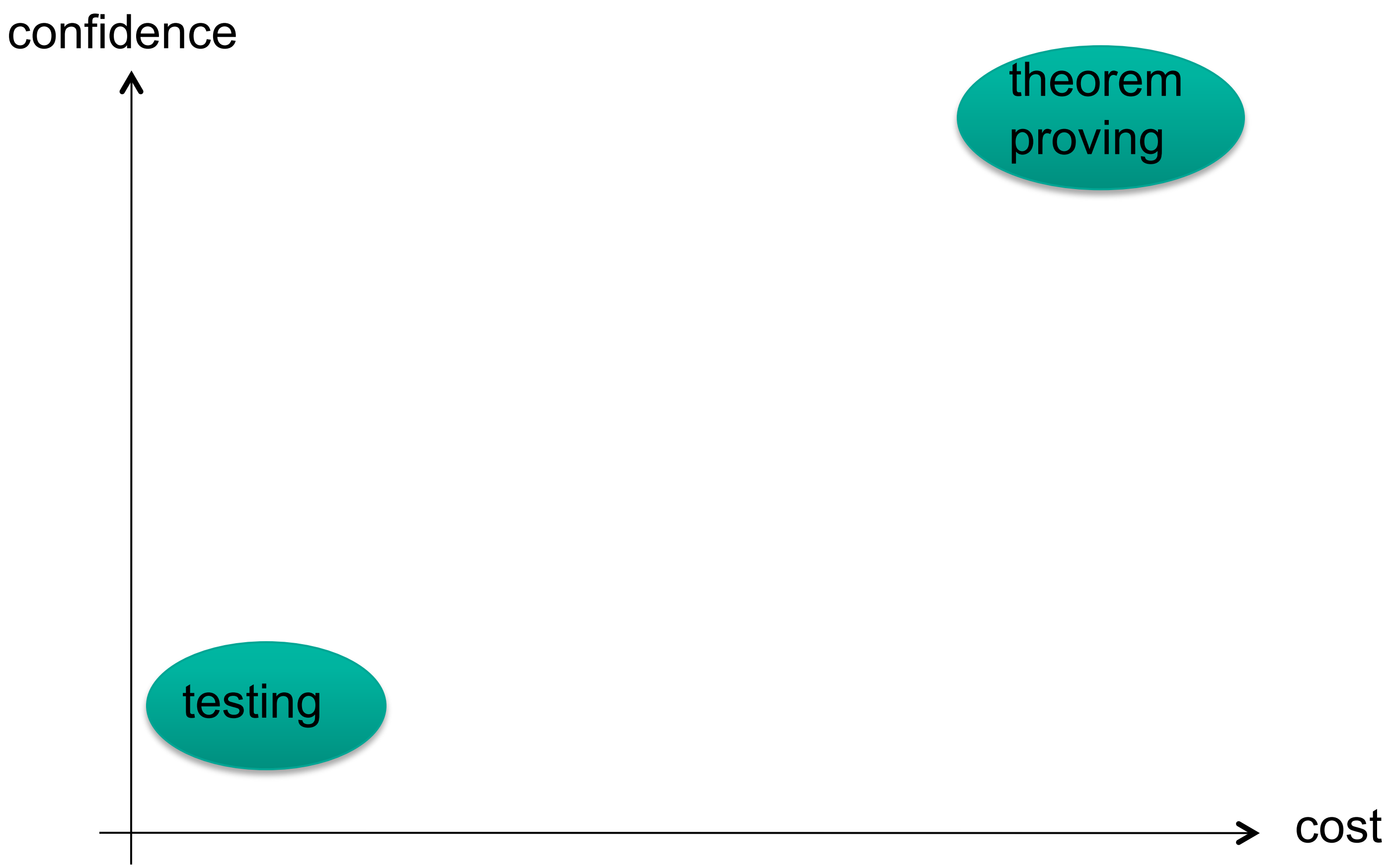
- Random generation
  - But “feedback-directed”
  - Randomly selects which method to call next and its arguments from available objects
  - Executes generated tests and uses the feedback to generate better tests
  - Execution results determine whether the input is redundant, illegal, contract-violating, or useful for generating more inputs

- Automated test generation is a solution, but not our topic!

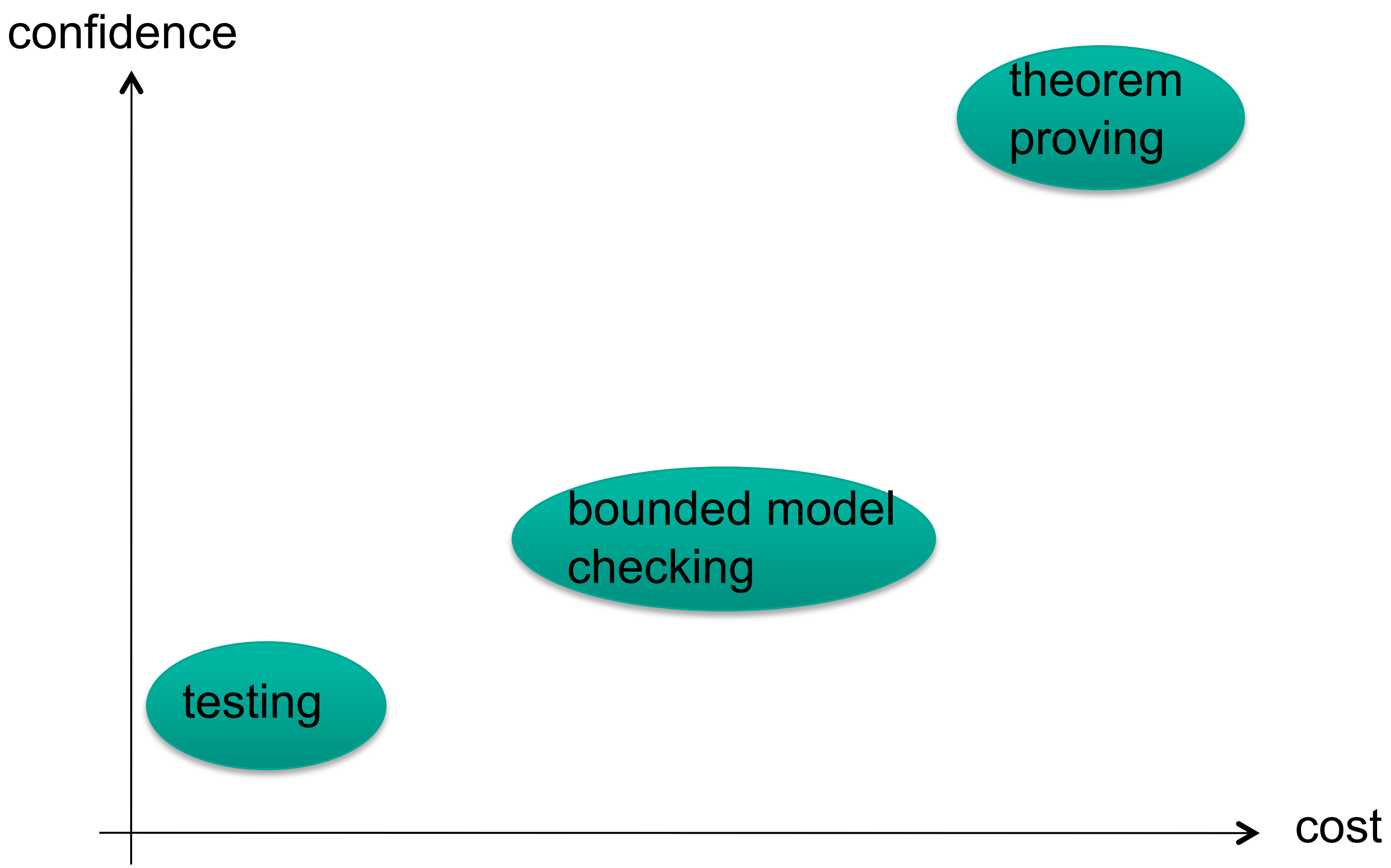
Cost vs. confidence



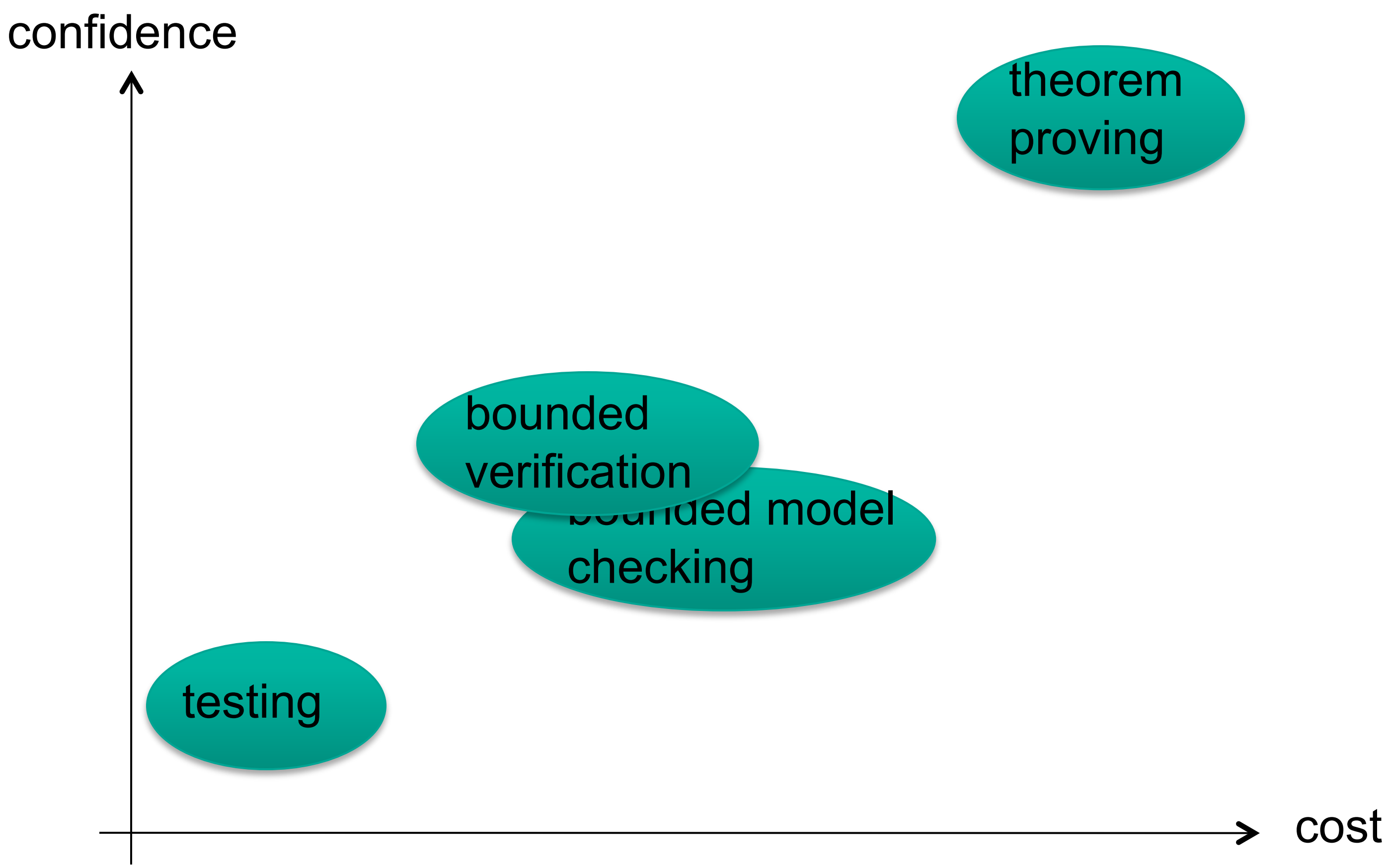
Cost vs. confidence



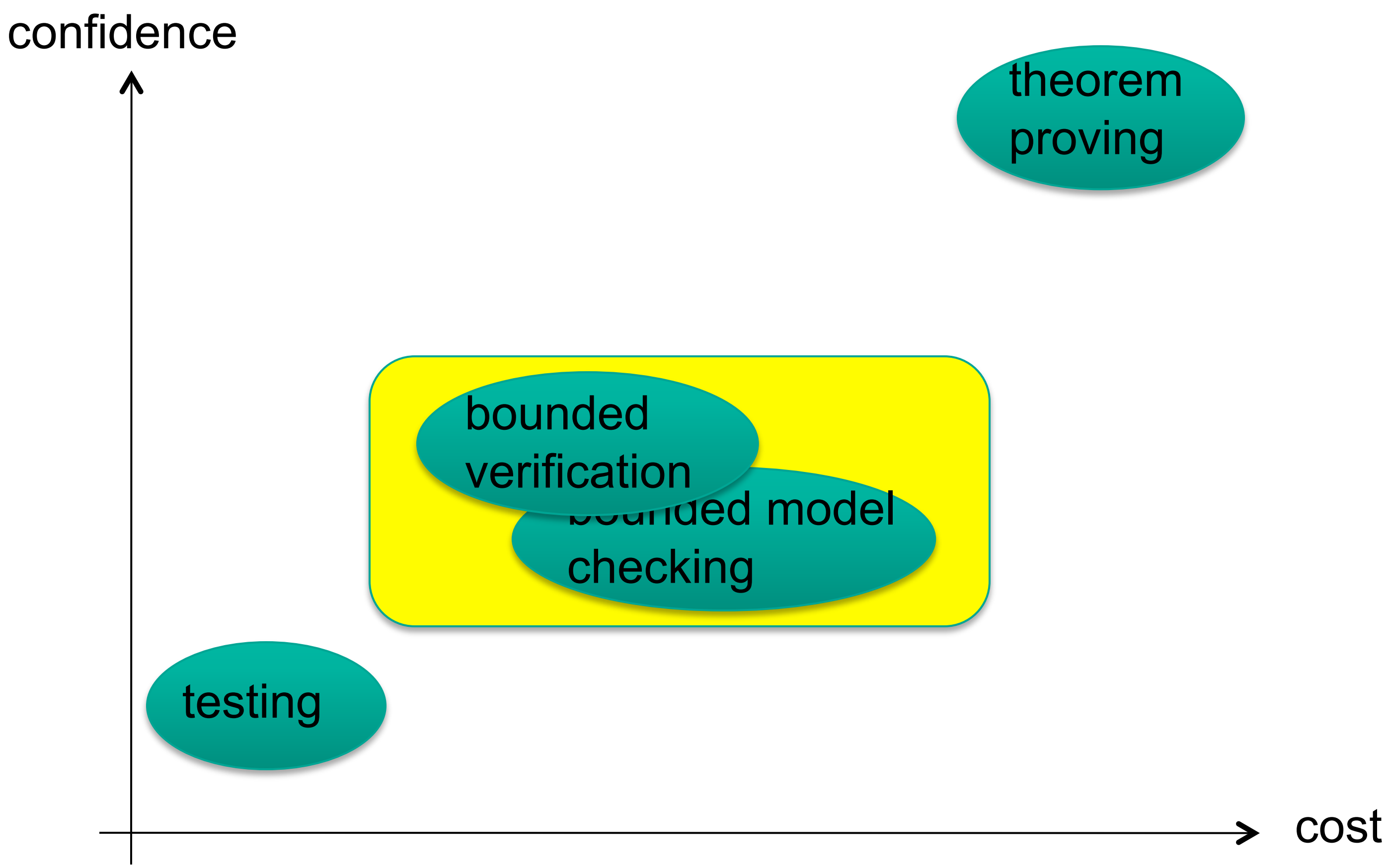
Cost vs. confidence



Cost vs. confidence



Cost vs. confidence



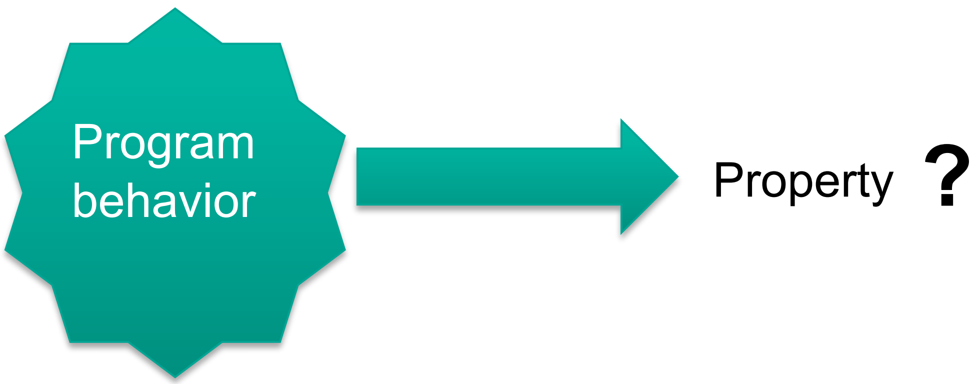
Static software checking

- Checks a functionality of the code (property)
  - Provided by the user
  - Says what the code is supposed to do
- Provides certainty for program correctness (confidence)
  - What kind of properties does it check?
  - How complete is the analysis?
- Requires efforts from users (cost)
  - Code preparations before the analysis?
  - User interaction during the analysis?
  - Understanding the reported bug?
  - False alarms?
  - Analysis time?

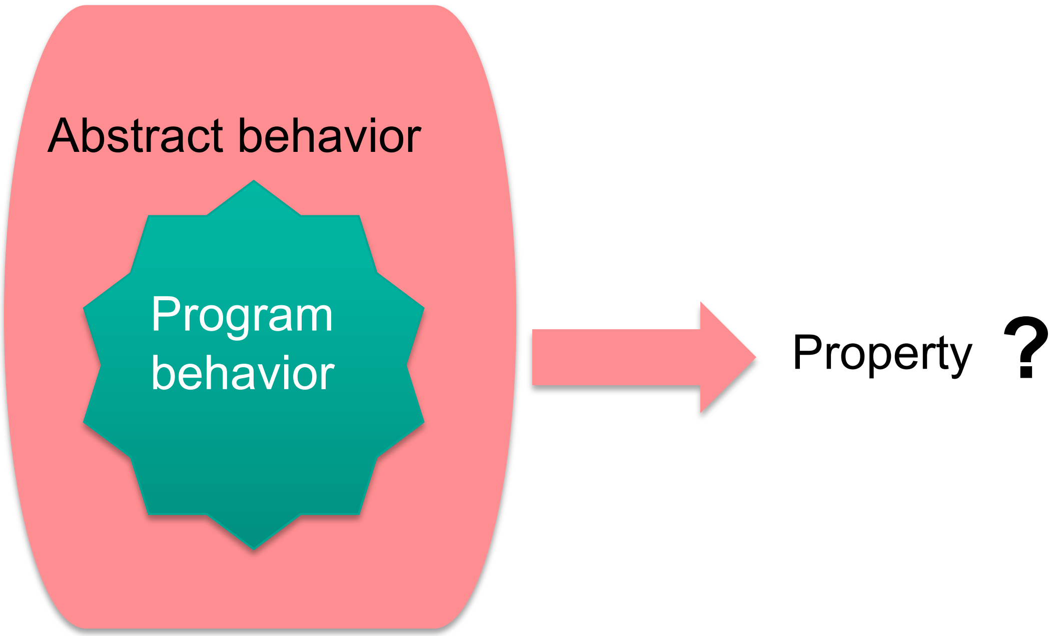
Inferring what programs do (Examples)

- Summarization
  - Static
  - Syntactic specifications in Alloy
  - Infers post-conditions based on pre-state values
  - Good for OO code
  - Based on symbolic execution and abstract interpretation
- Invariant detection (Daikon)
  - Dynamic
  - A machine learning technique
  - Properties that hold at a certain point in the program
  - Unsound, but likely
  - Runs on a suite of test cases and learns invariants
- Why is invariant detection/summarization important?

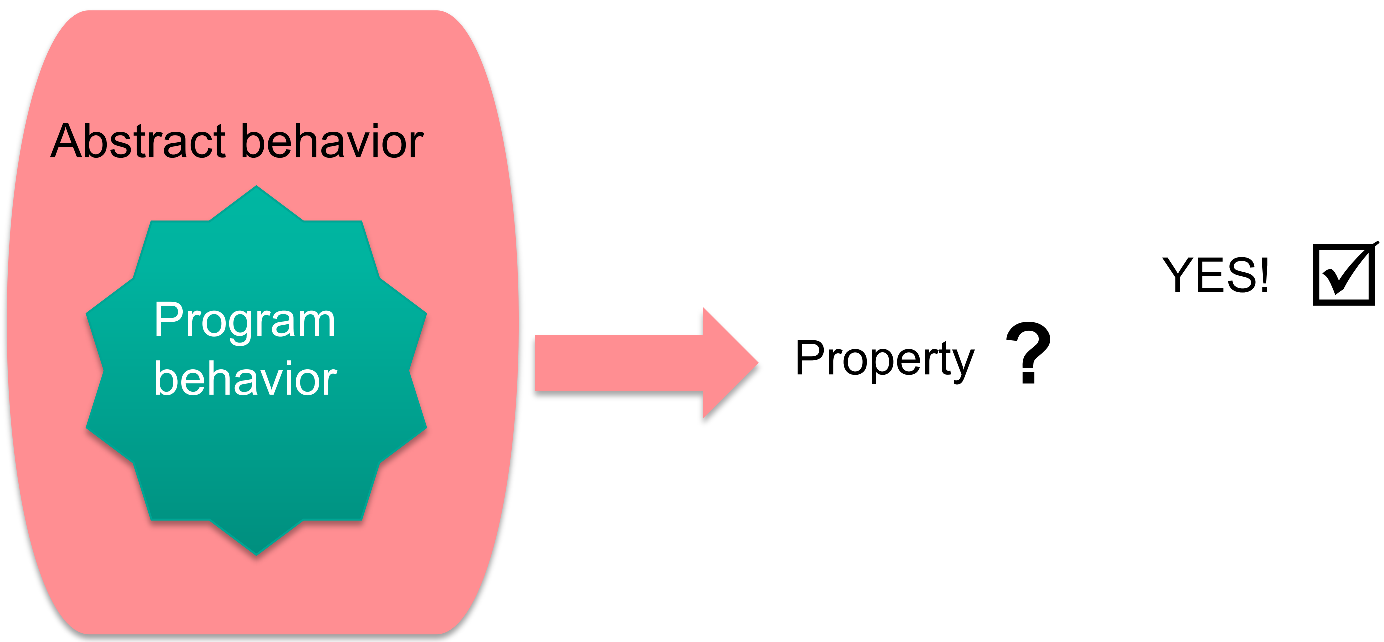
Iterative analysis via feedback loops



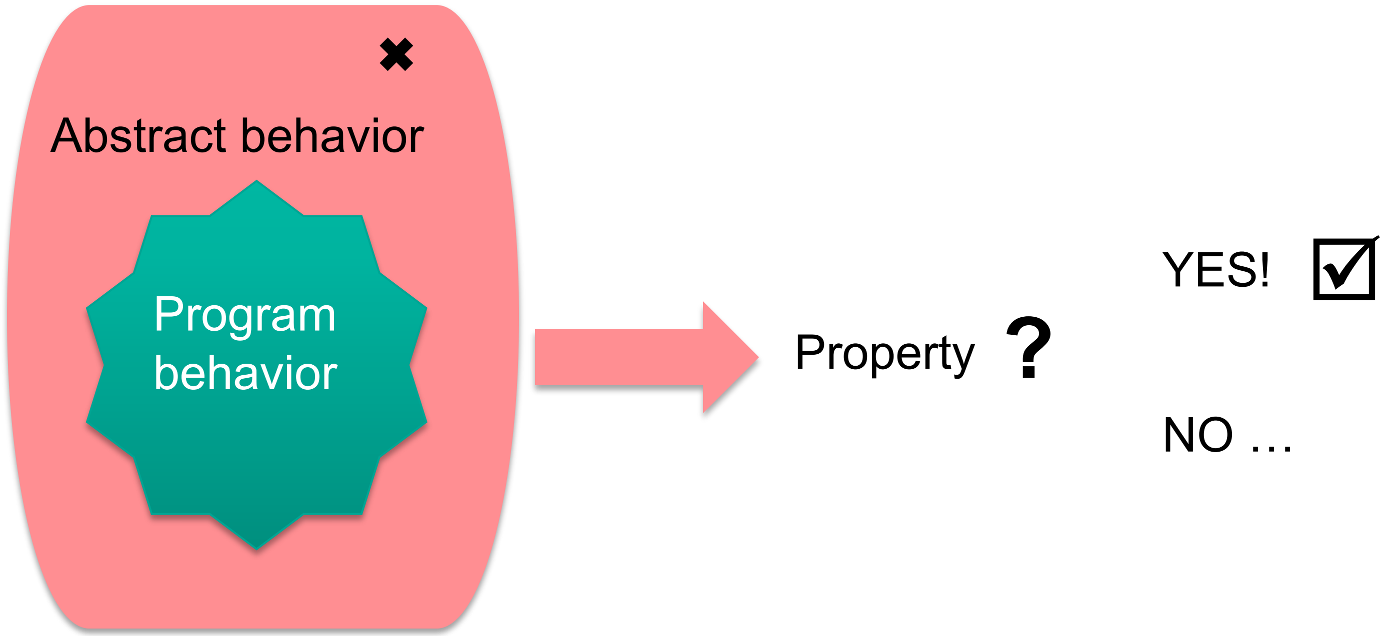
Iterative analysis via feedback loops



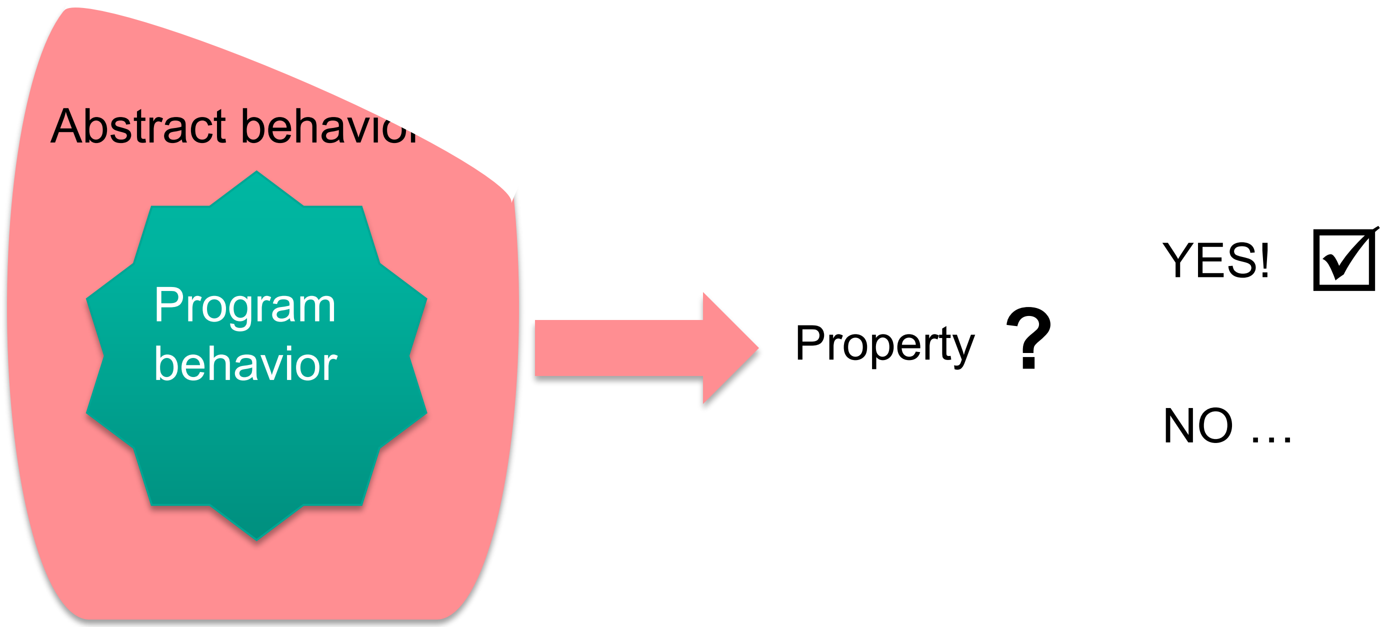
Iterative analysis via feedback loops



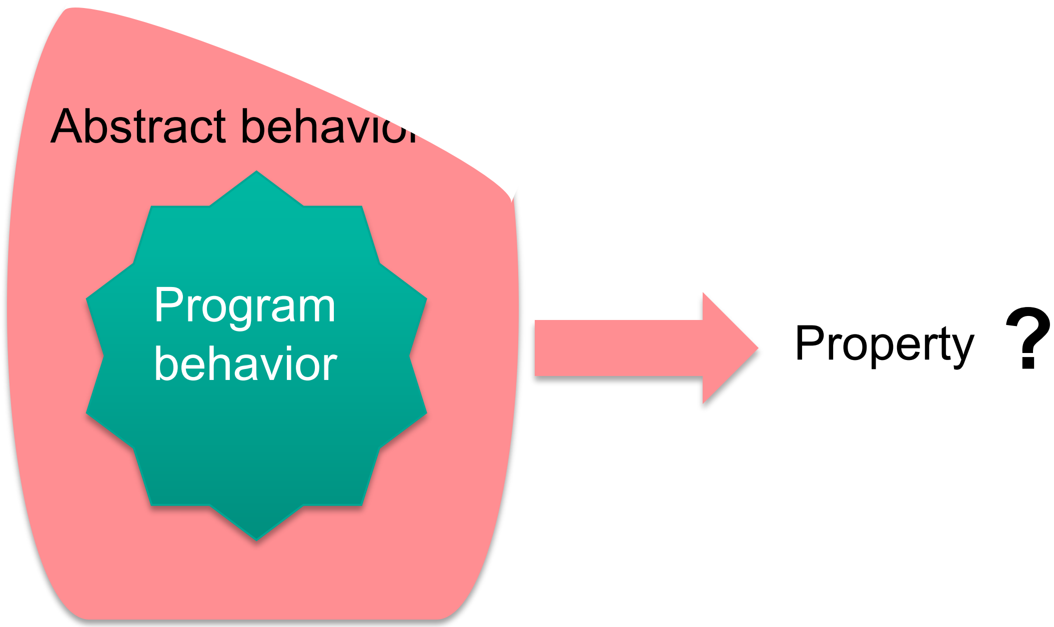
Iterative analysis via feedback loops



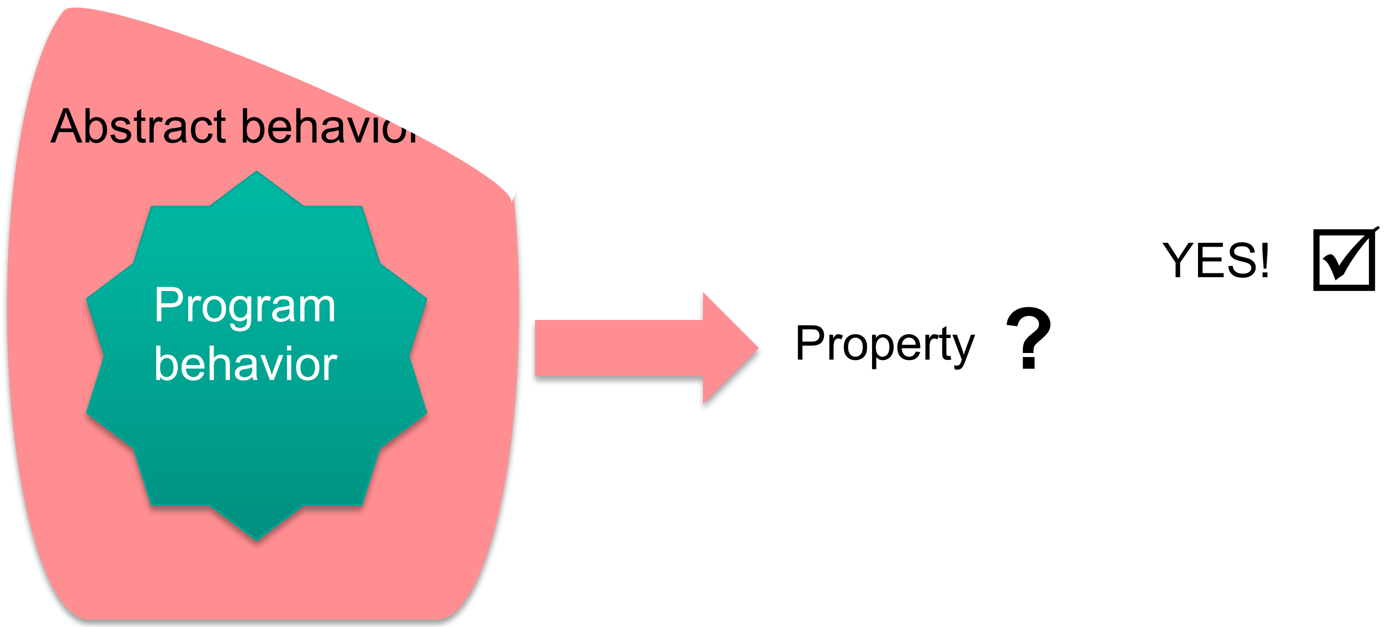
Iterative analysis via feedback loops



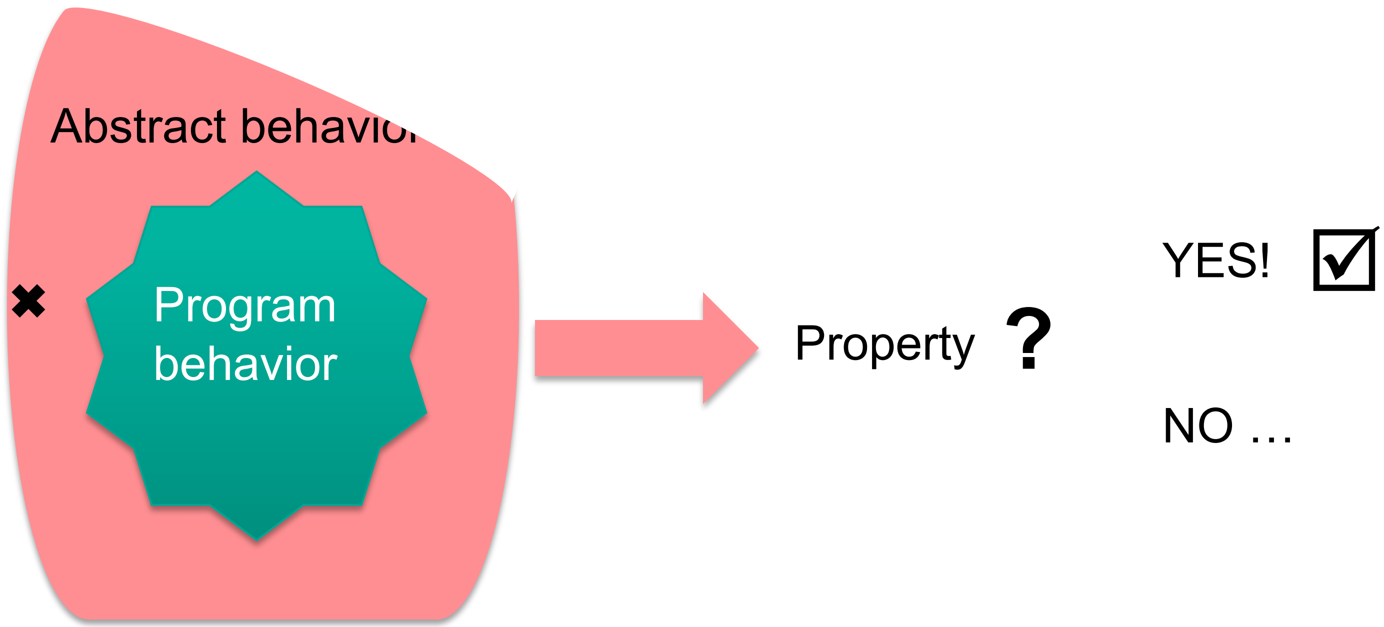
Iterative analysis via feedback loops



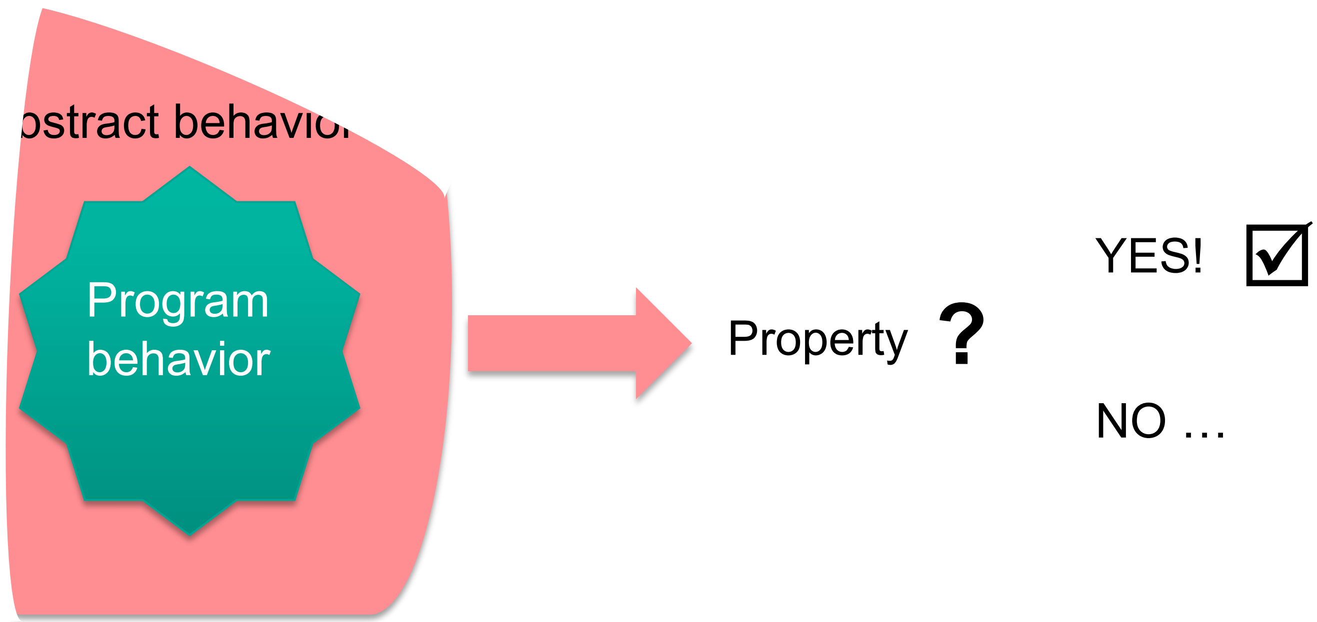
Iterative analysis via feedback loops



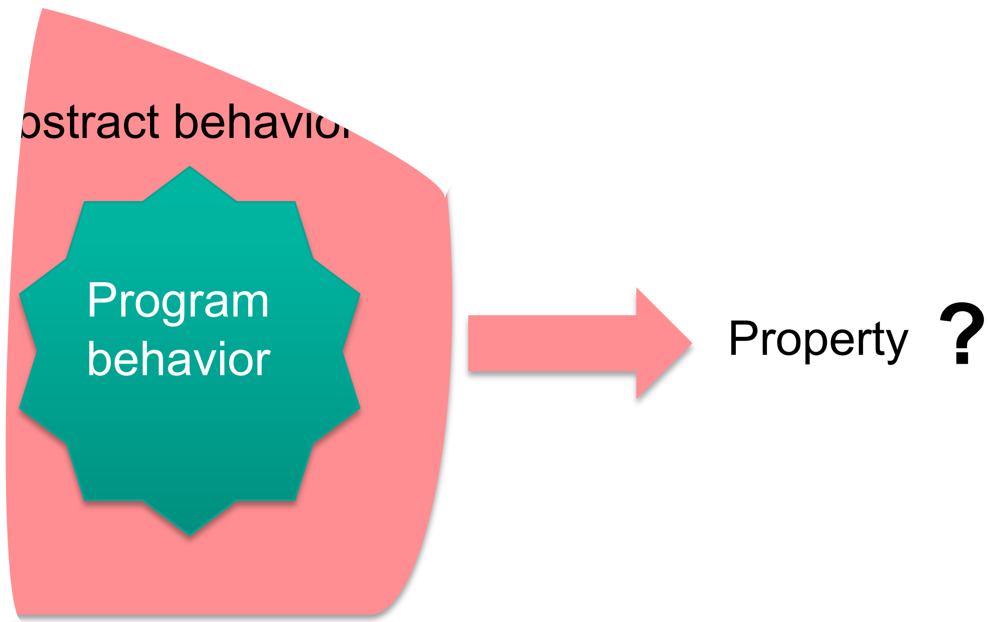
Iterative analysis via feedback loops



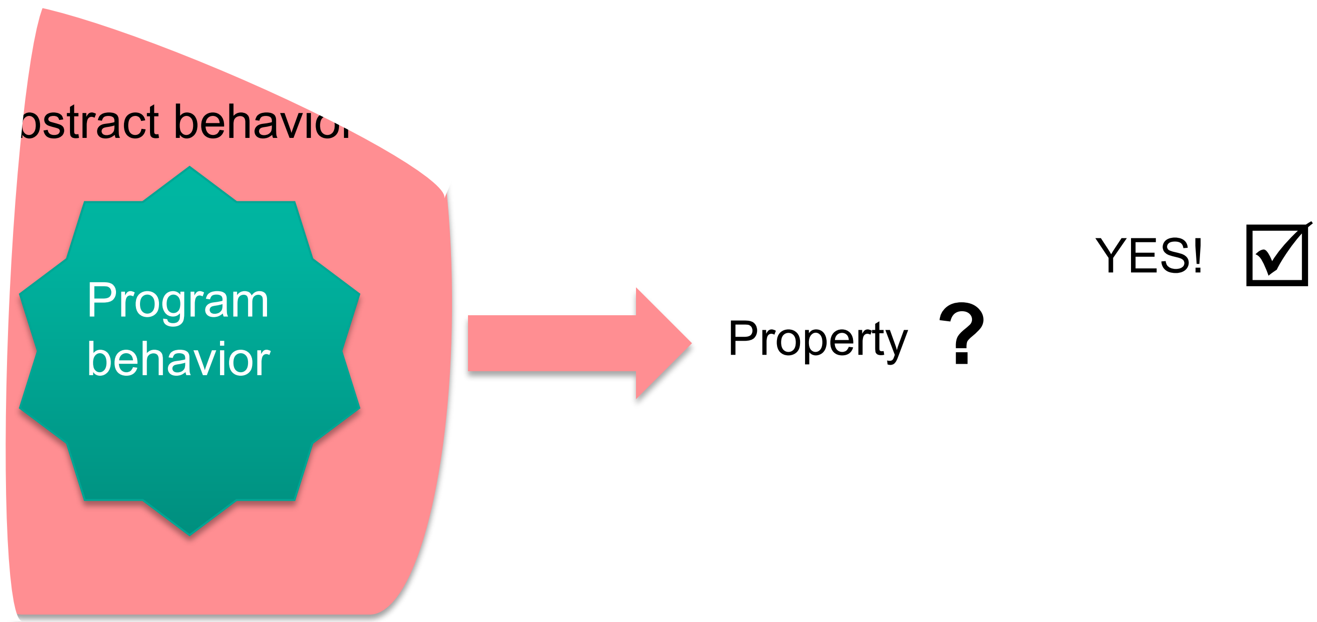
Iterative analysis via feedback loops



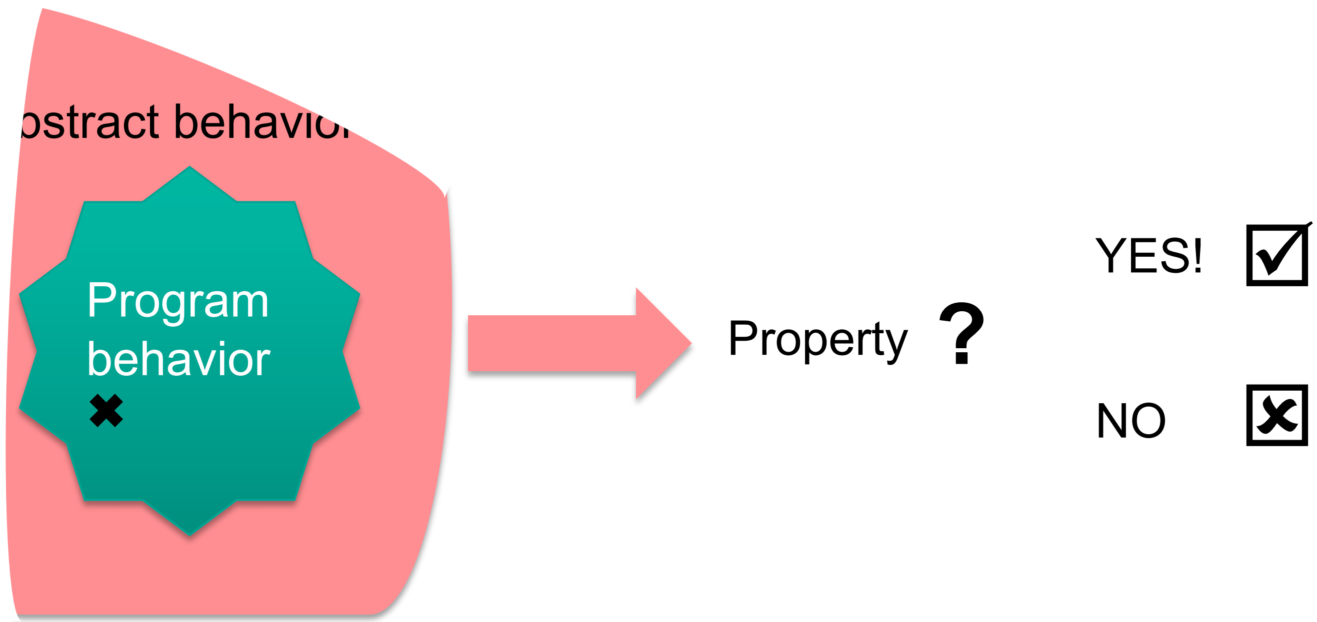
Iterative analysis via feedback loops



Iterative analysis via feedback loops



Iterative analysis via feedback loops



Counterexample-guided Abstraction Refinement (CEGAR)

Alloy

- Invented by Daniel Jackson at MIT in 2000
  - http://alloy.mit.edu/community/
  - Daniel Jackson. *Software Abstractions: Logic, Language, and Analysis. MIT Press. Cambridge, MA. 2012.*
- A modeling language
- Declarative
  - As opposed to imperative
  - Describes the logic of a computation without describing its control flow
  - Example
    - Sorting
  - Common declarative languages
    - Regular expressions
    - Logic programming (Prolog)
    - Functional programming (ML)

Other modeling languages

- JML, OCL
- Larch
  - Developed in 1980s
  - Good for concurrent programs and algebraic datatypes
  - Based on theorem proving
  - Not fully automatic, but good for its time
- Z
  - Based on the simple notions of set theory
  - But even less analyzable than Larch
- SMV language
  - Model checker
  - Checked a billion states in seconds with no aid from user – explicit
  - Formal methods became fashionable overnight
  - Widely used for hardware
  - Language not suitable for structure-rich software

Alloy

- Motivation
  - Brings the SMV-like automation to a Z-like language
- For writing succinct and precise descriptions of
  - Software systems (design level)
    - Pick the right design, implementation follows naturally
    - Check properties before committing to code
    - Build a model incrementally, simulate and check as you go along
  - Program behavior (implementation level)
    - Check properties before delivering the software
- Applications
  - File system analysis
  - Network protocols
  - Course scheduler

Alloy

- Efficient for describing structures
  - Network topology
  - Program data structures
- Can be analyzed automatically
  - Research tool, but very well supported
  - Useful library functions, sample models
- Analysis technique
  - Nothing like model checkers of that time
  - Translates constraints to boolean formulas and uses SAT solver
  - Exploits off-the-shelf solvers
  - Now model checkers translate to SAT too
- Both as
  - Environment for checking correctness by manual modeling
  - Engine for checking correctness by automatic modeling