Static Analysis

ThanhVu Nguyen
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“Program testing can be used to show the presence of bugs, but never to show their absence.” (DJK, 1972)

What is Static Analysis?

Static Analysis

A method for automated reasoning on a representation of program

- **Static**: apply to some static representation (e.g., source code) of a program (in contrast to testing, profiling, or run-time checking)
- **Automated**: "push-button" technology, i.e., little user intervention

Applications

- **Compilers**: optimization (runtime, memory), remove dead code, etc
- **Verification**: verify program correctness

The Dream

Static Analyzer

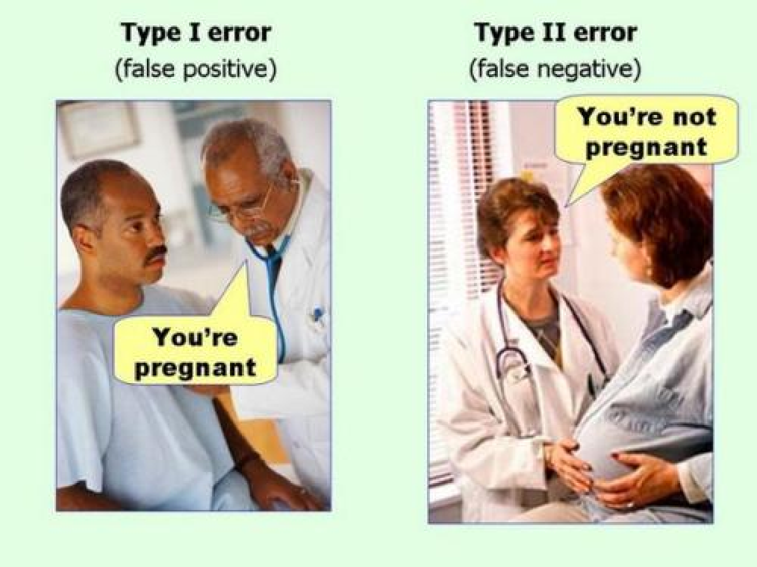
- **Inputs**: program, specifications (pre/post conditions, assertions)
- **Output**: correct/safe (provable), incorrect/unsafe (witness)

Requirements for a Perfect Analyzer

- **Soundness**: don't miss errors (no false negative)
- **Completeness**: don't raise false alarms (no false positive)
- **Termination**: always terminate

Question: is testing sound, complete, or terminate ?

False and True Positives



The Issue

Decision Problems

- Is the program P free of null ptr error?
- Does the program P satisfy given some given specification S?
- Does the program P terminate?

Rice Theorem (1953)

All non-trivial semantic questions about programs from a universal programming language are undecidable.

Approximation / Abstraction

- Example: $x = 42 \subseteq x \geq 40 \subseteq x \geq 0 \subseteq x \in Z$
- Approximate allows decidability and efficiency
- The approximation must still be *sound* , (often) sacrifice *completeness*, should preserve *termination*
- Properties:
  - **Precision**: must still be precise enough to give some *useful* answer
  - **Efficiency**: time/space usage
  - **Scalability**: work with realistic, real world programs

The WHILE language

Category	Domain	Meta variable
Numbers	$Z = \{0, 1, -1, \dots\}$	z
Truth values	$B = \{T, F\}$	t
Variables	$Var = \{x, y, ...\}$	x
Arithmetic expressions	AExp	a
Boolean expressions	BExp	b
Commands (statements)	Cmd	c

Context-Free Grammar of WHILE

$$\begin{aligned}
a ::= \quad & z \mid x \mid a1 + a2 \mid a1 - a2 \mid a1 * a2 \in \mathsf{AExp} \\
b ::= \quad & t \mid a1 = a2 \mid a1 > a2 \mid \neg b \mid b1 \wedge b2 \mid b1 \vee b2 \in \mathsf{BExp} \\
c ::= \quad & \mathsf{skip} \mid x := a \mid \\
& \mathsf{if}\ b\ \mathsf{then}\ c1\ \mathsf{else}\ c2\ \mathsf{end} \mid \\
& \mathsf{while}\ b\ \mathsf{do}\ c\ \mathsf{end} \in \mathsf{Cmd} \mid \\
& c1; c2
\end{aligned}$$

Example of a WHILE program

```
x := 6;
y := 7;
z := 0;
while x > 0 do
  x := x - 1;
  v := y;
  while v > 0 do
    v := v - 1;
    z := z + 1;
    end
end
```