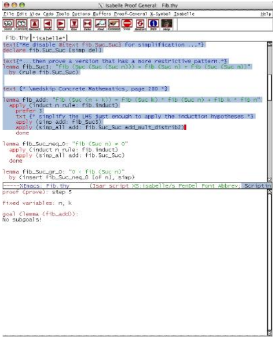
Name: Christian Urban

- I am using theorem provers:

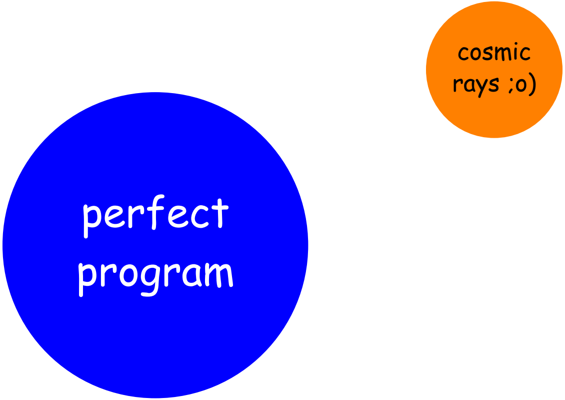


- My goal is to reduce the number of bugs in programs.

Imagine You Are a Perfect Programmer

What can make your program still **not** behave as you intended?

Imagine You Are a Perfect Programmer



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Why Bothering with Compilers?

- Ken Thompson hid a Trojan horse in a compiler **without** leaving any traces in the source code.

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- Assume you ship binary and sources of a compiler.

1) Make the compiler aware when it compiles itself.
2) Add the Trojan horse.
3) Compile.
4) Delete Trojan horse from sources.
5) Go on holiday for the rest of your life. ;o)

Why Bothering with PLs?

"I call it my billion-dollar mistake. It was the invention of the null reference in 1965. At that time, I was designing the first comprehensive type system for references in an object oriented language. My goal was to ensure that all use of references should be absolutely safe, with checking performed automatically by the compiler. But I couldn't resist the temptation to put in a null reference, simply because it was so easy to implement. This has led to innumerable errors, vulnerabilities, and system crashes, which have probably caused a billion dollars of pain and damage in the last forty years..." Tony Hoare recently in a talk

Tony Hoare
Turing Award, 1980
(Quicksort)

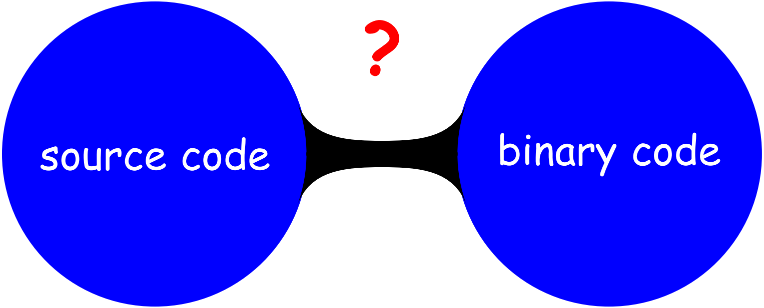
Why Bothering with PLs?

Q: Why bother doing proofs about programming languages? They are almost always boring if the definitions are right.

A: The definitions are almost always wrong.

"Anonymous" cited in B. Pierce's book on Types and Programming Languages

What Do We Have to Do?



What We Have to Do?

- specify precisely which programs we can write (syntax)
- specify precisely what a program means (semantics)
- specify precisely how the compiler translates a program to machine code
- specify precisely what machine code is and how it is executed
- finally check (prove) that the result of the machine code run is what we expect

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- **everything in 2h!**

Simplifying Assumptions

- our language will access the infinitely big memory
- every memory location contains an arbitrary big natural number

- therefore a memory snapshot (a state) is a function from locations to natural numbers

  types

  state = "loc ⇒ nat"

- for example: s 42 = 666

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- for example: s 42 = 666, s′ 42 = 0

Our Language

- Each program is a sequence of commands:

```
datatype cmd =
      SKIP
    | ASSIGN loc aexp        ("_ ::= _ " 60)
    | SEQ   cmd cmd          ("_; _" [60, 60] 10)
    | COND   bexp cmd cmd    ("IF _ THEN _ ELSE _" 60)
    | WHILE  bexp cmd        ("WHILE _ DO _" 60)
```

where aexp and bexp are arithmetic and boolean expressions (in a moment).

for example

WHILE true DO (42 ::= 1; SKIP)

Arithmetic Expressions

- Arithmetic expressions:

```
datatype
  aexp = N nat
       | Op1 "nat ⇒ nat" aexp
       | Op2 "nat ⇒ nat ⇒ nat" aexp aexp
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- What is the meaning of an arithmetic expressions?

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$$\frac{}{\mathsf{N}\ n \longrightarrow_a n}$$

$$\frac{e \longrightarrow_a n}{\mathsf{Op1}\ f\ e \longrightarrow_a f\ n} \qquad \frac{e_0 \longrightarrow_a n_0 \quad e_1 \longrightarrow_a n_1}{\mathsf{Op2}\ f\ e_0\ e_1 \longrightarrow_a f\ n_0\ n_1}$$

Memory Access

- Arithmetic expressions:

```
datatype
  aexp = N nat
       | X loc
       | Op1 "nat ⇒ nat" aexp
       | Op2 "nat ⇒ nat ⇒ nat" aexp aexp
```

$$\frac{}{(N\ n,s) \longrightarrow_a n} \qquad \frac{}{(X\ i,s) \longrightarrow_a s\ i}$$

$$\frac{(e,s) \longrightarrow_a n}{(Op1\ f\ e,s) \longrightarrow_a f\ n}$$

$$\frac{(e_0,s) \longrightarrow_a n_0 \qquad (e_1,s) \longrightarrow_a n_1}{(Op2\ f\ e_0\ e_1,s) \longrightarrow_a f\ n_0\ n_1}$$

How Far We Got

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