CS 3110

Interpreters

Prof. Clarkson

Fall 2018

Today's music: *Step by Step* by New Kids on the Block

CS 4160: Formal Verification

My new course for Spring 2019

An introduction to formal verification, focusing on correctness of functional and imperative programs relative to mathematical specifications. Topics include computer-assisted theorem proving, logic, programming language semantics, and verification of algorithms and data structures. Assignments involve extensive use of a proof assistant to develop and check proofs.

Attendance question

Which sounds more interesting to you?

A. Software engineering
B. Design and implementation of programming languages
C. Mathematical verification of program correctness

The Goal of 3110

Become a better programmer
though study of
programming languages

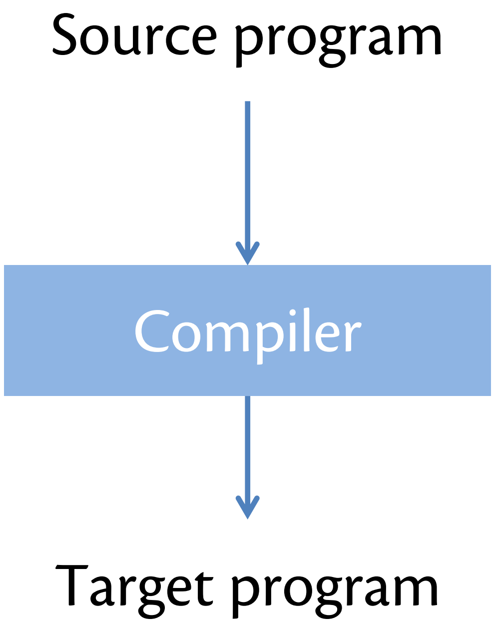
Review

Previously in 3110:

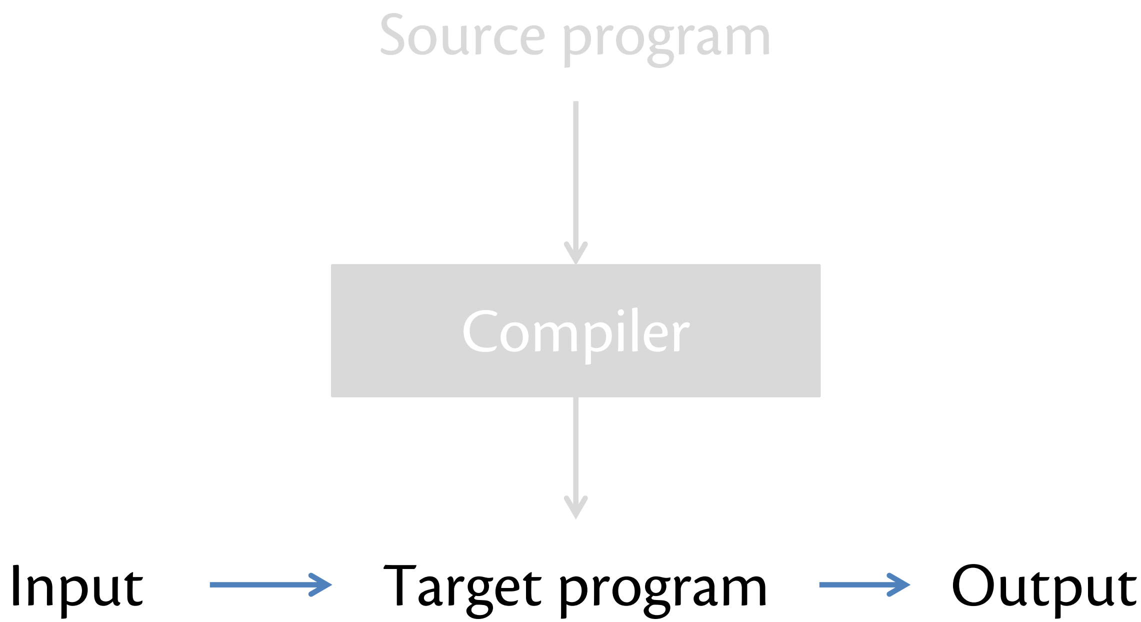
- functional programming
- modular programming
- data structures

Today:

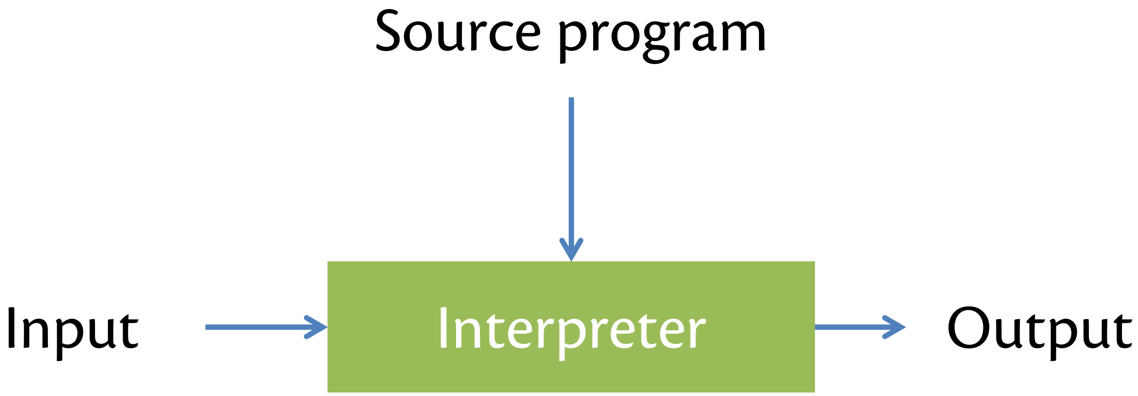
- new unit of course: interpreters



code as data: the compiler is code that operates on data; that data is itself code



the compiler goes away; not needed to run the program



the interpreter stays; needed to run the program

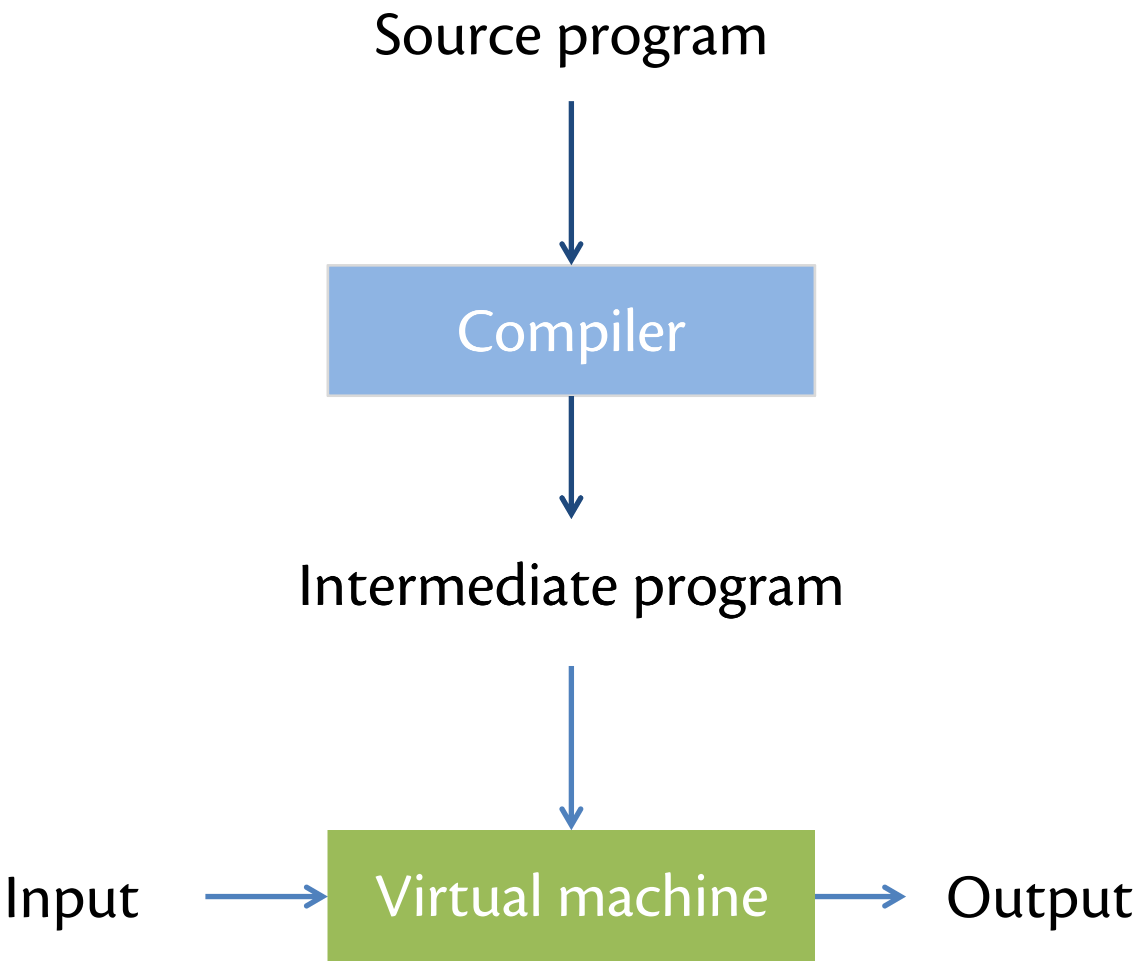
Compilers:

- primary job is *translation*
- better performance

vs.

Interpreters:

- primary job is *execution*
- easier implementation


Source program
Compiler
Intermediate program
Input
Virtual machine
Output

Architecture

Two phases:

- **Front end:** translate source code into *abstract syntax tree* (AST) then into *intermediate representation* (IR)
- **Back end:** translate AST into machine code

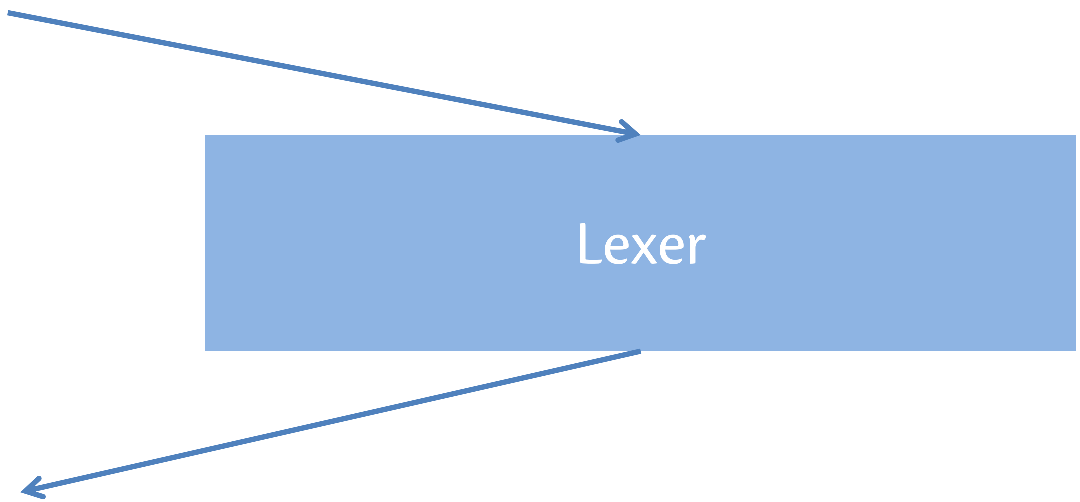
Front end of compilers and interpreters largely the same:

- *Lexical analysis* with lexer
- *Syntactic analysis* with parser
- *Semantic analysis*

Front end

Character stream:

```
if x=0 then 1 else fact(x-1)
```



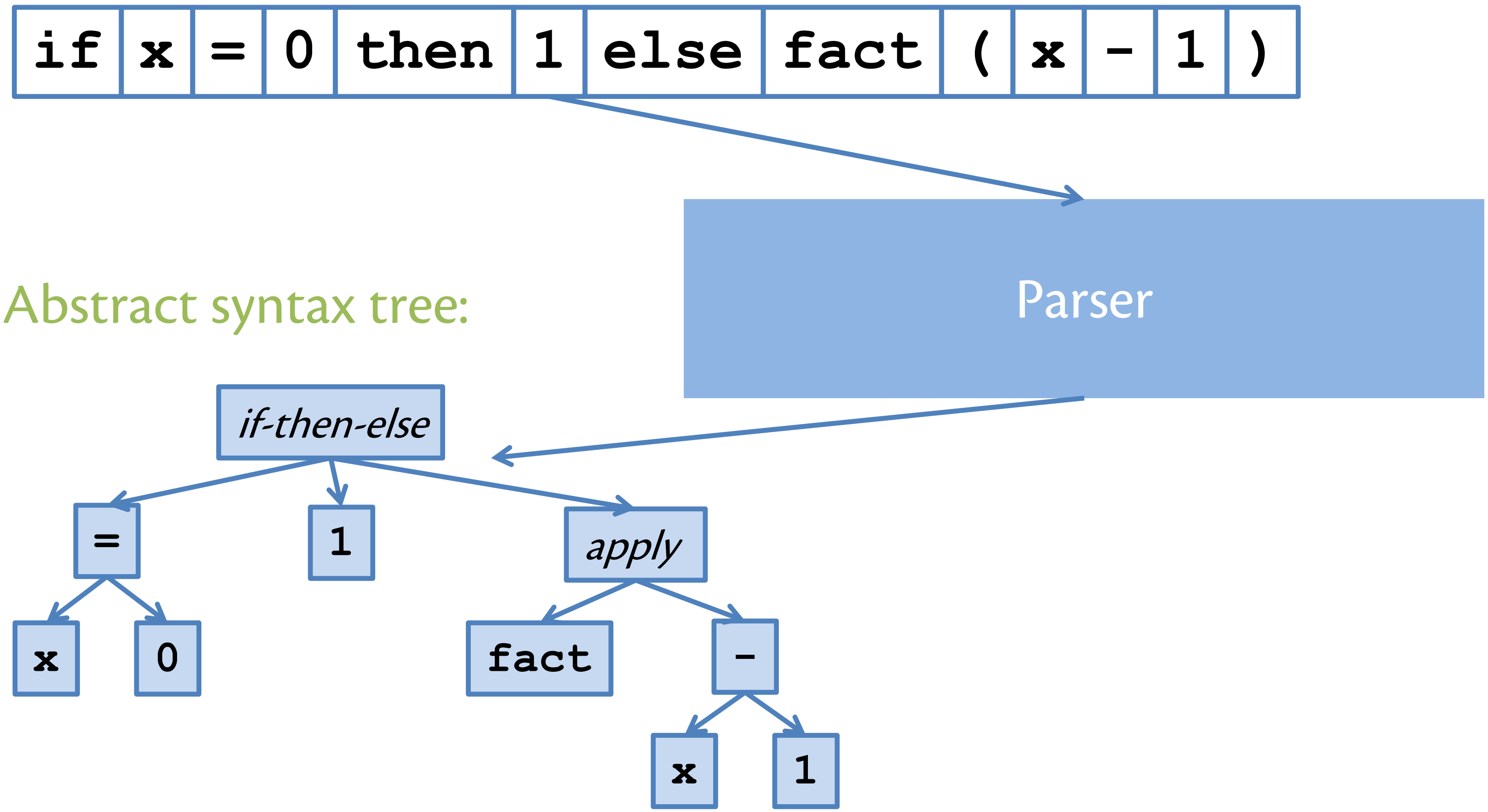
Token stream:

if	x	=	0	then	1	else	fact	(	x	-	1	)

Front end

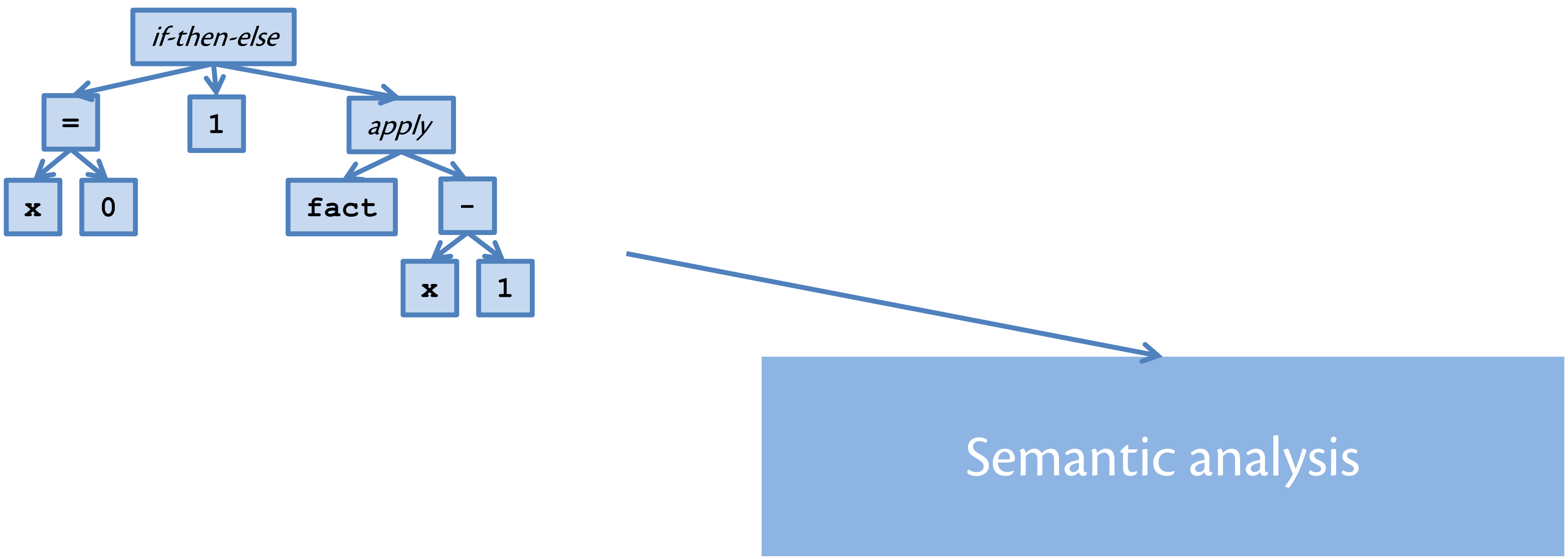
Token stream:

Abstract syntax tree:



Front end

Abstract syntax tree:



- accept or reject program
- create *symbol tables* mapping identifiers to types
- *decorate* AST with types
- etc.

Next

Might translate AST into a *intermediate representation* (IR) that is a kind of abstract machine code

Then:

- **Interpreter** executes AST or IR
- **Compiler** translates IR into machine code

Implementation

Functional languages are well-suited to implement compilers and interpreters

- **Code** easily represented by tree data types
- **Compilation/execution** easily defined by pattern matching on trees

EXPRESSION INTERPRETER

Arithmetic expressions

Goal: write an interpreter for expressions involving integers and addition

Path to solution:

- let's assume lexing and parsing is already done
- need to take in AST and interpret it
- intuition:
  - an expression e takes a single *step* to a new expression e'
  - expression keeps stepping until it reaches a *value*

Demo

Question

```
let rec step = function
    | Int n -> failwith "Does not step"
    | Add(Int n1, Int n2) -> Int (n1 + n2)
    | Add(e1, e2) -> ???
```

A. **`Add(step e1, e2)`**
B. **`Add(e1, step e2)`**
C. **`Add(step e1, step e2)`**
D. **`step e1 + step e2`**

Hint: given (4+5)+(6+7), what should the first step be?

Arithmetic expressions

Goal: extend interpreter to **`let`** expressions

Path to solution:

- extend AST with a variant for **`let`** and for variables
- add branches to **`step`** to handle those
- that requires *substitution...*

`let` expressions [from lec 2]

```
let x = e1 in e2
```

Evaluation:

- Evaluate **`e1`** to a value **`v1`**
- Substitute **`v1`** for **`x`** in **`e2`**, yielding a new expression **`e2'`**
- Evaluate **`e2'`** to **`v`**
- Result of evaluation is **`v`**

$$e\{v/x\}$$

means e with v substituted for x

Substitution

Instead of:

"Substitute **`v1`** for **`x`** in **`e2`**,

yielding a new expression **`e2'`**;

Evaluate **`e2'`** to **`v`**"

Write:

"Evaluate **`e2{v1/x}`** to **`v`**"

Demo

Textbook sections are coming

Upcoming events

- [Sat 8 am]: Peer evals due

This is open to interpretation.

THIS IS 3110