Language Translators

Ronghui Gu

Spring 2019

Columbia University

* Course website: https://www.cs.columbia.edu/ rgu/courses/4115/spring2019

** These slides are borrowed from Prof. Edwards.

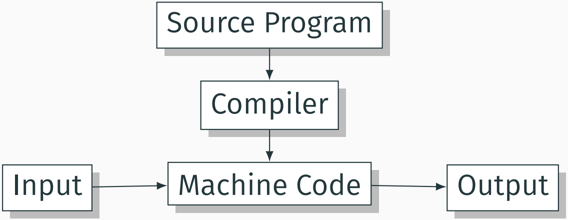
What is a Translator?

A programming language is a notation that a person and a computer can both understand.

- It allows you to express what is the **task** to compute
- It allows a computer to **execute** the computation task

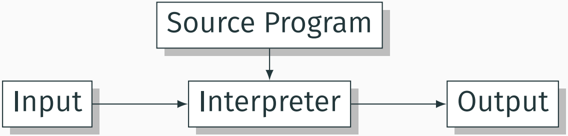
A translator translates what you express to what a computer can execute.

Compiler



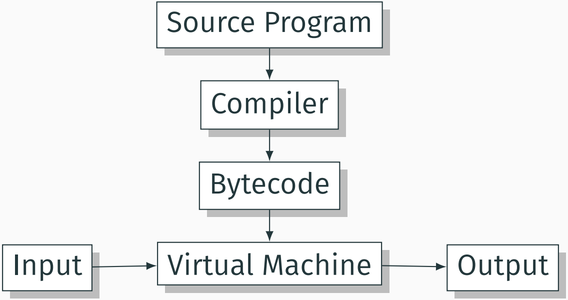
- **Pros**: translation is done once and for all; optimize code and map identifiers at compile time.
- **Cons**: long compilation time; hard to port.

Interpreter



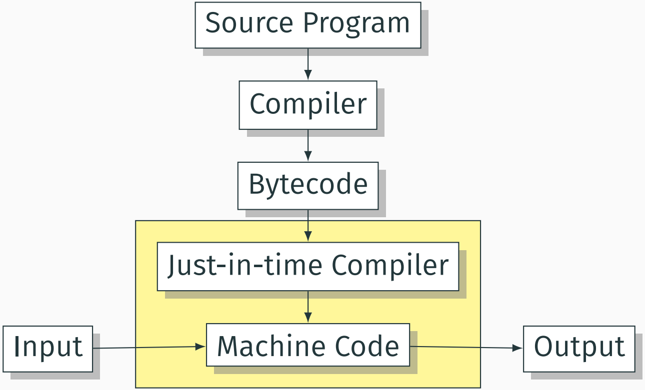
- **Pros**: source code distribution; short development cycle.
- **Cons**: translation is needed every time a statement is executed; lack optimization; map identifiers repeatedly.

Bytecode Interpreter



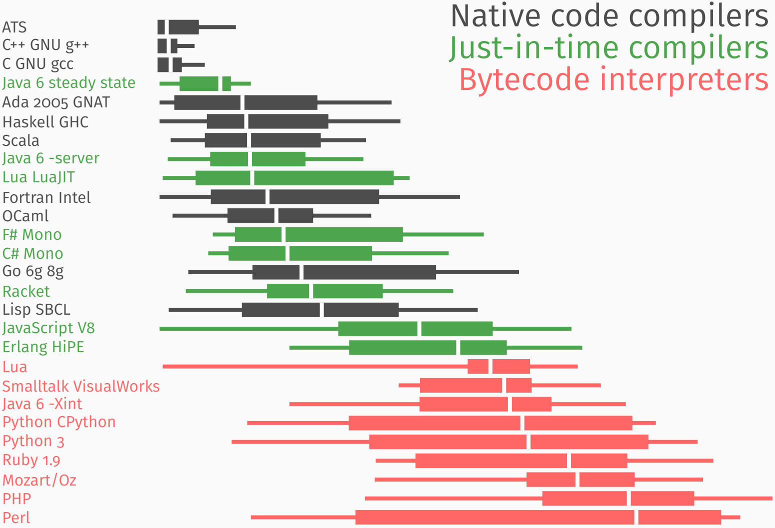
- **Pros**: bytecode is highly compressed and optimized; bytecode distribution.
- **Cons**: compilation overhead + interpreter overhead.

Just-In-Time Compiler



- **Pros**: compile and optimize many sections just before the execution; bytecode distribution.
- **Cons**: compilation overhead + warm-up overhead.

Language Speeds Compared

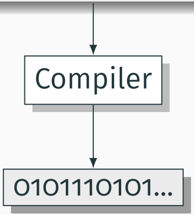


Source: http://shootout.alioth.debian.org/

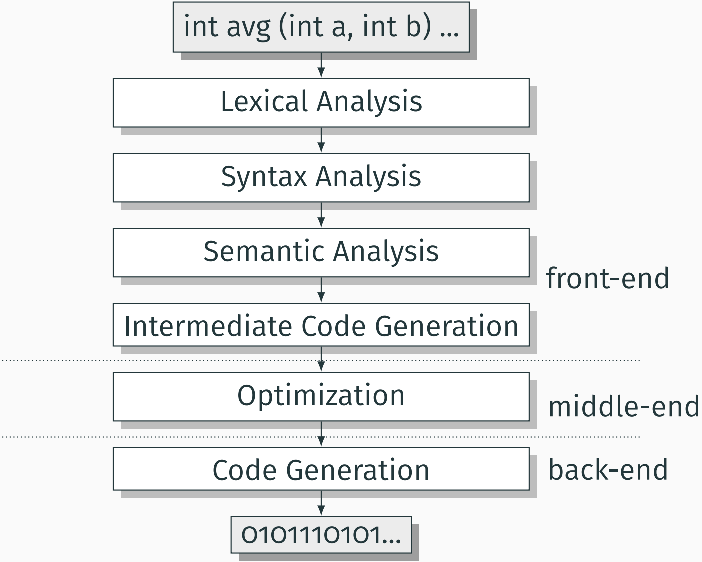
Compilation Phases

Compiling a Simple Program

```
int avg(int a, int b)
{
  return (a + b) / 2;
}
```



Compilation Phases



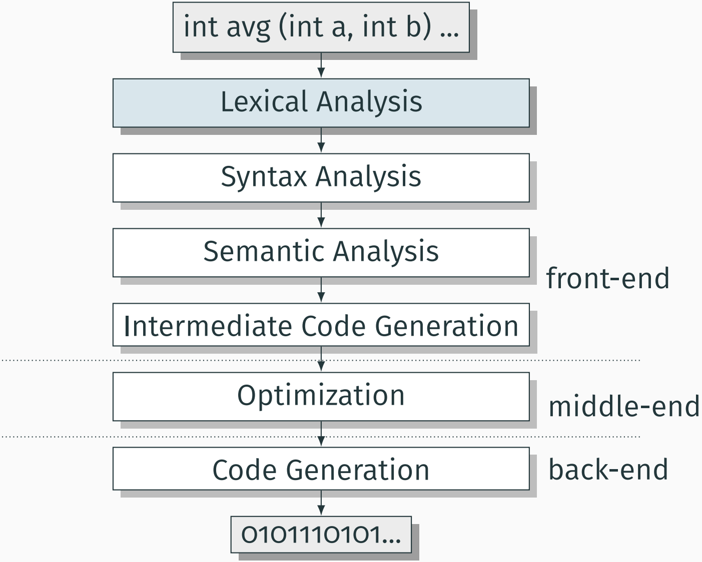
What the Compiler Sees

```
int avg(int a, int b)
{
  return (a + b) / 2;
}
```

i n t SP a v g (i n t SP a , SP i n t SP b) NL
{ NL
SP SP r e t u r n SP (a SP + SP b) SP / SP 2 ; NL
} NL

Just a sequence of characters

Lexical Analysis



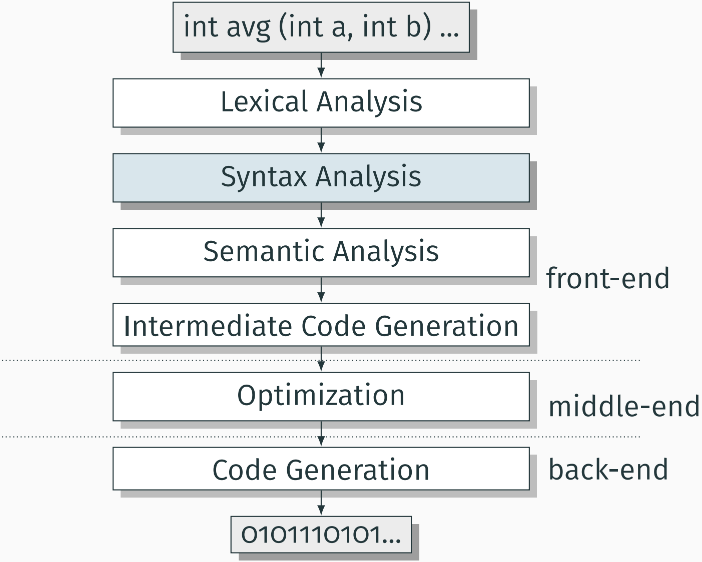
Lexical Analysis Gives Tokens

```
int avg(int a, int b)
{
  return (a + b) / 2;
}
```

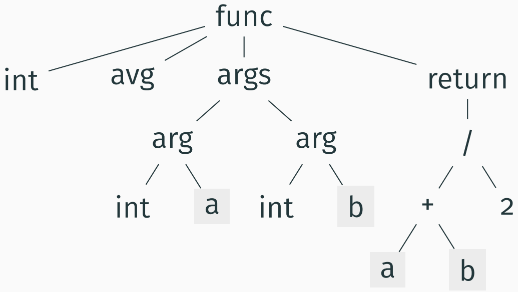
int | avg | (| int | a | , | int | b |) | { | return | (| a | + | b |) | / | 2 | ; | }

- A stream of tokens; whitespace, comments removed.
- Throw errors when failing to create tokens: malformed strings or numbers or invalid characters (such as non-ASCII characters in C).

Syntax Analysis



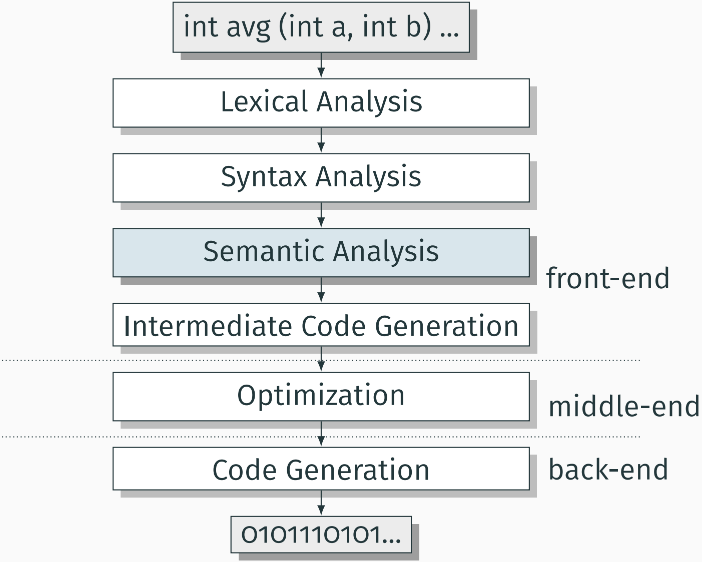
Syntax Analysis Gives an Abstract Syntax Tree



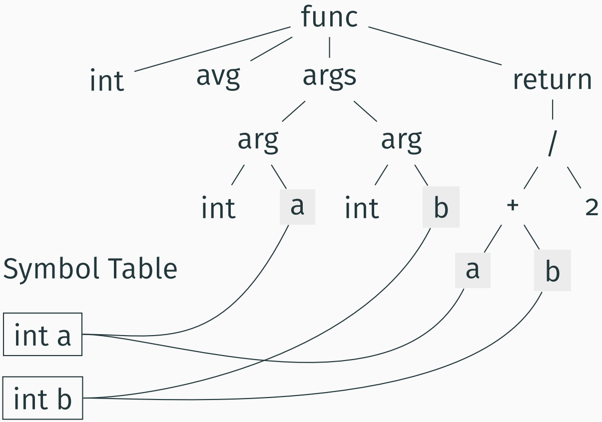

```
int avg(int a, int b)
{
  return (a + b) / 2;
}
```

- Syntax analysis will throw errors if “}” is missing. Lexical analysis will not.

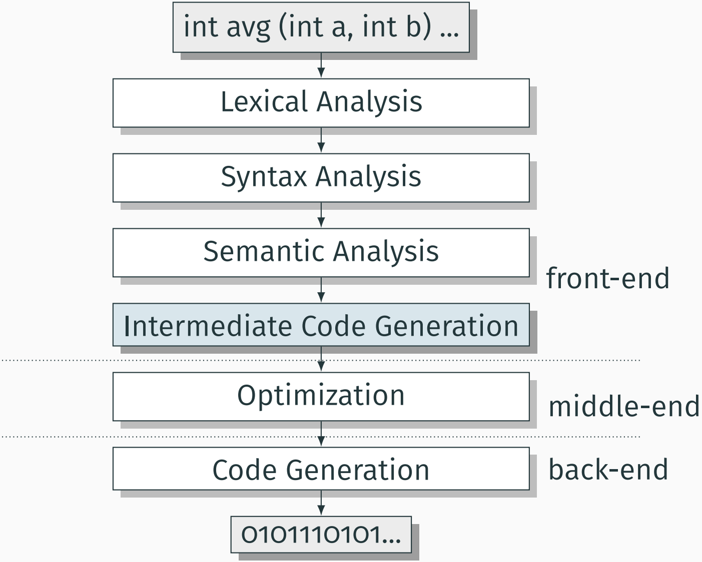
Semantic Analysis



Semantic Analysis: Resolve Symbols; Verify Types



Intermediate Code Generation



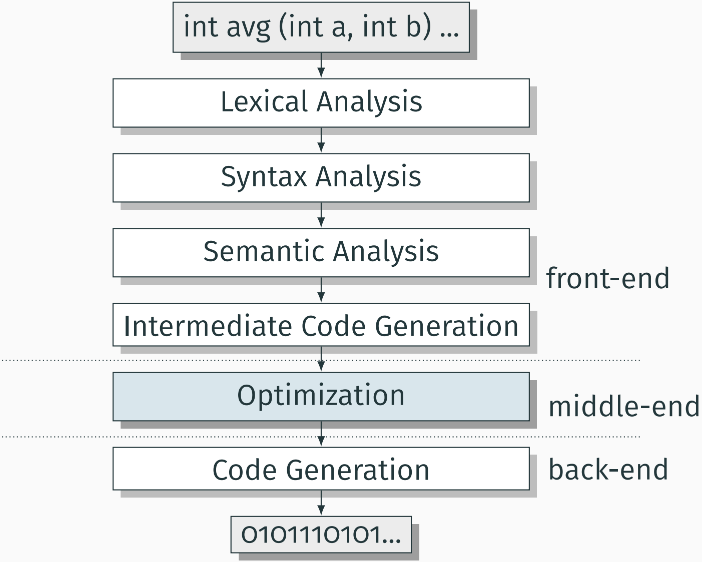
Translation into 3-Address Code

```c
int avg(int a, int b)
{
  return (a + b) / 2;
}
```

Idealized assembly language w/ infinite registers

```
avg:
  t0 := a + b
  t1 := 2
  t2 := t0 / t1
  ret t2
```

Optimization



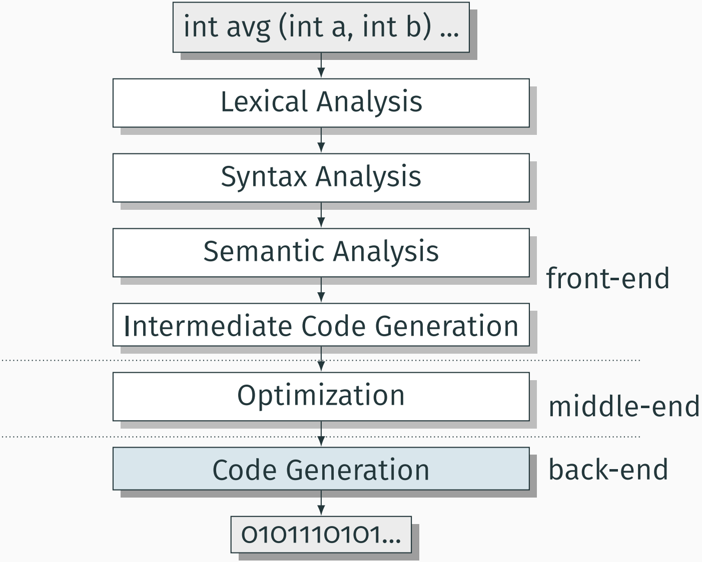
Optimization

```
avg:
  t0 := a + b
  t1 := 2
  t2 := t0 / t1
  ret t2
```

Optimization

```
avg:
  t0 := a + b
  t2 := t0 / 2
  ret t2
```

Code Generation



Generation of x86 Assembly

```
avg:
   t0 := a + b
   t2 := t0 / 2
   ret t2
```

Code Generation

```
avg:   pushl %ebp              # save BP
       movl  %esp,%ebp
       movl  8(%ebp),%eax      # load a from stack
       movl  12(%ebp),%edx     # load b from stack

       addl  %edx,%eax         # a += b
       shr   $1,%eax           # a /= 2
       ret
```