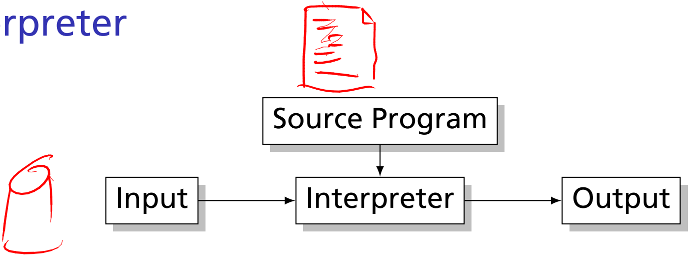
Language Processors

Stephen A. Edwards

Columbia University

Spring 2021

Interpreter



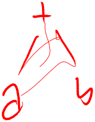
Source Program

Input

Interpreter

Output

c = a + b

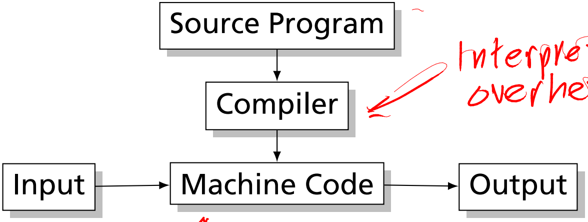


overhead

r=o1 + o2

long

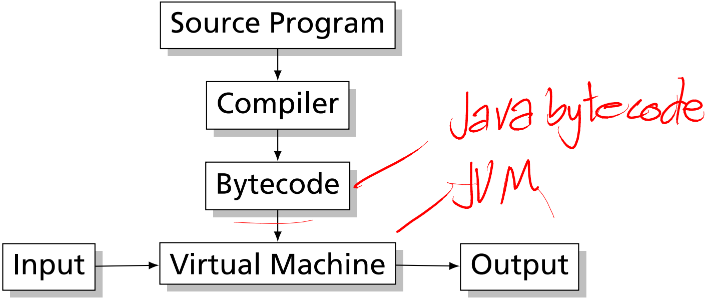
Compiler



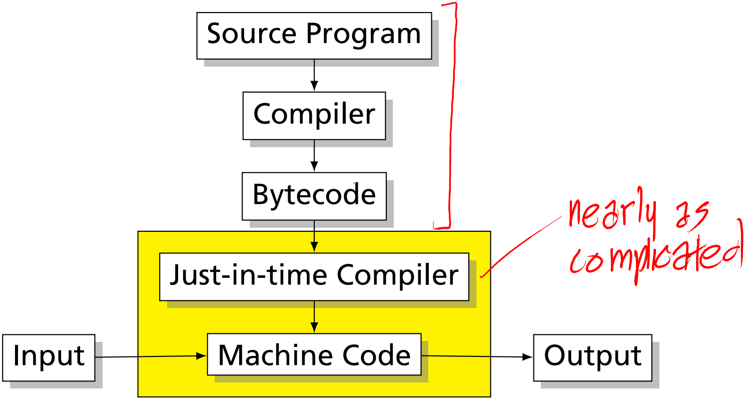
Interpreter overhead

Very processor-specific

Bytecode Interpreter

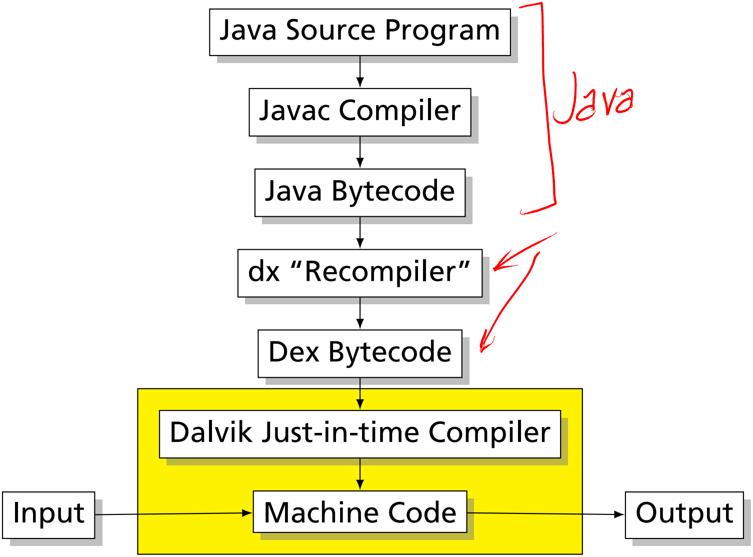


Just-In-Time Compiler

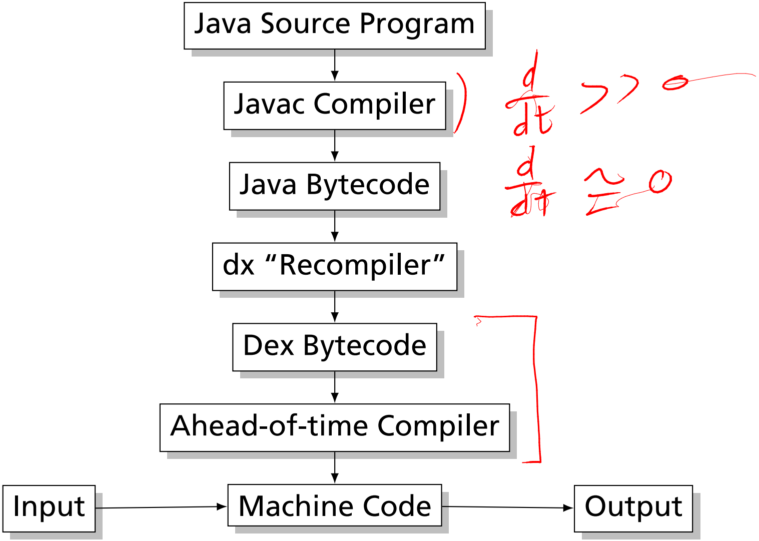


nearly as complicated

Android 4.4 KitKat and earlier



Android 5.0 Lollipop



Java Source Program

Javac Compiler

Java Bytecode

dx "Recompiler"

Dex Bytecode

Ahead-of-time Compiler

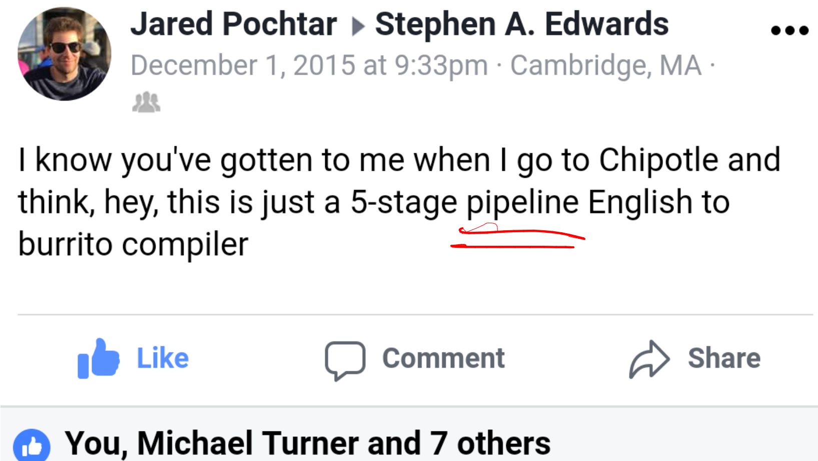
Input

Machine Code

Output

$\frac{d}{dt} \gg 0$

$\frac{d}{dt} \simeq 0$

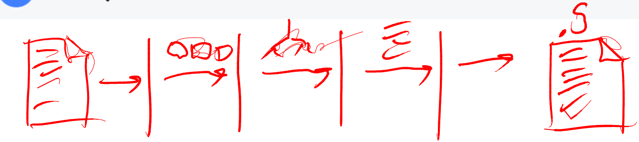


Jared Pochtar ▸ Stephen A. Edwards •••

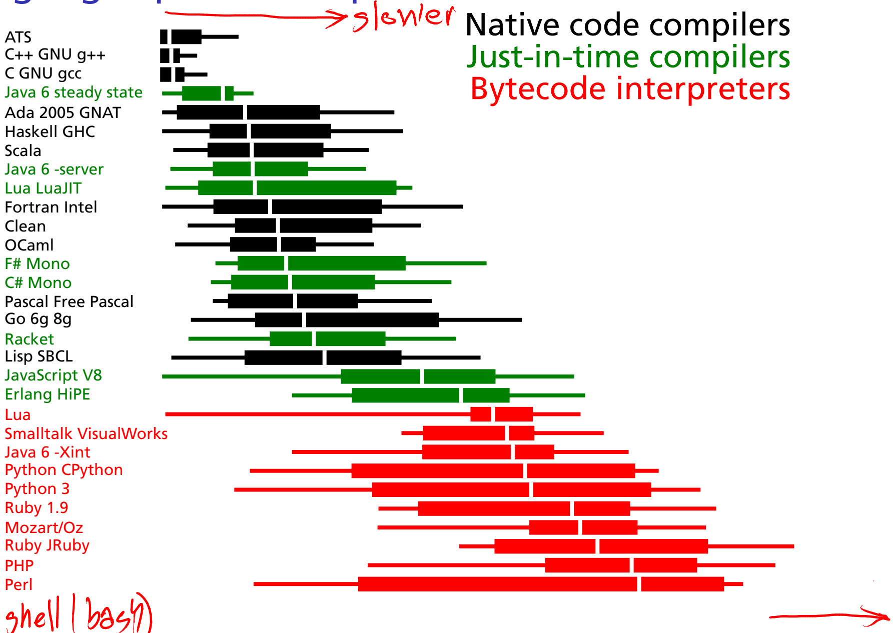
December 1, 2015 at 9:33pm · Cambridge, MA ·

I know you've gotten to me when I go to Chipotle and think, hey, this is just a 5-stage pipeline English to burrito compiler

You, Michael Turner and 7 others



Language Speeds Compared



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

Compiling a Simple Program

```
int gcd(int a, int b)
{
  while (a != b) {
    if (a > b) a -= b;
    else b -= a;
  }
  return a;
}
```

What the Compiler Sees

```
int gcd(int a, int b)
{
  while (a != b) {
    if (a > b) a -= b;
    else b -= a;
  }
  return a;
}
```

```
i  n  t  sp g  c  d  (  i  n  t  sp a  ,  sp i
n  t  sp b  )  nl {  nl sp sp w  h  i  l  e  sp
(  a  sp !  =  sp b  )  sp {  nl sp sp sp sp i
f  sp (  a  sp >  sp b  )  sp a  sp -  =  sp b
;  nl sp sp sp sp e  l  s  e  sp b  sp -  =  sp
a  ;  nl sp sp }  nl sp sp r  e  t  u  r  n  sp
a  ;  nl }  nl
```

Just a sequence of characters

Lexical Analysis Gives Tokens

REs

superflous

```
int gcd(int a, int b)
{
  while (a != b) {
    if (a > b) a -= b;
    else b -= a;
  }
  return a;
}
```

~~#~~ ~~#~~ ~~\n~~ \t\n. . .

int gcd (int a , int b) { while (a

!= b) { if (a > b) a -= b ; else

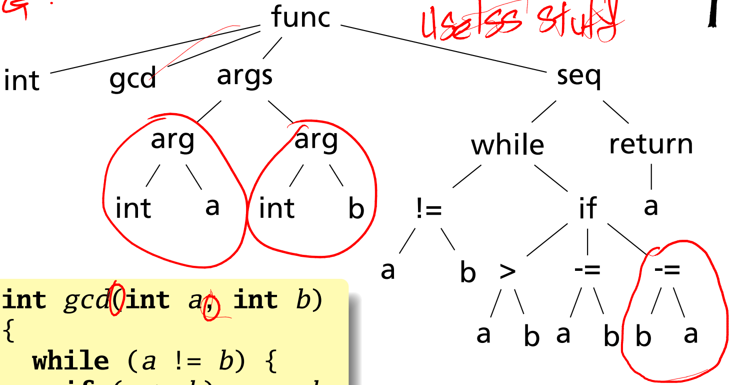
b -= a ; } return a ; }

A stream of tokens. Whitespace, comments removed.

Parsing Gives an Abstract Syntax Tree

CFG .

Throw away useless stuff



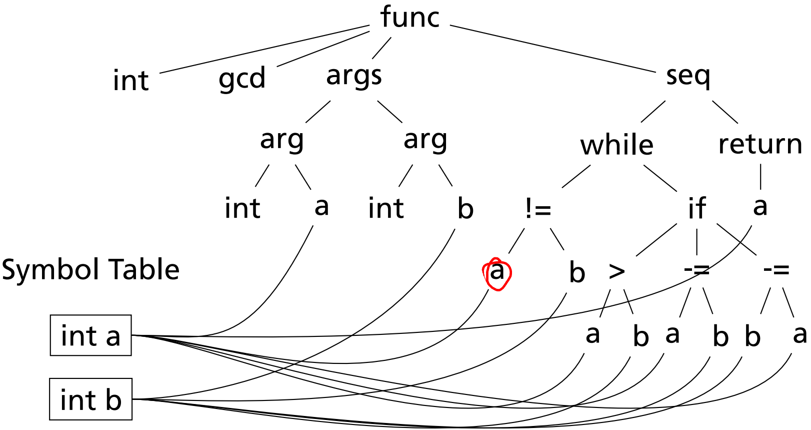
```
int gcd(int a, int b)
{
  while (a != b) {
    if (a > b) a -= b;
    else b -= a;
  }
  return a;
}
```

~~b -=~~

b = b - a

b
a
-= a

Semantic Analysis: Resolve Symbols; Verify Types



a > b

Translation into ~~3-Address~~ LLVM Code

```
L0: sne   $1,  a, b
    seq   $0, $1, 0
    btrue $0, L1     # while (a != b)
    sl    $3,  b, a
    seq   $2, $3, 0
    btrue $2, L4     # if (a < b)
    sub   a,   a, b # a -= b
    jmp   L5
L4: sub   b,   b, a # b -= a
L5: jmp   L0
L1: ret   a
```

both operands

Unbounde #of registers then

test

Else

```
int gcd(int a, int b)
{
  while (a != b) {
    if (a > b) a -= b;
    else b -= a;
  }
  return a;
}
```

Idealized assembly language w/ infinite registers

Generation of 80386 Assembly

```
gcd:  pushl %ebp           # Save BP
      movl  %esp,%ebp
      movl  8(%ebp),%eax   # Load a from stack
      movl  12(%ebp),%edx  # Load b from stack
.L8:  cmpl  %edx,%eax
      je    .L3            # while (a != b)
      jle   .L5            # if (a < b)
      subl  %edx,%eax      # a -= b
      jmp   .L8
.L5:  subl  %eax,%edx      # b -= a
      jmp   .L8
.L3:  leave                # Restore SP, BP
      ret
```

%ea < %edx

%edx

```
int gcd(int a, int b)
{
  while (a != b) {
    if (a > b) a -= b;
    else b -= a;
  }
  return a;
}
```