

Check-In

Review - Parameters

Give an example of a program that would compile under both a pass-by-value and pass-by-reference scheme but gives different output under both.

Or

How does Rice's Theorem generalize the result of the Halting Problem to show that any non-trivial semantic property of a program is undecidable?

Check-In 19 Solution

Review - Parameters

Announcements

Administrivia

ECCS 665 **COMPILER** *CONSTRUCTION*

Runtimes

Previous Lecture

Review - Parameters

Vocabulary:

- lval/rval
- Memory references
- Arguments

Parameter Passing

- Call by value
- Call by reference
- Call by value-result
- Call by name

You Should Know

- What the vocab terms are, how they'd appear in error messages
- The difference between *formal* arguments and *actual* arguments
- The semantic effect of call-by-value and call-by-reference parameter passing schemes



Semantics

Lecture Outline

Runtimes

Runtimes

- Runtime Environments
- The semantic gap (again)
- Interpreters



Semantics



Switching Gears: Targets

Runtime Environments – Setup

Time to look at how code is actually run

- For this we'll need to understand execution systems (runtimes)



Compilers: A Tasty Mix of Disciplines

Runtime Environments - Setup



Front-end:

- Automata theory
- Algorithms



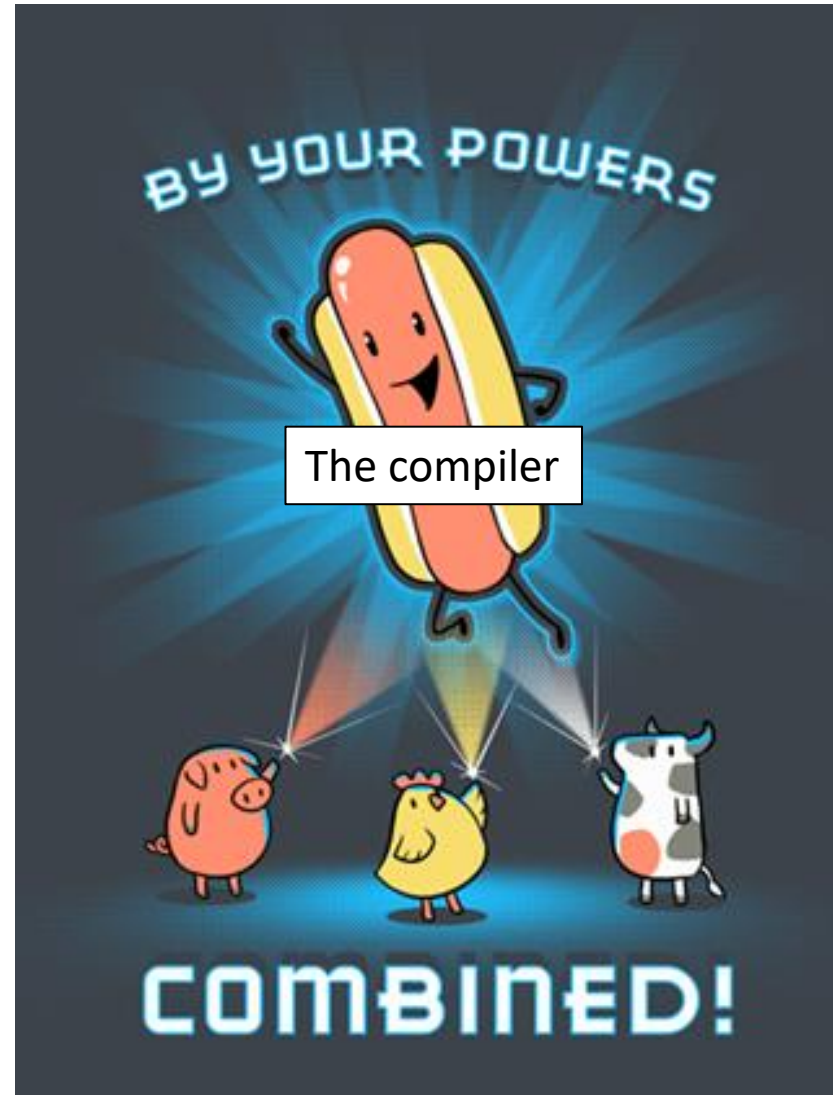
Middle-end:

- Software engineering
- Program semantics



Back-end:

- Emulation
- Architecture



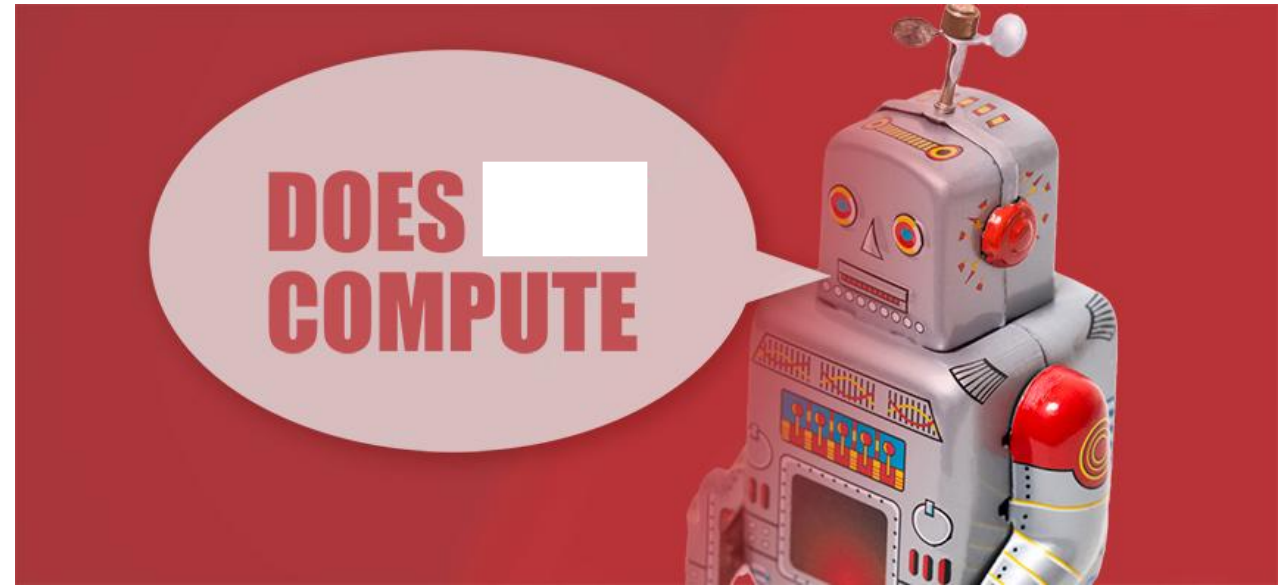
Relation to Compilers

Overview

Compilers job (roughly):

turn something from a non-executable format into
that same thing in an executable format

Hard to pin down!

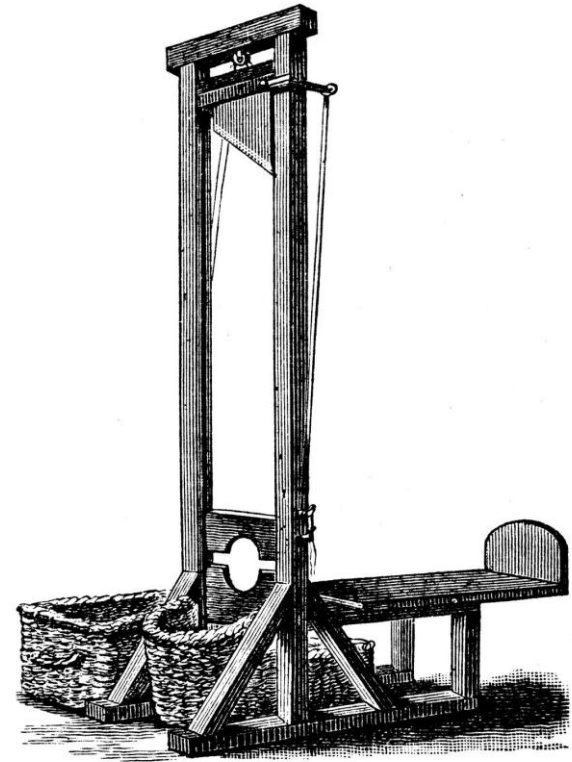


The Tools of Execution

Overview

Stepping back from compilers

What do we need for execute code?



Not this kind of execution!

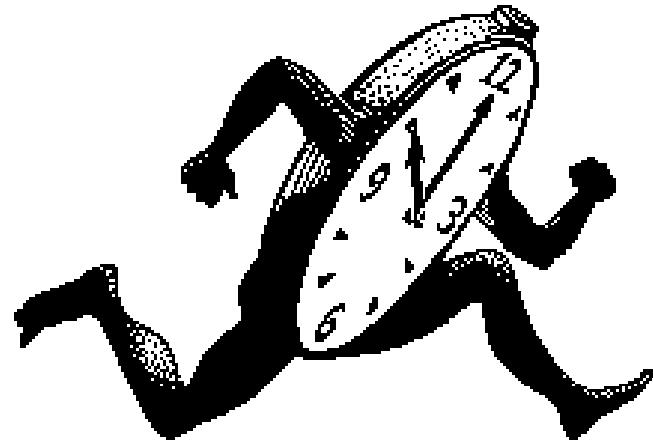
Runtime Environment Working Defn.

Runtime Environments

Underlying software and hardware configuration assumed by the program

- May include an OS (may not!)
- May include a virtual machine

May be co-designed with the programming language



Get it? “Run time”

Some Example Runtime Environments

Runtime Environments

Audience Participation: What are some example languages / runtime environments they provide?

java	erlang /elixir	java script	C++	bash
jvm	beam	browser or nodejs	dynamic linker architecture	shell OS

Wait, why DO we need a Compiler?

Runtime Environments

“Obvious” Answer

- To implement a programming language
- To avoid dealing with target language directly

But is compilation the only option?

- Depends on your definition

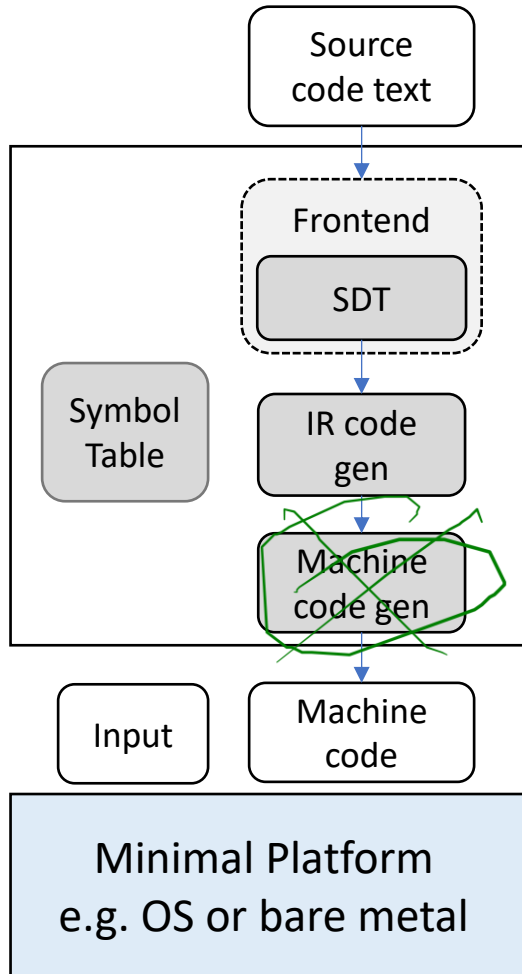


A strawman

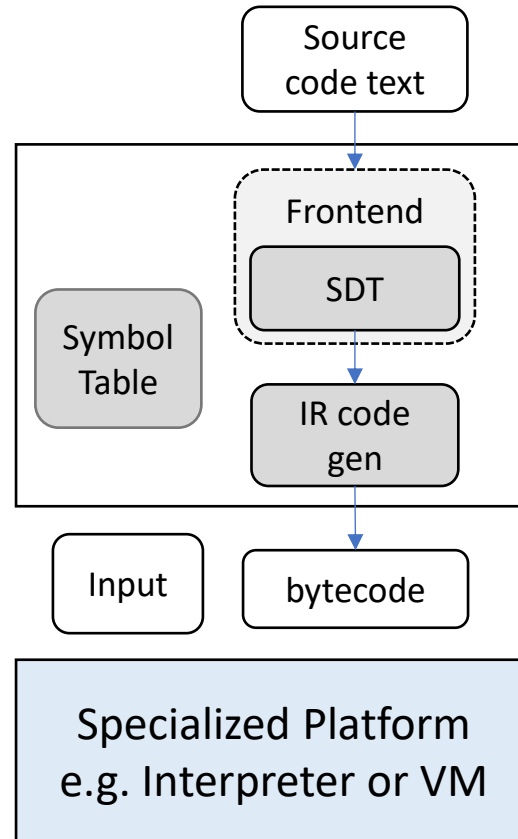
“Alternatives” to “Compilation”

Runtime Environments

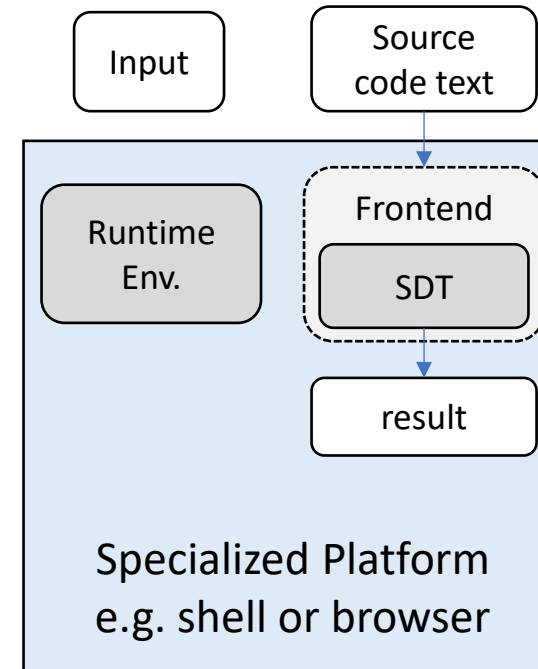
Compiling



Interpreting



Scripting



Defining Compilers

Introduce IRs

Oxford languages dictionary

com·pil·er

/kəm'pīlər/ 

noun

1. a person who produces a list or book by assembling information or written material collected from other sources.

"this passage was revised in different ways by later compilers"

2. **COMPUTING**

a program that converts instructions into a machine-code or lower-level form so that they can be read and executed by a computer.

"conversion would require more than just running it through a different compiler"



Rely on
scripting,
skip compilation

Then Why Compile at All?!?!?!?

Introduce IRs

```
Commence Existential Crisis?  
(y/n)  
>
```

Then Why Compile at All?!?!?!?

Introduce IRs



Rely on
scripting,
skip compilation

Analysis

- Error checking: predict bugs before they strike
- Optimization: generate better code statically



Write target
code directly

Abstraction

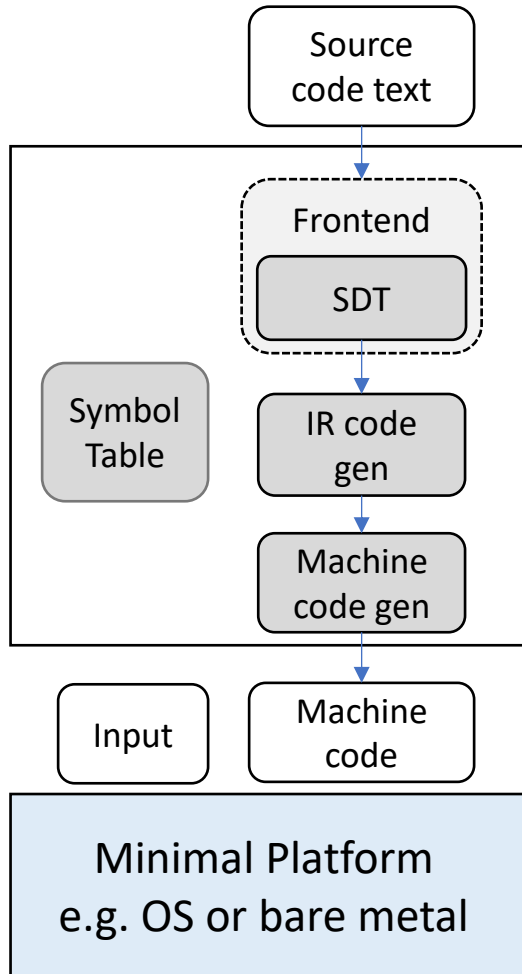
- Allow some distance from the target language

```
Commence Existential Crisis?  
(y/n)  
>
```

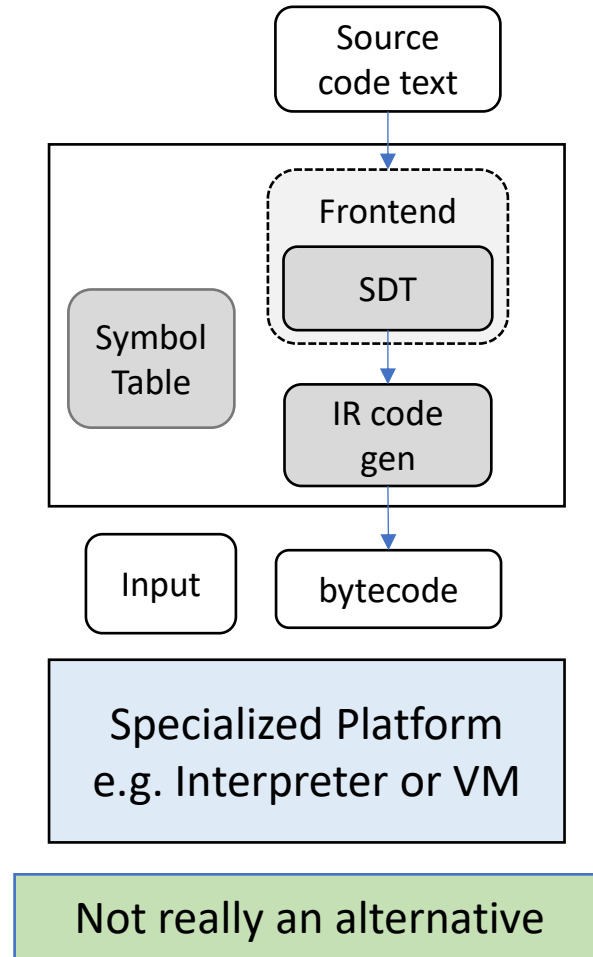
“Alternatives” to “Compilation”

Runtime Environments

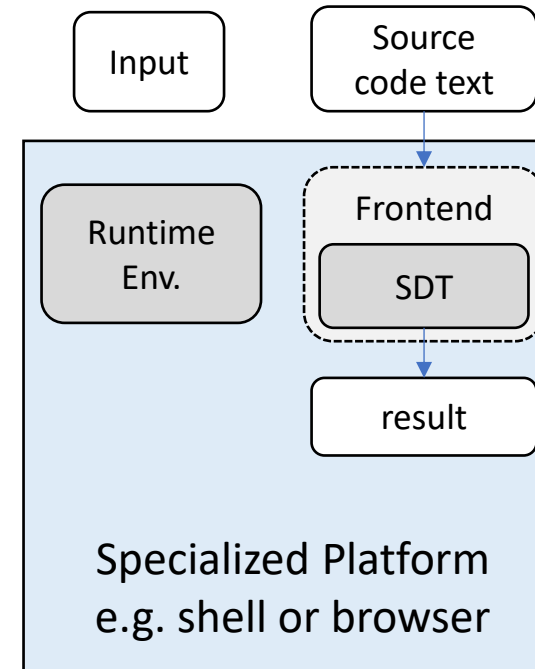
Compiling



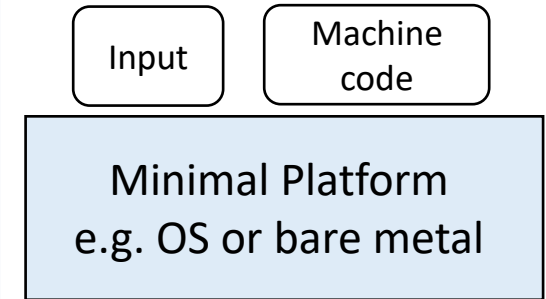
Interpreting



Scripting



Writing target code



Limitations that make large system building impractical

A Wider View of Compilation

Runtime Environments

Our definition

“A translator from source code to target code”

- May alter the source language for tractability
- May (or may not!) manipulate the target runtime for a variety of purposes

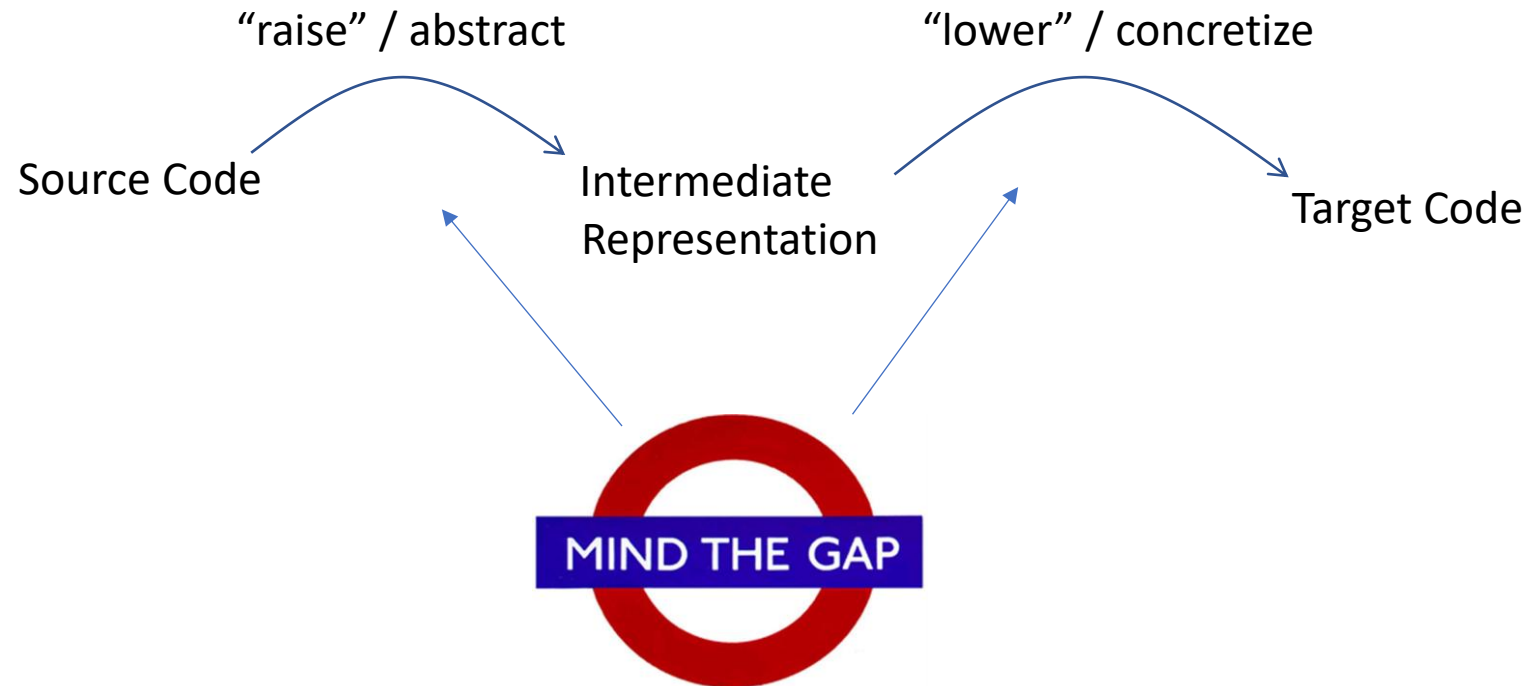


Another Semantic Gap

Runtime Environments

Difference between the specification in IR and executable

- Usually means shedding abstractions to concretize runnable code



Bridging the Semantic Gap

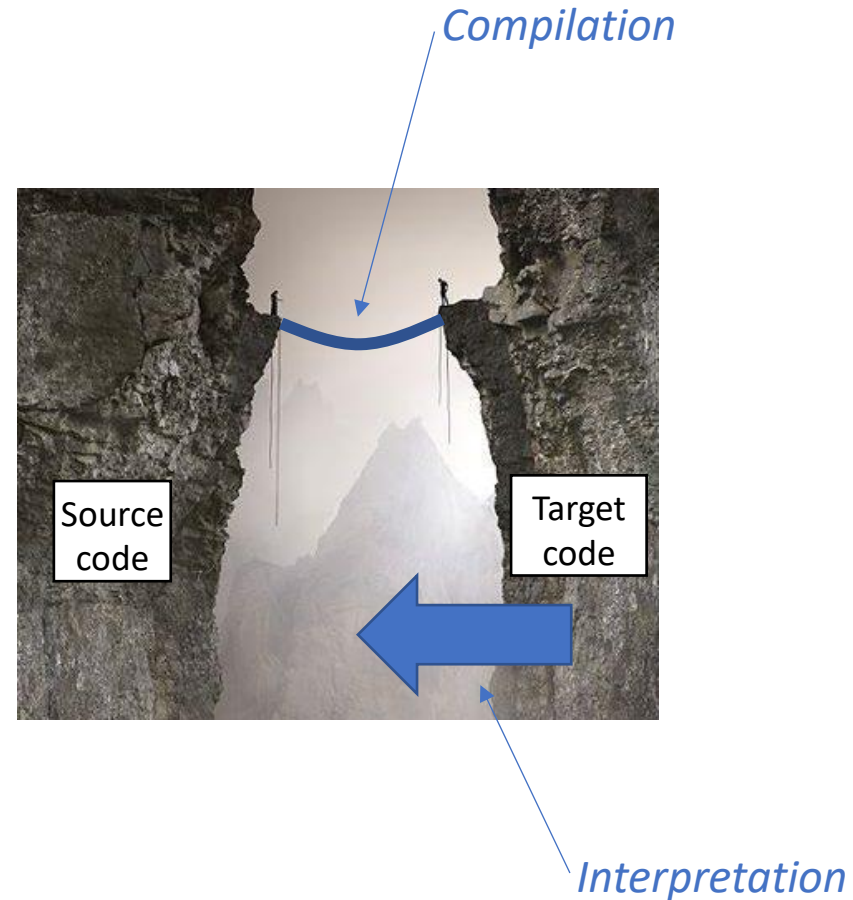
Runtime Environments

We need code that is...

- Easy for humans to understand
- Easy for computers to run

There are various approaches to span this divide

- Build a translator (compiler)
- Move the target (interpreter)



Target Platforms

Runtime Environments

Static workload depends on the platform we target

- Real hardware
- Virtual hardware
- Shell



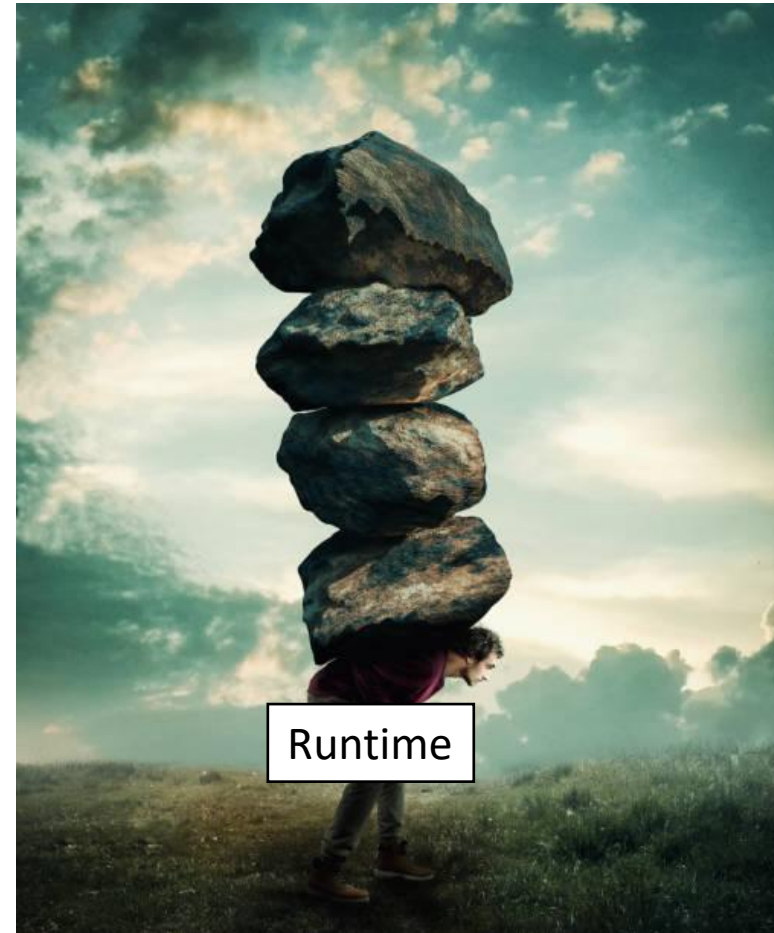
It's a platform!

Heavyweight Runtimes

Runtime Environments

**Interpreted languages often
relegate a lot of work to
their runtime**

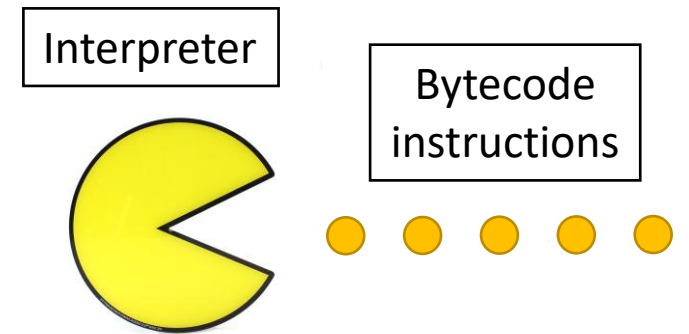
- Why?



Bytecode

Runtime Environments

An executable format that doesn't target hardware!



Mediation Means Checking

Runtime Environments

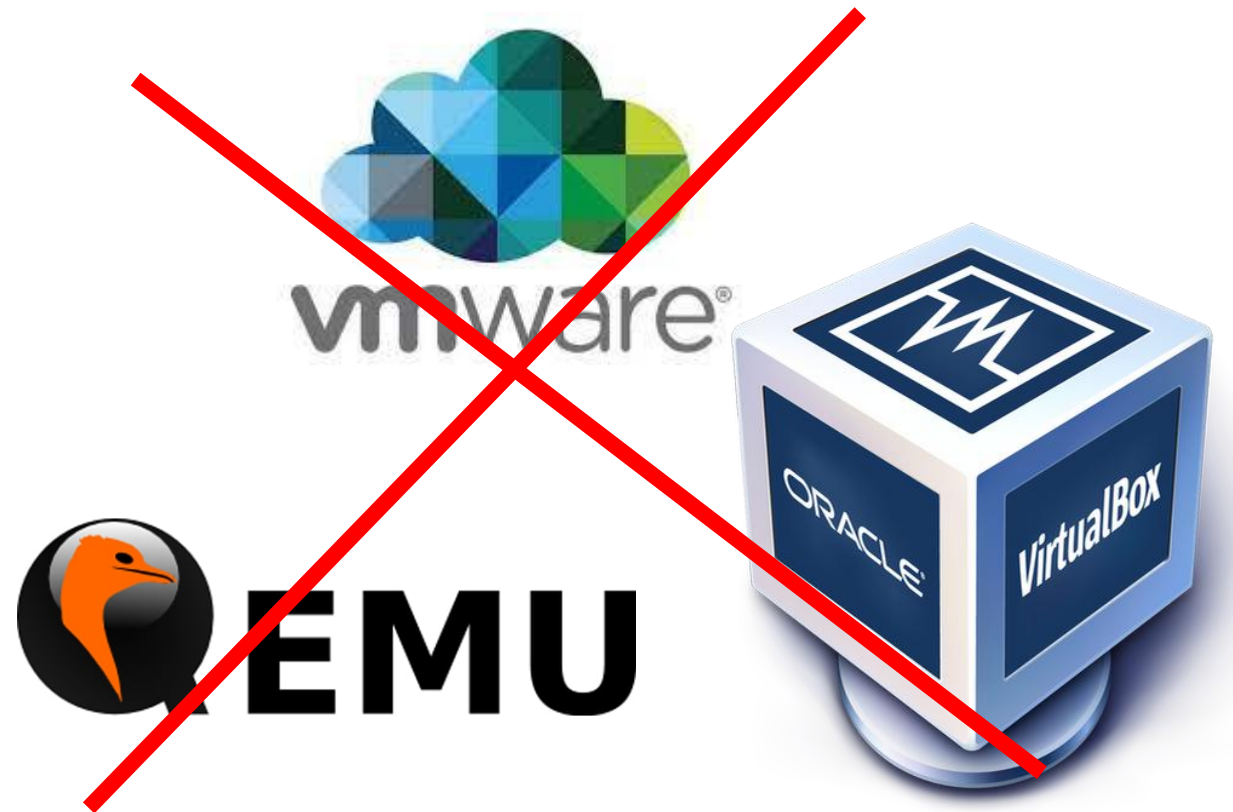
**Many safety checks cannot
be done until runtime**



Virtual Machines

Runtime Environments

Provide a runtime environment for the abstract instruction set!



Less ambitious than whole-system virtualization

Lightweight Runtimes

Runtime Environments

Compiled languages often minimize their runtime

- Why?

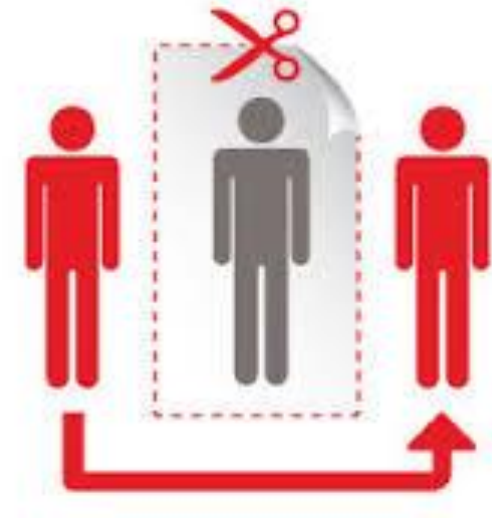


Lighter than a feather!

Mediation is Slow

Runtime Environments

- For the most part, OS does not control program
- Compiler's job to use the environment as best as possible
 - This often means interfacing with the hardware architecture



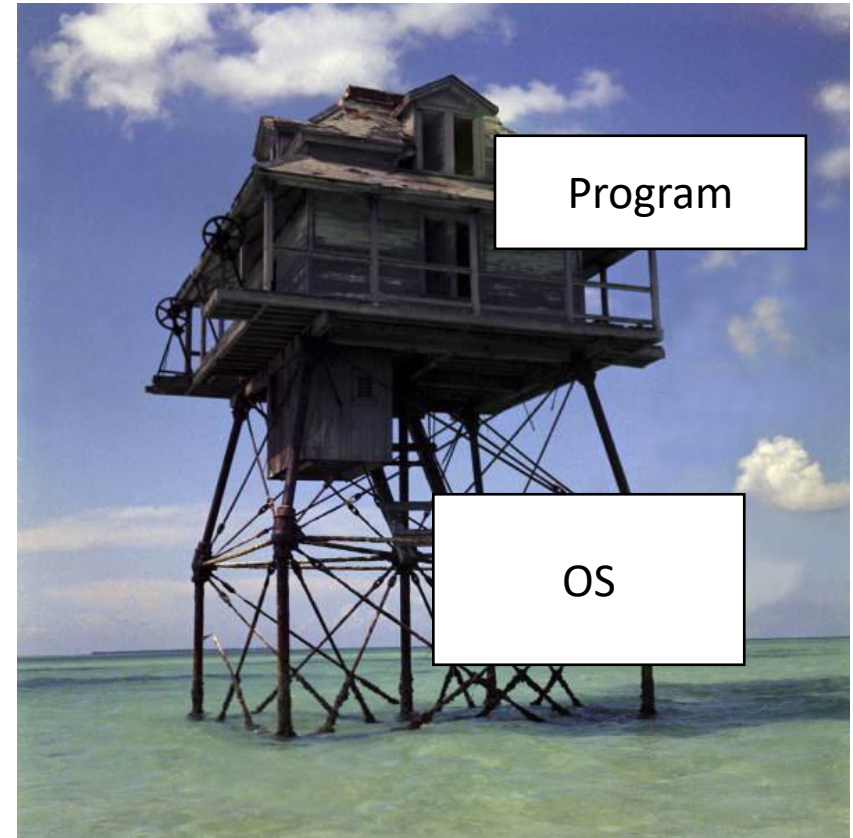
Cuttin' out the middle-man

The Role of the OS/VM

Runtime Environments

Provides a platform for program

- System calls to access hardware
- “Illusion of uniqueness”
- Protects processes and system from each other



Our Language

Runtime Environments

We target machine code for two reasons (beyond the classic reasons)

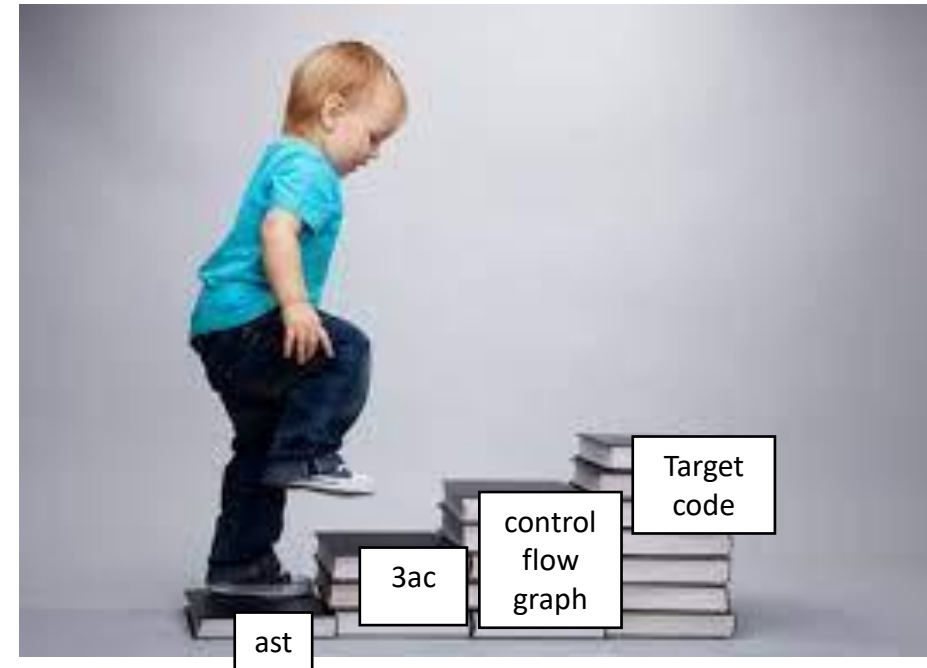
- 1) Discharge the obligation of writing a virtual machine
- 2) Get to learn how X64 code works

Many Steps Towards Target Code

Runtime Environments

Rather than bridging the semantic gap in one step, transform the code in many baby steps

- Encourages modularity
- Accommodate analysis goals



Summary

Runtime Environments – Wrap-up

- Defined runtime environments
 - The implicit dependencies of a program
 - May not be real hardware
- The compilers job is to support program abstractions in the runtime
 - For hardware platforms, these abstractions need to be simulated from memory, registers, and instruction sets
 - For software platforms, the abstractions of the software may be designed to support the language

Next Time

Runtime Environments – Wrap-up

- Talk about intermediate representations more generally
- Begin discussing our next intermediate representation, three-address code

