Compiled & Interpreted Languages

Programming Languages

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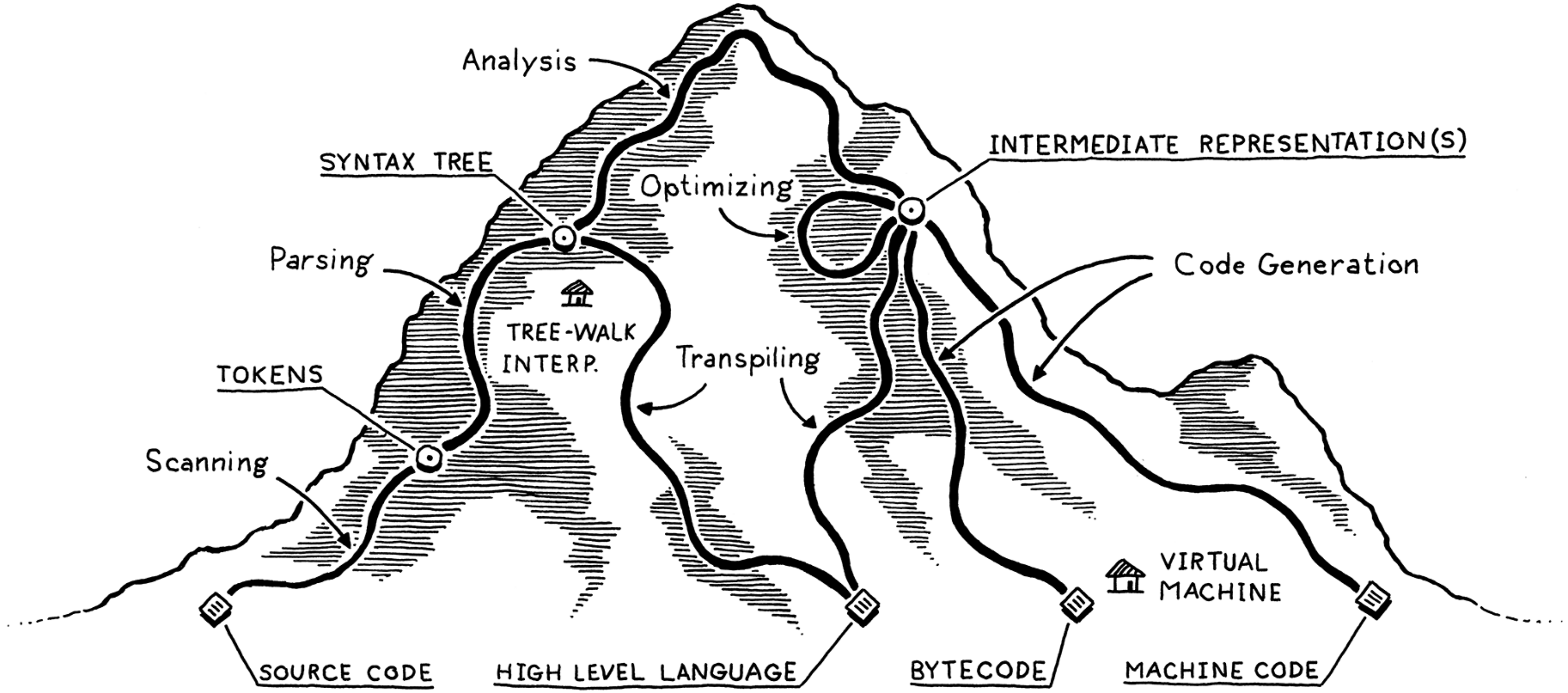
Lecture Outline

- The Language Translation Pipeline
  - Scanning
  - Parsing
  - Analysis
  - Optimizing
  - Code Generation
- Running Your Program
- The Compiler
- The Interpreter

The Language Translation Pipeline

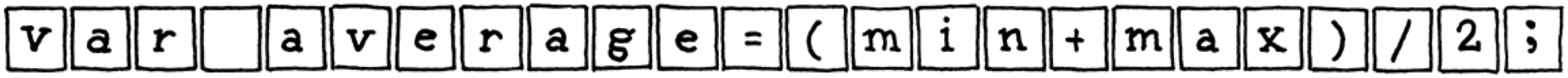
The BIG Picture



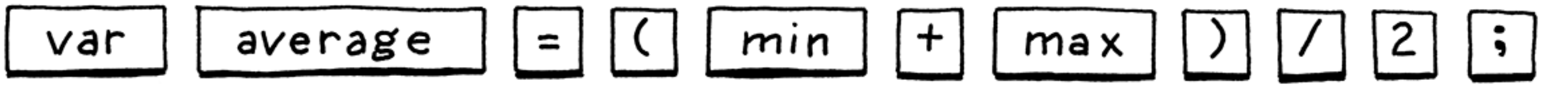
Source: Crafting Interpreters (https://craftinginterpreters.com)

Scanning

- A **scanner** takes in the linear stream of characters and chunks them together into **tokens**

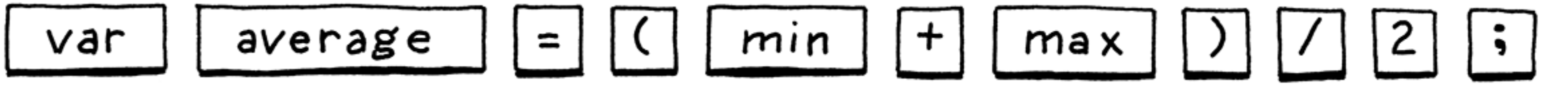


- Some characters don’t mean anything.
  - Whitespace is often insignificant
  - Comments, by definition, are ignored by the language.
  - The scanner usually discards these, leaving a clean sequence of meaningful tokens.

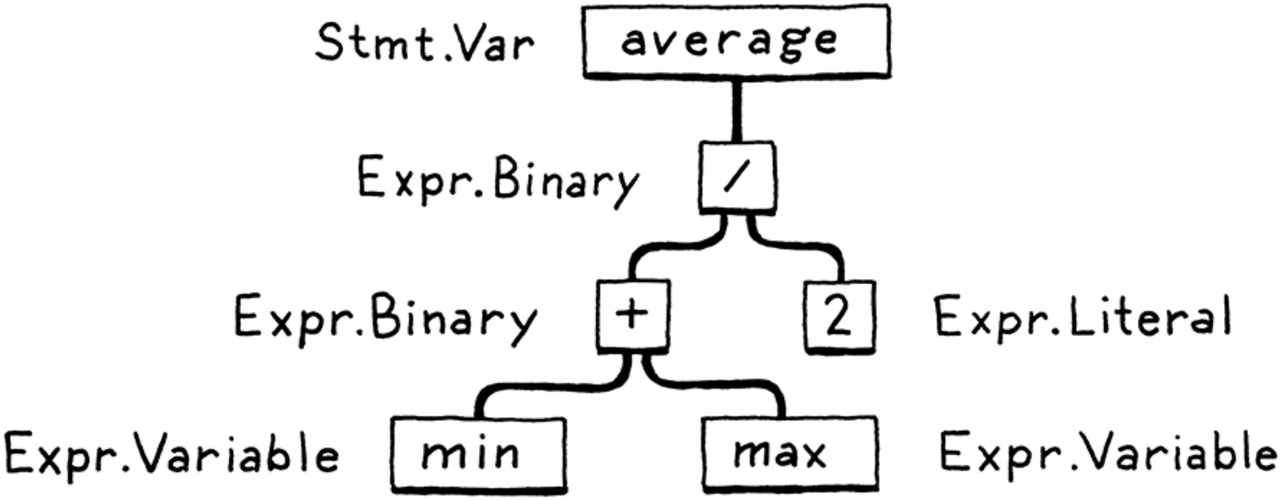


Parsing

- A **parser** takes the sequence of tokens and builds a tree structure that mirrors the ***grammar***.



- Programming language experts call these tree structures **“syntax trees”**, **“ASTs”**, or just **“trees”**



Analysis (i.e. Static Analysis)

- Binding / Resolution
  - For each **identifier** we find out where its <u>name is defined</u> and wire the two together.
  - This is where **scope** comes into play—the region of source code where a name refers to a declaration.
- Type Checking
  - Once we know where <u>names are defined</u>, we can also figure out their **types**. All operations must be valid.
  - If operations aren't supported, we report a **type error**.

Optimizing

- Once we understand what the user's program means, we can "change it"
- Optimizing is a **safe change to the program** that results in the **same semantics** (e.g. has the same behavior)
- The resulting program is usually *more efficient*

```
pennyArea = 3.14159 * (0.75 / 2) * (0.75 / 2);
pennyArea = 0.4417860938;
```

Example: *Constant Folding*

Code Generation

- The last step
- Converting it to a form the machine can run.
  - Usually **primitive assembly-like instructions** a CPU runs and not the kind of “source code” a human reads.
- Do we generate instructions for a real CPU or a virtual one?
  - **Real CPU:** Intel x86, ARM AArch64, IBM PowerPC, MIPS
  - **Virtual CPU:** LLVM IR, Microsoft CIL, Java Bytecode, Python bytecode
    - Advantages: Portable across Real CPUs
    - Disadvantages: Performance penalty

Running Your Program

Two Major Components

- Virtual Machine
  - Only needed for languages that target **Virtual CPUs**
  - Converts from **Virtual CPU** to **Real CPU** at ***runtime***
- Language Runtime
  - Needed by all languages
  - The “extra pieces” required to have a language operate

Virtual Machine

- When you target a **Virtual CPU**, you need a program that converts the *Virtual CPU instructions* to *Real CPU instructions*
- This is done with a **Virtual Machine**
  - A program that emulates a hypothetical chip supporting your virtual architecture at runtime.

Language Runtime

- We usually need some services that our language provides while the program is running.
- Examples:
  - If a language automatically manages memory, we need a garbage collector running to reclaim memory
  - If a language supports **`instanceof`**, then we need to keep track of the type of each object during execution.
- In a compiled language, the code implementing the runtime gets inserted into the resulting executable.
- If the language is run inside an interpreter or VM, then the runtime lives there.

Compilers and Interpreters

Compilers and Interpreters

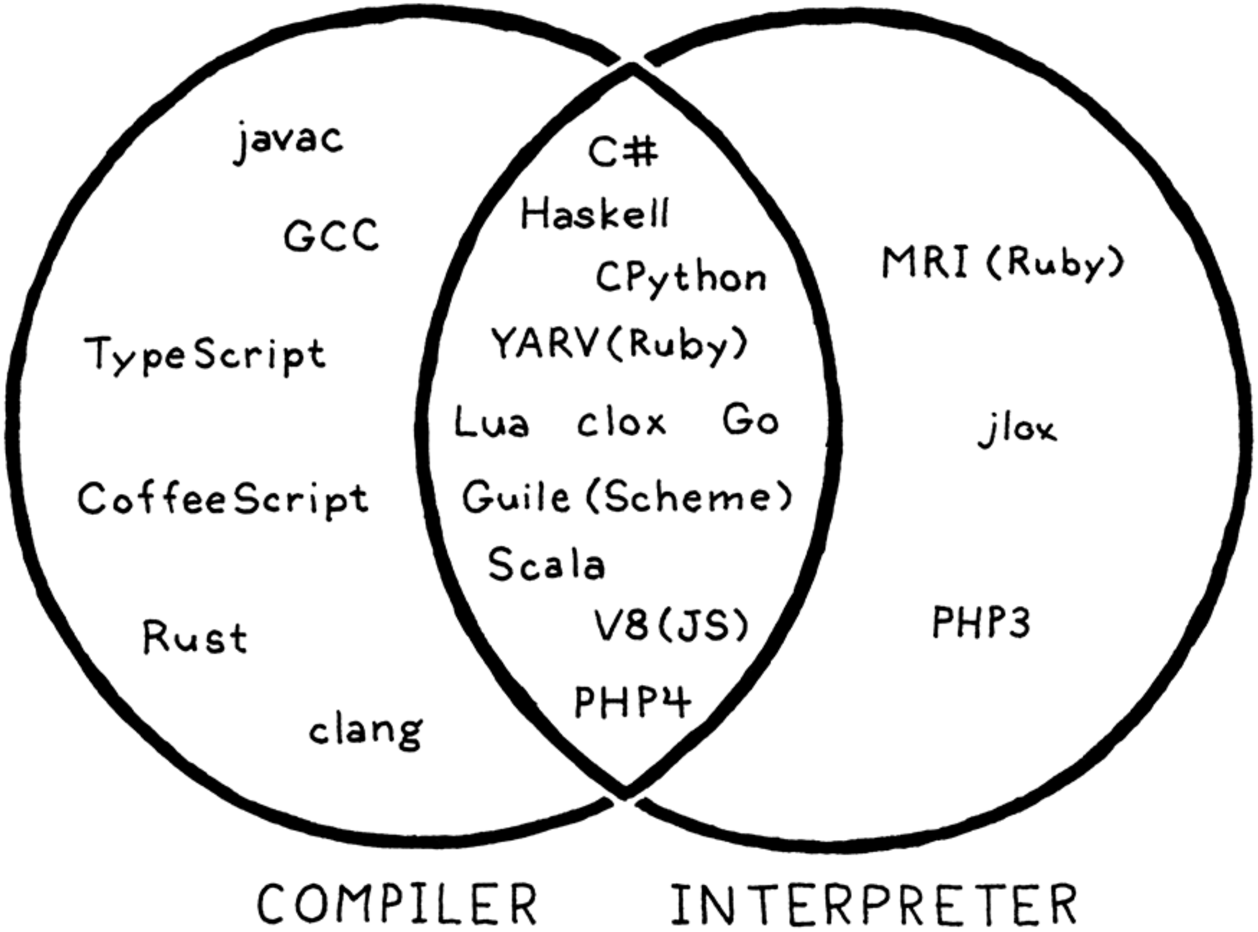
- **BOTH** must perform all stages in the language translation pipeline
- The difference is ***when*** certain stages happen

- What languages do you think are **compiled**?
- What languages do you think are **interpreted**?
- Which languages do you think can be **both**?

Compiled/Interpreted Languages

Language	Compiled	Both	Interpreted
Java			
C / C++			
OCaml			
Javascript			
Python			
C#			

Common Languages



Compiled Languages

- **Compiling** is an *implementation technique* that involves translating a source language to some other form.
  - When you generate bytecode or machine code, you are compiling.
  - When you transpile to another high-level language you are compiling too.
- When we say a **language implementation** "is a **compiler**", we mean it translates source code to some other form but doesn't execute it.

Interpreted Languages

- When we say a **language implementation** is an **interpreter**, we mean it takes in source code and executes it immediately.
- It runs programs “from source”.
- There is no separate entity created

Language != Implementation

- Language Implementations can either be:
  - Compiled
  - Interpreted
- Notice how we didn’t mention a language?
- Statements:
  - I can write an interpreter for C++ (see cling)
  - I can write a compiler for Javascript
  - I can write an interpreter for C#
  - I can write a compiler for ____________
  - I can write an interpreter for ____________

Bonus Video

Interpreters and Compilers (Bits and Bytes, Episode 6)
https://www.youtube.com/watch?v=_C5AHaS1mOA