Programming Language Concepts

Principles of Programming Languages

Colorado School of Mines

https://lambda.mines.edu

Learning Group Activity

With your learning group:

1. Share your code snippets from the assignment. Explain why one language is **inherently** less maintainable, readable, or abstractable in one language than the other for that particular example.
2. Collectively, as a group, either:
    1. create a **great** definition for *expressivity*
    2. *or*, create a **great** explanation for how *expressiveness* differs from (and is similar to) *conciseness*

Prove Them Wrong?

Think that there's a better way to express the problem for a piece of code your group member is showing? Show an example. **Remember to be nice.**

Language Implementation Techniques

Compiled Languages

Advantages:

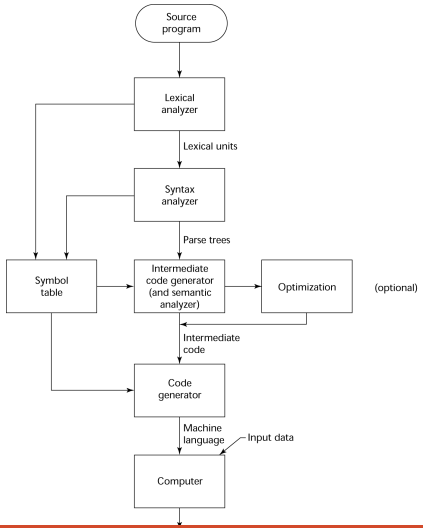
- Runtime is *fast!*

Disadvantages:

- Compile time is slow
- Source code cannot be a part of the input data

Examples

C, C++, and FORTRAN are generally implemented as compiled languages



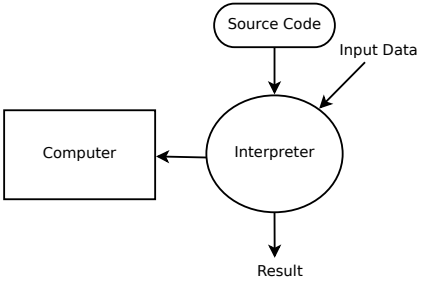
Interpreted Languages

Advantages:

- No need to compile
- Source code *can* be a part of input data: you can transmit functions across the network to be run!

Disadvantages:

- Runtime is slow



Examples

BASIC, PHP, and Perl are generally implemented as interpreted languages

Hybrid Interpreters

To speed up the execution of interpreted languages, implementers started getting clever:

- **Interpreted VM Bytecode:** Input is lexed, parsed, then translated to bytecode. The bytecode gets optimized, then the low level bytecode is interpreted. Examples: Python, Java, Ruby
- **Just In Time Compiler:** Source code is compiled as it's executed, putting machine code on the processor "just in time". Examples: PyPy, LuaJIT, Chrome V8

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Advantages include all the benefits of interpreted languages, with run times occasionally approaching compiled languages.

Evaluating a Programming Language

Evaluation Metrics

Evaluating programming languages based on:

- *Writability:* *How easy is it to write good code?*
- *Readability:* *How easy is it to read well written code? Is the language easy enough to learn?*
- *Reliability:* *What features does the language provide to make sure our code works as it is supposed to?*
- *Feasibility:* *Does an interpreter or compiler actually exist for the platform we need to use? Is it fast enough for our application?*

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A System of Trade-Offs

Often times, adding features which improve one metric can harm another metric. Examples to come...

Simplicity

The overall simplicity of a language plays a large role in both writability and readability.

For example, these features are *non-simple*:

- **Feature Multiplicity:** 👍 Writability, 👎 Readability
- **Operator Overloading:** 👍 Writability, 👎 Readability
- **Large Grammars:** 👍 Writability, 👎 Readability

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Simplicity can be carried too far

Assembly languages and esoteric languages generally aren't considered very writable or readable.

Orthogonality

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Example of a lack of orthogonality (C/C++)

Arrays can contain data of any type, including pointers.
Unless it's a function pointer.
But you can wrap that function pointer in a `struct` and you should be fine.

Impacts of poor orthogonality: poor readability, poor writability, and potentially reduced reliability.

Abstraction

Abstraction: The ability to define and use complicated structures and operations in a way that allows implementation to be ignored.

Examples:

- **Functions:** Simplest form of abstraction. Often taken for granted, but gives us easy recursion.
- **Heap Memory:** Imagine trying to create a large unbalanced binary tree in a single-dimensional array.
- **Generics:** Allows us to define operations that apply to multiple data types without reimplementing for each type.
- **Garbage Collection:** A form of automatic memory management.

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What other kinds of PL-level abstractions can you name?

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Good Abstractions: Writability, Readability, Reliability

Reliability Features

Some languages come with features *designed for reliablitiy*:

- **Type Checking:** Making sure the type of data can be used with the function or operation you are calling. Independent of static/dynamic: more on this later.
- **Exception Handling:** The ability of a running program to intercept run-time errors and take corrective measures.
- **Taint Protection:** Protects the security of an application by not allowing privileged operations to be preformed on tainted data (e.g., user input from a web application).

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Some features can *harm* a language's reliability:

- **Goto:** the ability to jump to different locations in the code without restriction.
- **Aliasing:** allows two different symbolic names (variables, function names, etc.) to refer to the same data. Think pointers in C/C++.

Expressivitiy

With your learning group:

1. If one language is less expressive than another, how might it be less **writable**?
2. If one language is less expressive than another, how might it be less **readable**?
3. If one language is less expressive than another, how might it be less **reliable**?

Be prepared to share your answers with the class.

Typing Systems

Bindings

A **binding** refers to the association between:

- a variable and its type,
- a function and its definition,
- a type and its representation (e.g., `int` is 32-bits),
- or an operation and its symbol (e.g., multiplication is usually *)

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Binding time refers to the time at which a binding takes place.

Common Binding Times
Design time, implementation time, compile time, link time, run time

Static Typing

In a **static typing** system, the binding of a variable to its type occurs *before* run time.

In other words, the type of data is associated with the variable.

```
int x = 12;
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Advantages:

- No need to do type checking at run time, this can be done at compile time.
- 👍 Reliability

Disadvantages:

- Generics are needed to create operations and functions that apply to multiple types
- 👎 Writability

Dynamic Typing

In a **dynamic typing** system, the binding of a variable to a type occurs *during* run time.

In other words, the type of data is associated with the data itself.

```
x = int(12)
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```

Advantages:

- Collections can be of mixed type without generics, functions can take multiple types without generics
- Types can be dynamically created at run time
- 👍 Writability

Disadvantages:

- Type checking must be done at run time; makes things slow
- 👎 Reliability

Untyped Systems

In an **untyped** system, variables are never bound to a type.
In other words, the functions and operations called on the variables determine the type:

```
12 x define
x int->string print-string
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Note

Don't confuse untyped for type inference. Type inference is generally used with static typing systems.

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Advantages:

- No need to do type checking, ever.
- 👍 Feasibility

Disadvanges:

- 👎 👎 👎 Reliability

Strong and Weakly Typed

- **Type safety** means a language will not allow bits to be intepreted as the incorrect data type. For example: treating the bits of an integer as a floating point number.
- **Implicit type conversions** are when a language will automatically convert data types to allow an expression to be computed.
- **Strongly typed** programming languages are both type safe *and* do not allow implicit type conversions.
- **Weakly typed** programming languages are either not type safe *or* allow implicit type conversions.
- Whether a language is strongly or weakly typed has **nothing** to do with whether it is statically/dynamically typed, or compiled/interpreted.

Type Systems: Language Examples

	Strong	Weak
Static	Java, Haskell, Rust, Go	C, C++
Dynamic	Python, Ruby	PHP, JavaScript

End of Lecture: Roadmap

Roadmap

- **Before you leave class**, divide up LGA-02 with your group members.
- I'm going to be in Germany 1/17 thru 1/23. R. Blake Jackson will lecture during this time.
- No office hours on Monday 1/22, as I won't be in the country.
- Your **first quiz** will be Thursday, 1/25. Don't expect it to be too hard.
- Your **first programming assignment** will be due Friday, 1/26 at midnight. I will post the assignment later today.