Language Principles

CSCI 400 – Lecture 1

Colorado School of Mines

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Binding

The Concept of Binding

- **Binding:** an association/mapping
  - Type to variable: `int x`
  - Operation to symbol: `x * y`, `*ptr`
  - Function to definition: `int main() { ... }`
- **Binding time:** time at which binding takes place
- **Bindings** may be
  - *Static* or *dynamic*
  - *explicit* or *implicit*

Possible Binding Times (1)

- *Language design time*
  - Bind operator symbol (e.g. +) to meaning/operation
    - `sum = sum + count`
    - `sum = "Hello" + name`
- *Language implementation time*
  - Bind type to representation
    - `char` $\rightarrow$ 8 bits, etc.
- *Compile time*
  - Bind variable to type
    - `int sum`

Possible Binding Times (2)

- *Link time*
  - Bind library subprogram to code
    - `std::cout << x`
- *Load time*
  - Bind a C `static` variable to memory address
- *Runtime*
  - Bind a non-static local variable to a memory address

Static vs. Dynamic Binding

- A **static** binding...
  1. First occurs *before runtime*
  2. and remains *unchanged* throughout execution
- A **dynamic** binding...
  1. First occurs *during execution*
  2. or it can *change during execution*

Static vs. Dynamic

Static vs. Dynamic: Usage

Show up in various contexts:

- Variable typing
- Variable lifetime
- Variable scope
- Polymorphism
  - Overloaded operators vs. late binding

Not to be confused with ‘static‘ keyword used in OO

Dynamic Type Binding

- Type not specified by declaration
  - Javascript, PHP, Ruby, Python
- Specified through assignment statement
  - `list = [2, 4.33, 10, 15]`
  - `list = 17.3`

Dynamic Type Binding

- Advantages
  - Flexibility (**generics**)
    - e.g. Duck typing
- Disadvantages
  - High cost (**run-time descriptors**)
  - Compiler can miss many type errors

Explore Generics

- Read this:
  - https://en.wikipedia.org/wiki/Generics_in_java
- With a partner
  - Read the definition of a type variable
  - Look at how `List` is defined (section: **Motivation**)
    - What is the type variable? How is it used?
  - Read/understand the `Entry` class (section: **Generic class definitions**)

Explore Generics

- Read this:
  - http://www.tutorialspoint.com/cplusplus/cpp_templates.htm
- Discuss the `Stack` example
- Syntax not important, but understand templates/their purpose

Assume you're desigining a language with dynamic typing

- How would you implement dynamic types?
  - What data structure(s) would you use?
- How does this impact code in this language?
  - Consider *efficiency*, *reliability*
- Now consider challenges with +
  - `total = 3 + 5`
  - `message = "hello " + "world"`
  - `something = "count" + 3 + 5`
  - Would these be a challenge for either a compiler or runtime system?

Dynamic Typing Reliability

Issue

```
i = x # desired, x is scalar
i = y # typed accidentally, y is array
```

- Possibly very difficult to find source of error
- Well-implemented static typing can catch this

Strong vs Weak Typing

Definitions

Definitions of strong/weak typing are not precise.

- **Strong typing**
  - Generally, *compiler error* if value does not meet expected type
  - Dynamically typed language: might be considered strongly typed if type errors are *prevented at runtime*
- **Weak typing**
  - Types can be used interchangeably

Features regarded as 'weaker'

- Implicit type conversations
- Pointers*
- Untagged unions*

*covered later

Type Conversions

- Widening conversions
  - Exact or close-approximation to all of values in original type
  - `byte` → `short` → `int` → `long` → `float` → `double`
- Narrowing conversions
  - Cannot include all values of original type
  - `double` → `float` → `long` → `int` → `short` → `byte`

Type Conversions: Dangerous?

- Widening conversions may lose accuracy
  - 32-bit `int` $\rightarrow$ 32-bit `float` (Lose 2 digits of precision, `float` uses 8 bits for exponent)
- Conversions should be used with care
  - Warnings should not be ignored
- Strongly typed languages minimize implicit type conversions

Implicit Type Conversions

- Language will try to convert types behind-the-scenes if necessary
  - Programmer must be aware
  - Compiler/interpreter should inform programmer
- More implicit type conversions $\rightarrow$ considered more weakly typed
  - C supports more implicit conversions than Java

Explore Implicit Conversions

http://en.cppreference.com/w/cpp/language/implicit_conversion

- Write a line of code that illustrates one of the scenarios
- Section: **Array to pointer conversion**
  - Draw a picture and 1-2 lines of code that illustrate
  - e.g. code might show how to access a value before and after conversion

Explore Implicit Conversions

https://www.securecoding.cert.org/confluence/pages/viewpage.action?pageId=3416

- *Did you know*: C++ will do an implicit conversion if there is a single-arg constructor that will do the needed conversion?

More on Types

Type Safety

- The extent to which a PL discourages/prevents type errors
- **Type error**
  - Erroneous or undesirable program behavior
  - Caused by discrepancy between different data types
  - e.g. passing `int` to function that expects a `string`
- **Type enforcement**
  - *Static:* compile time
  - *Dynamic:* runtime

Explicit vs. Implicit

- **Explicit:** stated by programmer
- **Implicit:** determined by language
- Contexts
  - Type declaration
  - Variable lifetime

Note: These are *not* the same as static/dynamic.

Explicit/Implicit Declaration

- **Explicit declaration**
  - Program statement used for declaring variable types.
    - `int count;`
- **Implicit declaration**
  - Default mechanism for specifying variable types.
- Both create *static bindings* to types
  - Type doesn't change during execution

Implicit Declaration

- Dynamic typing (e.g. Python, Ruby, Lisp)
  - No type annotations
  - Typechecking at *runtime*
  - Writeability at the *cost* of Reliability
- Static type-inference (e.g. Haskell, Rust, OCaml)
  - Optional type annotations
  - *Compiler* type-checks program
  - *Balance* between writeability and reliability

Other Concepts

Keywords vs. Reserved Words

Keyword

- Has a special meaning in a particular context
- Can be used as a variable name
- Older languages
  - Algol, PL/I, Fortran

Keywords vs. Reserved Words

Reserved

- Can't be used as variable name
- COBOL has ~400, Java has ~50
- Advantage: May avoid confusion
- Disadvantage: Awareness of language parts you aren't even using

Keywords vs. Reserved Words

- Potentially valid Fortran:
  - `if if then then else else`
- Java: `goto` is...
  - Reserved (you can't use it)
  - Not a keyword (language doesn't use it)
- Functions in libraries are neither keywords nor reserved words
  - Can sometimes cause confusion

Unconditional Branching

- Transfers execution control to specified place in program
- Topic of one of the most heated debates in 1960s/70s
- Well-known mechanism: `goto`
  - Concern: Readability, reliability (maintenance)
  - Most modern languages do not have `goto`
- Languages with `goto`
  - Assembly languages, C
  - C# – limited to `switch` statements

Links

- Tony Hoare on the harm of `NULL`
  - This page might be kind of confusing – you want the video on the top right
- Edgar Dijkstra on the harm of `goto`