Programming Language Concepts
Type Systems

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- The purpose of **type checking** is to verify that operations performed on a value are in fact permissible.
- *Type checking* cannot prevent all meaningless operations but it catches enough of them to be useful.

Examples of Data Types

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- Primitive data types
- Reference data types
- ADT (abstract data types)

Data Types

What are types good for?

- implicit context,
- checking,
- make sure that certain meaningless operations do not occur.

What Does “Implicit Context” Mean?

When we see a statement such as: `total = num1 + num2;`
are we:

- adding two `int` values, storing in an `int`?
- adding two `int` values, storing in a `double`?
- concatenating a `String` and an `int`, storing in a `String`
- adding an `int` and a `double`, storing in a `double`?

What Does “Implicit Context” Mean?

- If we were writing machine code, WE WOULD HAVE TO SPECIFY THIS, e.g.
    - explicitly convert `int` to `double` before adding to a `double` or storing as a `double`, or
    - have to reserve space for the new `String`, etc.

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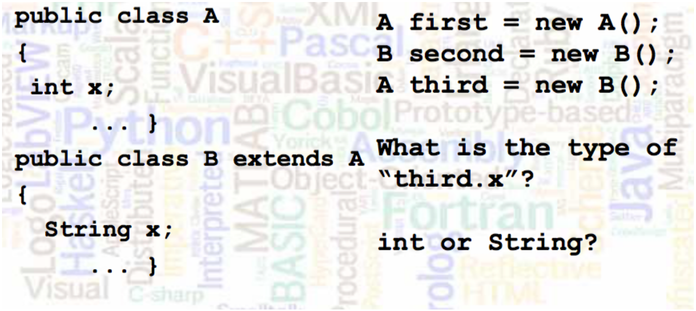
  - have to reserve space for the new `String`, etc.
- Type information gives the compiler or interpreter a context that enables it to figure this out.

What is Polymorphism?

- **Polymorphism** results when the compiler finds that it doesn't need to know certain things.
- In this context we are concerned with situations when the same variable can refer, at different times, to values of different types.
- The most familiar example to Java programmers occurs in subclasses.

Polymorphism



```
public class A
{
 int x;
    ... }
public class B extends A
{
  String x;
    ... }
```

```
A first = new A();
B second = new B();
A third = new B();
```

What is the type of "third.x"?

int or String?

Polymorphism

In Java, a subclass cannot override an instance variable of the parent class; however, it can “shadow it”.
On the other hand, methods CAN be overridden.

Data Types

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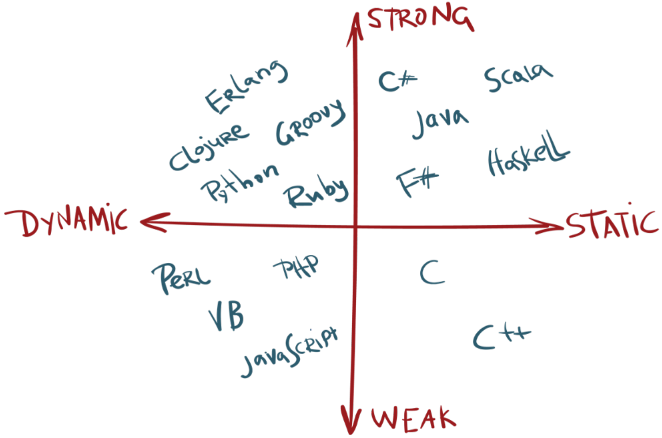
STATIC TYPING
means that the compiler can do all the checking at compile time.

Type Systems: Examples



Credit: Mayank Bhatnagar

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  integer, boolean, char, enumeration, subrange

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- **Scalar types** - one-dimensional
- **Composite types**
  records (unions), arrays, sets, pointers, lists, files

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- Made somewhat obsolete by classes and instances in object-oriented programming.

```
struct rec { /* here we declare the type */
     int i; double x; char s[10];
 };
 struct rec a,b,c; /* declare variables */
 a.i = 10; b.x = 4.14
```

Composite types: Unions

Several values of varying types under a common name and sharing the same memory.

```
union share { /* here we declare the type */
    int i; double x; char s[10];
};
union share a,b,c; /* declare variables */
a.i = 10; /* this changes a.x and a.s also */
```

Composite types: Enumerated types

Symbolic names (actual underlying values not important).

```
enum weekday {mon,tue,wed,thu,fri,sat,sun};
   enum weekday day;
   day = mon;
   if (day < fri) ...
```

Type Systems

A collection of features is **orthogonal** if there are no restrictions on the ways in which the features can be combined

.

- ORTHOGONALITY is a useful goal in the design of a language, particularly its type system.
- It makes a language easy to understand, easy to use, and easy to reason about

Orthogonality Examples

1. *Pascal* is more orthogonal than *Fortran*, (because it allows arrays of anything, for instance), but it does not permit variant records as arbitrary fields of other records (for instance).

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1. *Pascal* is more orthogonal than *Fortran*, (because it allows arrays of anything, for instance), but it does not permit variant records as arbitrary fields of other records (for instance).
2. In *C*, parameters are passed by value, unless they are arrays (which are passed by reference).
3. The most orthogonal programming language is *ALGOL 68*. Every language construct in ALGOL 68 has a type, and there are no restrictions on those types.

Type Checking

A TYPE SYSTEM has rules for:

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A TYPE SYSTEM has rules for:

- **type equivalence** (when are the types of two values the same?)
- **type compatibility** (when can a value of type A be used in a context that expects type B?)
- **type inference** (what is the type of an expression, given the types of the operands?)