To Type or not to Type:

Why is there a Question?

What is Type?

- *Value* and *Objects*...
  - the entities with which we compute
- Types
  - a specification of what can meaningfully be done to, or done by, those Values or Objects
- Examples:

v, w: Integer	⇒ can add v and w
c: Char, v: Integer	⇒ can't add v and c
s: Stack, e: Element	⇒ push e onto s

An older view:

- Types describe data layouts in memory
  - this is essentially the meaning of type in C
- This view of type is deprecated
  - it's important to distinguish between implementation and interface
- In a class-based language
  - The class describes the implementation
  - The type describes the protocol (a.k.a. the interface)

Varieties of Typing

- Most languages compute with typed *values*
  - Tkl, Lisp, Snobol, Csh
  - most machines too (float *vs.* int *vs.* long)
- The distinctions between languages:
  - whether the types of *identifiers* are fixed
  - whether the types of *identifiers* and *expressions* are inferred
  - whether there are checks between the programmer’s intent and the executing code
    - compare Lisp to BCPL (or C)

Typing Expressions

Static

- Types are known and checked at compile time.
  - explicitly typed, *e.g.*, Java
  - implicitly typed, *e.g.*, ML, Haskell

Dynamic

- Types are known and checked at runtime

Whether types are checked

Untyped:

- The programmer is on her own!

Typed:

- syntactic elements of language—the variables and expressions—are assigned types by the programmer and by inspecting the code.
- The *type system* is the set of rules that let us do this assignment, or check the programmer's assignment.

Sample Type Rules

Inference

$$\frac{o\!:\!\mathrm{obj}\{\ldots,\ \phi\!:\!\alpha \rightarrow \rho,\ \ldots\},\ a\!:\!\alpha}{o.\phi(a)\!:\ \rho}$$

Checking

$$\frac{\phi\!:\!\alpha \rightarrow \rho,\ r\!:\!\rho,\ \mathrm{ok}(s_0),\ \mathrm{ok}(s_1),\ \phi = \{s_0;\ s_1;\ \ldots;\ \mathrm{return}\ r\}}{\mathrm{ok}(\phi)}$$

Each language has its own type system

= set of rules for checking and inference

Type Systems

- Type systems exist for languages, logics, inter-operation frameworks (*e.g.*, COM, CORBA)
- "Healthiness condition"
  - When an expression *e* is determined to have type *t* (via the type system, statically) then …
  - when *e* is evaluated (at run time), the resulting value will have type *t*.

e.g., a+b/c

- The subject-reduction property
  - When an expression is “reduced” (*i.e.*, evaluated), the type of the reduced form conforms to the type of the expression
  - In other words: soundness
- Sample Rule applications

a: int
b: int
c: int
div: int x int → rat
plus: int x int → int

plus(a, b): int
div(plus(a, b), c) : rat

Typed and Untyped Languages

Explicitly typed

- all functions and variables are given types (signatures) by the programmer.
  - *e.g.*, Java:

```
Person p;
Student s;
```

Implicitly typed

- all functions and variables are given types by the compiler. The type (signature) is the most general signature that is
  - expressible in the type language
  - consistent with the code that the programmer wrote
- Examples

concat : $\text{int} \times \text{int list} \rightarrow \text{int list}$
$\text{char} \times \text{char list} \rightarrow \text{char list}$
$\Lambda\alpha.\ \alpha \times \alpha\ \text{list} \rightarrow \alpha\ \text{list}$

  - Different type languages have different expressiveness.

Type Inference

- Type inference (or type reconstruction) is the process by which the compiler assigns types to expressions
  - using the type rules for the language.
- All compilers use some inference

```
a.append("Hi").append(" ").append("there")

x / (n + 1)
```

- Some languages do a great deal (ML, Haskell)

Untyped Languages

- Examples: Lisp, Csh, Smalltalk, Self
  - any variable can name data of any type (including methods!)
  - the type of a variable may vary from one program point to another:

```
   ...
s find: x        <——
   ...
x match: y       <——
   ...
f reportOn: x    <——
```

The Rôle of Types

- Types characterize what *can be done* to values or objects
- Used in conjunction with your code (which states what *you want done* to your values and objects) provides ***redundancy***:
  - if what you want done is consistent with what the types say *can* be done, your code is more likely to be doing something sensible.
  - Types are an explicit statement about intent:

list xs; xs will behave like a list and all actions on xs will be consistent with action on lists.

Types in a Value Oriented Language

- Values are bit patterns.

  0011010001110011

  – an int? a date? a uid? what is it?

- a types defines a set of operations that act as interpreters of the bit patterns.

```
Date d;
nextDay(d);
previousDay(d);

String s, t;
strcat(s,t);
streq(s,t);
```

Types in OO Languages

- We can’t *see* bit patterns any more!
- Every object is a package: bit pattern + set of operations.
- Can’t see the bit pattern except through the set of operations.
  - The action of *strcat*, *streq*, *substring*, *etc*. are entirely encapsulated in the *String* object.

What can Go Wrong Without Types?

- With values: an incorrect operation can be applied to a bit pattern.

```
Date d; String s;
strcat(d,s);
```

  - the code now treats *d* as a String even though it isn't.
- The Result?

Chaos!

In a precise technical sense!

- The resulting state cannot be determined from the definition of the language!
  - We would have to know the details of how dates are represented
  - This ought to be machine dependent
- the failure of the program may not be apparent until much later.

In a Statically typed, Value-oriented Language

This program could never be run!

- Only “well-typed” programs are legal
  – an application of a function to a value is only well typed if it can never be applied to a value of an incorrect type.
- “Well-typed programs don’t go wrong”
  – in ways that can’t be understood in terms of the language itself

In Dynamically Typed, Value-Oriented Languages

- A run-time type error occurs
  - “attempt to apply operation *strcat* to a *date*”
- A type error usually indicates a conceptual problem in the algorithm
  - it can be corrected at the level of the programming language and rather than at the level of the bits.
  - The type structure of the program reflects the conceptual model of the solution.

In an Object-Oriented Language

- The client asks an object to perform an operation. What kind of error can occur?
  - the requested operation is not one of the supported operations defined by the object.
  - the result is *Message Not Understood*
- This occurs in *both* typed and untyped OO languages.
- This is better than a jumble of bits!

Is it good enough?

- Yes… because we don't "do" an incorrect message.
- No... we may travel a long way from the original conceptual error before we finally get *message not understood*.
  - We have to wait until the message is sent before we get the warning of our error
- Typed OO languages
  - Let us find all potential *message not understood* errors *before* we ever run the program.

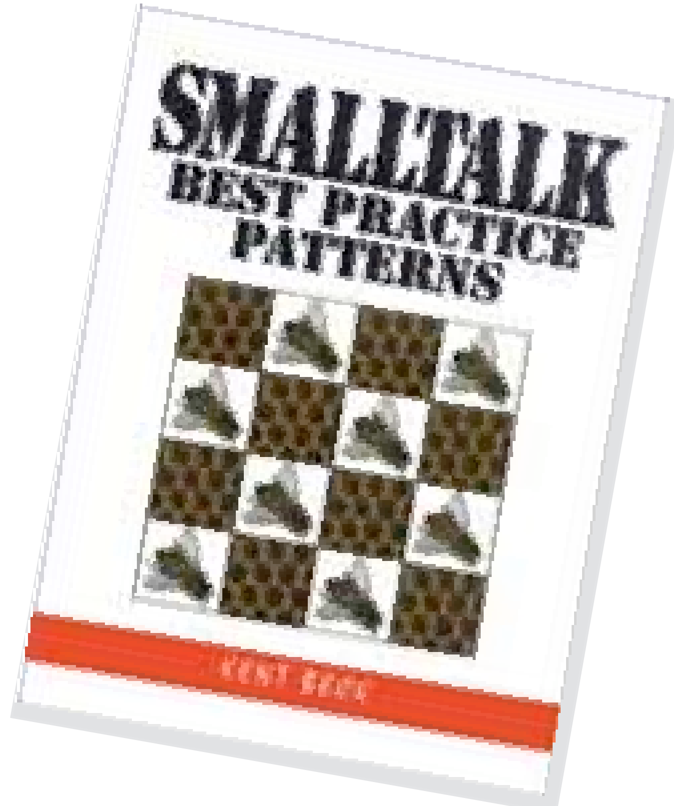
Costs of typed languages

- Syntactic noise
- Some programs that will *never* generate an error will be type-incorrect
  - the type language is not expressive enough to handle the type.
- In practice, we need a dynamic type system too!
  - Java casts in and out of Vectors and tests into Arrays
  - Objects that arrive at run-time
  - The "right" type system is an engineering compromise

- More development time (and more information needed) in order to compile programs written in typed languages...
  - incremental development must include type information on all pieces, even those not written yet.
  - While development time increases, the increase in the quality of correct code usually more than compensates for the time and effort.
- Higher-order type systems are being investigated to increase the expressiveness of the object language so that more programs can be well typed.

Good OO Practices Interlude

Kent Beck, 1997



The Choosing Message (Beck p. 45)

- Suppose we want to do one of several things... depending on the value of an attribute. e.g.,:

```
responsible := (aCatalogEntry isKindOf: Film)
                    ifTrue: [anEntry producer]
                    false: [anEntry author]
responsible fileAlphabetically
```

- Let the *Object* choose!

- Each object for which we need this kind of behavior should support a ***responsible*** method that returns whoever is responsible.

Decomposition Methods (Beck p. 47)

- Always use small methods, and have messages that say what is being done:

```
interpreter
    initialize
    loop
    terminate
initialize
    ...
loop
    ...
terminate
    ...
```

Intention Revealing Names (Beck p. 49)

- Example: Rectangle
  - defines a method

```
highlight
        reverse
```

  - Why define the method **highlight** with this 1-line body?
  - Emphasize the intent rather than the implementation.
  - Better data encapsulation:
    - we can change how highlighting is accomplished, for instance, by a change of color, without affecting the intent that we highlight

Reversing Method (Beck p. 33)

- Has your code got rhythm?

```
Point >> printOn: aStream
    x printOn: aStream.
    aStream nextPutAll: '@'.
    y printOn: aStream.
```

  – Three messages to three different objects.

- Code a method on the parameter. Make the original receiver a parameter of the method.

```
Stream>>print: anObject        "methods for printing"
    anObject printOn: self
```

- Now we can write:

```
Point >> printOn: aStream
      aStream
            print: x;
            nextPutAll: '@';
            print: y
```

- Is this just aesthetics? Beck says no
  - once you have cast the method into a form where all the messages are being sent to a single object (aStream in our example), then
  - that object can vary without affecting the parameters
  - in other words, or method is more reusable.