

Programming Language Concepts

Binding and Scope

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- Iterator Abstraction

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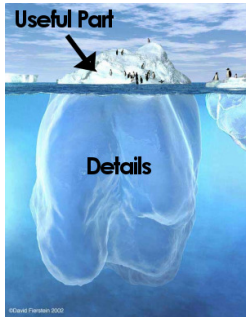
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Abstraction



- Iceberg: Details at the bottom, useful part at the top of the ocean. Animals do not care about the bottom.
 - User: "how do I use it?", Developer: "How do I make it work?"
 - User: "what does it do?", Developer: "How does it do that?"
-
- **Abstraction:** Make a program or design reusable by enclosing it in a body, hiding the details, and defining a mechanism to access it.
 - Separating the usage and implementation of program segments.
 - Vital large scale programming.

- Abstraction is possible in any discipline involving design:
- radio tuner. Adjustment knob on a radio is an abstraction over the tuner element, frequency selection.
- An ATM is an abstraction over complicated set of bank transaction operations.
- Programming languages can be considered as abstraction over machine language.
- ...

Purpose

- Details are confusing
- Details may contain more error
- Repeating same details increase complexity and errors
- Abstraction philosophy: **Declare once, use many times!**
- **Code reusability** is the ultimate goal.
- Parameterization improves power of abstraction

Function and procedure abstractions

- The computation of an expression is the detail (algorithm, variables, etc.)
- Function call is the usage of the detail
- Functions are **abstractions over expressions**
- void functions of C or procedure declarations of some languages
- No value but contains executable statements as detail.
- Procedures are **abstractions over commands**
- Other type of abstractions possible?

Selector abstraction

- arrays: `int a[10][20]; a[i]=a[i]+1;`
- `[..]` operator selects elements of an array.
- User defined selectors on user defined structures?
- Example: Selector on a linked list:

```
int & get(List *p, int el) {    /* linked list */
    int i;
    for (i=1;i<el;i++) {
        p = p->next;          /* take the next element */
    }
    return p->data;
}
get(head,i) = get(head,2) + 1; ...
```

- C++ allows overloading of `[]` operator for classes.

Generic abstraction

- Same declaration pattern applied to different data types.
- **Abstraction over declaration.** A function or class declaration can be adapted to different types or values by using type or value parameters.

```
template <class T>
class List {
    T content;
    List *next;
public: List() { next=NULL };
    void add(T el) { ... };
    T get(int n) { ...};
};

template <class U>
void swap(U &a, U &b) { U tmp; tmp=a; a=b; b=tmp; }
...
List<int> a; List<double> b; List<Person> c;
int t,x; double v,y; Person z,w;
swap(t,x); swap(v,y); swap(z,w);
```


Iterator abstraction

- Iteration over a user defined data structure. **Ruby** example:

```
class Tree
  def initialize(v)
    @value = v ; @left = nil ; @right = nil
  end
  def traverse
    @left.traverse {|v| yield v} if @left != nil
    yield @value           # block argument replaces
    @right.traverse {|v| yield v} if @right != nil
  end
end

a=Tree.new(3) ; l=[]
a.traverse { |node|      # yield param
               print node # yield body
               l << node  # yield body
            }
```

Iterator abstraction

- Iteration over a user defined data structure. [Python](#) example:

```
class BSTree(object):
    def __init__(self):
        self.val = ()
    def inorder(self):
        if self.val == ():
            return
        else:
            for i in self.left.inorder():
                yield i
            yield self.val
            for i in self.right.inorder():
                yield i

v = BSTree()
...
for v in v.inorder():
    print v
```

Abstraction Principle

- If any programming language entity involves computation, it is possible to define an abstraction over it

| Entity | → | Abstraction |
|---------------|---|--------------------|
| Expression | → | Function |
| Command | → | Procedure |
| Selector | → | Selector function |
| Declaration | → | Generic |
| Command Block | → | Iterator |

Parameters

- Many purpose and behaviors in order to take advantage of “declare once use many times”.
- **Declaration part:** `abstraction_name(Fp1, Fp2, ..., Fpn)`
Use part: `abstraction_name(Ap1, Ap2, ..., Apn)`
- Formal parameters: identifiers or constructors of identifiers (patterns in functional languages)
- Actual parameters: expression or identifier based on the type of the abstraction and parameter
- **Question:** How actual and formal parameters relate/communicate?
- Programming language design should answer
- **Parameter passing mechanisms**

Parameter Passing Mechanisms

Programming language may support one or more mechanisms. 3 basic methods:

- 1 Copy mechanisms (assignment based)
- 2 Binding mechanisms
- 3 Pass by name (substitution based)

Copy Mechanisms

- Function and procedure abstractions, assignment between actual and formal parameter:
 - 1 Copy In:
On function call: $Fp_i \leftarrow Ap_i$
 - 2 Copy Out:
On function return: $Ap_i \leftarrow Fp_i$
 - 3 Copy In-Out:
On function call: $Fp_i \leftarrow Ap_i$, and
On function return: $Ap_i \leftarrow Fp_i$
- C only allows copy-in mechanism. This mechanism is also called as **Pass by value**.

```

int x=1, y=2;
void f(int a, int b) {
    x += a+b;
    a++;
    b=a/2;
}
int main() {
    f(x,y);
    printf("x:%d, y:%d\n", x, y);
    return 0;
}

```

Copy In:

| <u>x</u> | <u>y</u> | <u>a</u> | <u>b</u> |
|----------|----------|----------|----------|
| 1 | 2 | 1 | 2 |
| 4 | | 2 | 1 |

x:4, y:2

Copy Out:

| <u>x</u> | <u>y</u> | <u>a</u> | <u>b</u> |
|----------|----------|----------|----------|
| 1 | 2 | 0 | 0 |
| 1 | 0 | 1 | 0 |
| 1 | | | |

x:1, y:0

Copy In-Out:

| <u>x</u> | <u>y</u> | <u>a</u> | <u>b</u> |
|----------|----------|----------|----------|
| 1 | 2 | 1 | 2 |
| 4 | 1 | 2 | 1 |
| 2 | | | |

x:2, y:1

- Based on binding of the formal parameter variable/identifier to actual parameter value/identifier.
- Only one entity (value, variable, type) exists with more than one names.
 - 1 **Constant binding:** Formal parameter is constant during the function. The value is bound to actual parameter expression value.
Functional languages including Haskell uses this mechanism.
 - 2 **Variable binding:** Formal parameter variable is bound to the actual parameter variable. Same memory area is shared by two variable references.
Also known as **pass by reference**
- The other type and entities (function, type, etc) are passed with similar mechanisms.


```

int x=1, y=2;
void f(int a, int b) {
    x += a+b;
    a++;
    b=a/2;
}
int main() {
    f(x,y);
    printf("x:%d, y:%d\n", x, y);
    return 0;
}

```

Variable binding:

| f():a / | f():b / |
|-----------|---------|
| x | y |
| <hr/> | <hr/> |
| 1 | 2 |
| 4 | 2 |
| 5 | |
| x: 5, y:2 | |

Pass by name

- Actual parameter syntax replaces each occurrence of the formal parameter in the function body, then the function body evaluated.
- C macros works with a similar mechanism (by pre-processor)
- Mostly useful in theoretical analysis of PL's. Also known as **Normal order evaluation**
- Example (Haskell-like)

```
f x y = if (x<12) then x*x+y*y+x
      else x+x*x
```

Evaluation: $f\ (3*12+7)\ (24+16*3) \mapsto \text{if } ((3*12+7)<12) \text{ then } (3*12+7)*(3*12+7)+(24+16*3)*(24+16*3)+(3*12+7) \text{ else } (3*12+7)+(3*12+7)*(3*12+7) \xrightarrow{*} \text{if } (43<12) \text{ then } \dots \mapsto \text{if } (\text{false}) \text{ then } \dots \mapsto (3*12+7)+(3*12+7)*(3*12+7) \xrightarrow{*} (3*12+7)+43*(3*12+7) \mapsto \dots \mapsto 1892$ (12 steps)

Evaluation Order

- **Normal order evaluation** is mathematically natural order of evaluation.
- Most of the PL's apply **eager evaluation**: Actual parameters are evaluated first, then passed.

$f(3*12+7)(24+16*3) \mapsto f(36+7)(24+16*3) \xrightarrow{*} f\ 43\ 72 \mapsto \text{if } (43 < 12)$
 $\text{then } 43*43+72*72+43 \text{ else } 43+43*43 \mapsto \text{if } (\text{false}) \text{ then } \dots \mapsto$
 $43+43*43 \xrightarrow{*} 1892 \quad (8 \text{ steps})$

- Consider “ $g \ x \ y = \text{if } x > 10 \text{ then } y \text{ else } x$ ” for $g \ 2 \ (4/0)$
- Side effects are repeated in NOE.
- **Church–Rosser Property**: If an expression can be evaluated at all, it can be evaluated by consistently using normal-order evaluation. If an expression can be evaluated in several different orders (mixing eager and normal-order evaluation), then all of these evaluation orders yield the same result.

- Haskell implements **Lazy Evaluation** order.
- Eager evaluation is faster than normal order evaluation but violates Church-Rosser Property. Lazy evaluation is as fast as eager evaluation but computes same results with normal order evaluation (unless there is a side effect)
- Lazy evaluation expands the expression as normal order evaluation however once it evaluates the formal parameter value other evaluations use previously found value:

```
f (3*12+7) (24+16*3)  $\mapsto$  if (x:(3*12+7)<12) then
x:(3*12+7)*x:(3*12+7)+y:(24+16*3)*y:(24+16*3)+x:(3*12+7) else
x:(3*12+7)+x:(3*12+7)*x:(3*12+7)  $\xrightarrow{*}$  if (x:43<12) then
x:43*x:43+y:(24+16*3)*y:(24+16*3)+x:43 else x:43+x:43*x:43  $\mapsto$  if
(false) then ...  $\mapsto$  x:43+x:43*x:43  $\mapsto$  x:43+1849  $\mapsto$  1892 (7 steps)
```

Correspondence Principle

■ Correspondence Principle:

For each form of declaration there exists a corresponding parameter mechanism.

■ C:

| | | |
|-----------------------------|-------------------|------------------------------------|
| <code>int a=p;</code> | \leftrightarrow | <code>void f(int a) {</code> |
| <code>const int a=p;</code> | \leftrightarrow | <code>void f(const int a) {</code> |

■ Pascal:

| | | |
|------------------------------|-------------------|---|
| <code>var a: integer;</code> | \leftrightarrow | <code>procedure f(a:integer) begin</code> |
| <code>const a:5;</code> | \leftrightarrow | <code>??? {</code> |
| <code>???</code> | \leftrightarrow | <code>procedure f(var a:integer) begin</code> |

■ C++:

| | | |
|-----------------------------|-------------------|------------------------------------|
| <code>int a=p;</code> | \leftrightarrow | <code>void f(int a) {</code> |
| <code>const int a=p;</code> | \leftrightarrow | <code>void f(const int a) {</code> |
| <code>int &a=p;</code> | \leftrightarrow | <code>void f(int &a) {</code> |