Programming Language Concepts

Binding and Scope

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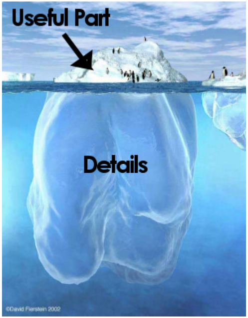
Outline

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	$\rightarrow$	**Abstraction**
Expression	$\rightarrow$	Function
Command	$\rightarrow$	Procedure
Selector	$\rightarrow$	Selector function
Declaration	$\rightarrow$	Generic
Command Block	$\rightarrow$	Iterator

Parameters

- Many purpose and behaviors in order to take advantage of "declare once use many times".
- **Declaration part:** `abstraction_name(`$\texttt{Fp}_1$`, `$\texttt{Fp}_2$`, ..., `$\texttt{Fp}_n$`)`
  Use part: `abstraction_name(`$\texttt{Ap}_1$`, `$\texttt{Ap}_2$`, ..., `$\texttt{Ap}_n$`)`
- 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.

```c
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:

x	y	a	b
~~1~~	2	~~1~~	~~2~~
4		2	1

`x:4, y:2`

Copy Out:

x	y	a	b
~~1~~	~~2~~	~~0~~	~~0~~
~~1~~	0	1	0
1			

`x:1, y:0`

Copy In-Out:

x	y	a	b
~~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.

```c
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 / x	f():b / y
~~1~~	~~2~~
~~4~~	2
5	

```
x: 5, y:2
```

Pass by name

- Actual parameter syntax replaces each occurence 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)` $\mapsto$ `if ((3*12+7)<12) then (3*12+7)*(3*12+7)+(24+16*3)*(24+16*3)+(3*12+7) else (3*12+7)+(3*12+7)*(3*12+7)` $\overset{*}{\mapsto}$ `if (43<12) then ...` $\mapsto$ `if (false) then ...` $\mapsto$ `(3*12+7)+(3*12+7)*(3*12+7)` $\overset{*}{\mapsto}$ `(3*12+7)+43*(3*12+7)` $\mapsto$ `...` $\mapsto$ `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)` $\overset{*}{\mapsto}$ `f 43 72` $\mapsto$ `if (43<12) then 43*43+72*72+43 else 43+43*43` $\mapsto$ `if (false) then ...` $\mapsto$ `43+43*43` $\overset{*}{\mapsto}$ `1892` (8 steps)
- Consider "`g x y= if x>10 then y 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)` $\overset{*}{\mapsto}$ `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:

`int a=p;`	↔	`void f(int a) {`
`const int a=p;`	↔	`void f(const int a) {`

- Pascal:

`var a: integer;`	↔	`procedure f(a:integer) begin`
`const a:5;`	↔	`??? {`
`???`	↔	`procedure f(var a:integer) begin`

- C++:

`int a=p;`	↔	`void f(int a) {`
`const int a=p;`	↔	`void f(const int a) {`
`int &a=p;`	↔	`void f(int &a) {`