Programming Language Concepts

Encapsulation

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Outline

Encapsulation

Managing the complexity → Re-usable code and abstraction.

Example:

50 lines	no abstraction is essential, all in main()
500 lines	function/procedure abstraction sufficient
5,000 lines	function groups forming modules, modules are combined to form the application
500,000 lines	heavy abstraction and modularization, all parts designed for reuse (libraries, components etc)

Modularization and Encapsulation

- Building an independent and self complete set of function and variable declarations (Packaging)

interface
detail (functions, variables, algorithm)

other application

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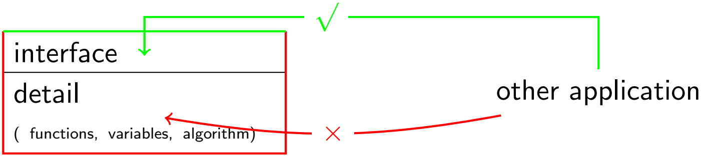

Advantages of Encapsulation

- High volume details reduced to interface definitions (Ease of development/maintenance)
- Many different applications use the same module via the same interface (Code re-usability)
- Lego like development of code with building blocks (Ease of development/maintenance)
- Even details change, applications do not change (as long as interface is kept same) (Ease of development/maintenance)
- Module can be used in following projects (Code re-usability)

- A group of declarations put into a single body.
- C has indirect way of packaging per source file. Python defines modules per source file.
- C++

```
namespace Trig {
    const double pi=3.14159265358979;
    double sin(double x) { ... }
    double cos(double x) { ... }
    double tan(double x) { ... }
    double atan(double x) { ... }
   ...
};
```

- `Trig::sin(Trig::pi/2+x)+Trig::cos(x)`
- C++: (::) Scope operator.
- Identifier overlap is avoided. `List::insert(...)` and `Tree::insert(...)` no name collisions.

Hiding

- A group of functions and variables hidden inside. The others are interface. Abstraction inside of a package:

```
double taylorseries(double);
double sin(double x);
double pi=3.14159265358979;
double randomseed;
double cos(double x);
double errorcorrect(double x);
```

```
{-- only sin, pi and cos are accessible --}
module Trig(sin,pi,cos) where
  taylorseries x = ...
  sin x = ...
  pi=3.14159265358979
  randomseed= ...
  cos x = ...
  errorcorrect x = ...
```

Abstract data types

- Internals of the datatype is hidden and only interface functions provide the access.
- Example: rational numbers: 3/4 , 2/5, 19/3

```
data Rational = Rat (Integer,Integer)
x = Rat (3,4)
add (Rat(a,b)) (Rat(c,d)) = Rat (a*d+b*c,b*d)
```

  1. Invalid value? `Rat (3,0)`
  2. Multiple representations of the same value?
     `Rat (2,4) = Rat (1,2) = Rat(3,6)`
- Solution: avoid arbitrary values by the user.

Main purpose of abstract data types is to use them transparently (as if they were built-in) without loosing data integrity.

```
module Rational(Rational,rat,add,subtract,multiply,divide) where
  data Rational = Rat (Integer,Integer)
  rat (x,y) = simplify (Rat(x,y))
  add (Rat(a,b)) (Rat(c,d)) = rat (a*d+b*c,b*d)
  subtract(Rat(a,b)) (Rat(c,d)) = rat (a*d-b*c,b*d)
  multiply(Rat(a,b)) (Rat(c,d)) = rat (a*c,b*d)
  divide (Rat(a,b)) (Rat(c,d)) = rat (a*d,b*c)
  gcd x y = if (x==0) then y
            else if (y==0) then x
            else if (x<y) then gcd x (y-x)
            else gcd y (x-y)
  simplify (Rat(x,y)) = if y==0 then error "invalid␣value"
                        else let a=gcd x y
                             in Rat(div x a, div y a)
```

Initial value? We need constructor function/values. (remember we don't have the data definition)

`rat (x,y)` instead of `Rat (x,y)`

Object

- Packages containing hidden variables and access is restricted to interface functions.
- Variables with state
- Data integrity and abstraction provided by the interface functions.
- Entities in software can be modelled in terms of functions (server, customer record, document content, etc). Object oriented design.
- Example (invalid syntax! imaginary C++)

```
namespace Counter {
private:   int counter=0;
public:    int get() { return counter;}
public:    void increment() { counter++; }
};
Counter::get()        Counter::increment()
```

Class

- The set of same typed objects form a class
- An object is an instance of the class that it belongs to (a counter type instead of a single counter)
- Classes have similar purposes to abstract data types
- Some languages allows both objects and classes
- C++ class declaration (valid syntax):

```
class Counter {
private:    int counter;
public:     Counter() { counter=0; }
            int get() { return counter;}
            void increment() { counter++; }
} men,vehicles;
men.increment(); vehicles.increment();
men.get(); vehicles.get();
```

Abstract data type
interface (constructor, functions)
detail (data type definition, auxiliary functions)

Object
interface (constructor, functions)
detail (variables, auxiliary functions)

Purpose

- preserving data integrity,
- abstraction,
- re-usable codes.

Closure

- Closure is an abstraction method using the saved environment state in a scope.
- When a function returns a local object or function as its result and language keeps the environment state along with the returned value, it becomes a closure

```
def newid():
    c = 0  # this is the hidden variable in the environment
    def incget():
        nonlocal c      #python 3, binds c above
        c += 1
        return c
    return incget

>>> a = newid()
>>> b = newid()
>>> a()
1
>>> b()
1
>>> b()
2
```

- Local variables of closures stay alive after call, as long as returned value is alive.
- closures can be used for generating new functions as in higher order functions:

```
def mult(a):
    def nested(b):
        return a*b
    return nested     # a different behaviour for each a value
twice = mult(2)
tentimes = mult(10)
a=twice(4)+tentimes(50)
```

- Also can be used for prototyping objects. Javascript example:

```
function counter() {
    var c = 0        // this is jailed in local environment, hidden
    var newobj = {}  // create a new empty object
    newobj.incr = function () { c++; }
    newobj.get = function () { return c;}
    return newobj
}
a = counter()
b = counter()
a.incr()
a.get()
b.get()
```

C++ 2011 Closures

- C++ 2011 implements closures in lambda expressions by adding a set of captured variables within `[]`. This copy or get reference of auto variables in the environment in an object.
- However C++ closures do not extend lifetime of captured variables. After exit, the behaviour is undetermined.
- `[a,&b] (int x) { return a+x+b;}` captures a and b from current environment, a is by copy, b by reference.

```
std::function<int(int)>  multiply(int a) {
    return [&] (int b) { return a*b;}; // capture by value
};
std::function<int()> cid() {
    int c = 0;
    return [=] () mutable { return ++c; }; // capture by copy
};
int main() {
    std::function<int(int)> twice = multiply(2);
    std::function<int(int)> three = multiply(3);

    cout << twice(12) << ' ' << three(34) << endl;

    auto c1 = cid();
    auto c2 = cid();

    cout << c1() << ' ' << c2() << endl;
    c1(); c1(); c1();
    cout << c1() << ' ' << c2() << endl;
    return 0;
}
```

Further Reusability

- Class relations. Extending one class definition to create more specific class definitions.
- Classes containing other classes
- Classes derived from other classes: inheritance
- Abstract classes and interfaces
- Polymorphism
- Design patterns: standard object oriented designs applicable to a family of similar software problems. Not included in this course.