

# Programming Language Concepts

## Object Oriented Prog: Objects

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# Object Oriented Programming

- Abstraction
- Encapsulation
- Hiding
- Inheritance

# Encapsulation/Scope

- Objects consist of:
  - attributes (member variables)
  - methods (member functions)

encapsulated in a package scope

- attributes: state of objects
- methods: behaviour of objects
- alternative terminology: messages  
call a method  $\equiv$  send message to an object
- A class is the family for similar objects.
- An object is an **instance** of a class.

Person
name
surname
no
+ getname()
+ setno()

```
class Person {  
    char name[40], surname[40];  
    int no;  
public:  
    const char * getname() { return name;}  
    void setno(int);  
} obj ;  
  
void Person::setno(int a) {  
    no=a;  
}
```

- C++ allows definitions inside the class or outside by **scope operator '::'**
- Environment is recursive collateral.
- `obj.getname()`; calls the method in the context of object `obj`.
- `this` keyword denotes pointer to current object in member functions. (`self()` in some other languages)

# Hiding

- Interface vs detail. Details are hidden, only interface members are exported outside.
- C++ uses `private:`, `protected:`, and `public:` labels to mark hiding.
- only members following a `public:` label are visible outside (the object for example). Member functions can access all members regardless of their labels.
- `obj.setno(4)` is legal, `obj.no` is not.
- Hiding depends on scope and it is lexical. In C++ pointer conversions can violate hiding.
- By convention all member variables should be private, some member functions can be private, only some of member functions are public.
- `protected` keyword is useful with inheritance.

# Abstraction

- An object is an abstraction over the programming entity defined by the model in the design.
- Model: customer, bank, registration, course, advisor, mail, chatroom,...
- Class should provide:
  - Transparent behaviour for the objects, access via interface functions.
  - Data integrity. Objects should be valid through their lifetimes.
- Data integrity at the beginning of lifetime provided by constructors (+destructors in C++)

# Constructors

- Special member functions called when lifetime of the object starts **just after storage of members are ready**
- Automatically called. No explicit calls.
- no return value, name is same with the class
- can be overloaded

```
class Person {  
    char *name[40], *surname[40];  
    int no;  
public:  
    Person(const char *n, const char *s) {  
        strcpy(name,n) ; strcpy(surname,s) ; no=0;  
    }  
    Person() { name[0]=0; surname[0]=0; no=0;}  
} obj ;
```



## ■ Constructors can be overloaded

Definition	Constructor
Person a ;	Person()
Person a("ali","veli");	Person(const char *, const char *)
Number a=3;	Number(int)
Number a(3);	Number(int)
Number b=a;	Number(Number &a)
Number a[2]={0,1}	Number(int)

- If no constructor implemented, empty constructor (do nothing) assumed
- If at least one constructor exists, variables should match at least one of them, no empty constructor assumed
- Constructors are called by the language when lifetime started:
  - 1 start of program for global objects
  - 2 entrance to function for local objects
  - 3 when heap objects are created (with `new`)

# Heap Objects

- `new` and `delete` operators instead of `malloc()` and `free()`.  
Why?
- `Person *p=new Person("ali","veli");`  
`delete p;`
- Array allocation/deallocation:  
`Person *p=new Person[100];`  
`delete [] p;`

# Destructors

- When storage (members) of an object allocated dynamically
- Lifetime is over : garbage
- We need calls to collect heap variables within the object
- Java solution: garbage collector does the job. We need nothing
- C++: **destructors**: member functions called when lifetime is over.
- A class only have one destructor with exact type and name: `~ClassName()`. Called:
  - 1 end of program for global objects
  - 2 return from function for local objects
  - 3 when heap objects are deallocated (with `delete`)

# Constructor Calls

- Calling a constructor as a member function is not allowed:

`Person p ; p.Person("john");` is a compiler error

- Constructor definitions can call each other with specific syntax:

`Person():Person("john_doe") { ... }`

- Explicit constructor calls create a temporary object:

`Person p; p = Person("john");` is equivalent to:

`Person p; { Person tmp("john"); p = tmp; }`

note that lifetime of `tmp` is over at the end of line

- In definitions, no intermediate object created:

`Person p = Person("john");`

- A constructor also works as a type conversion operator:

`p = (Person) "john";` is equivalent to `p = Person("john");`, creates a temporary object

- Also type conversion works implicitly. C++ calls constructors when type conversion is required:

`p = "john";` is equivalent to the call above.

# Copy Constructor

- Destructor does not solve all problems with objects with heap members:
  - Semantics of assignment
  - Semantics of parameter passing
  - Semantics of return value
  - Initialization
- Default behaviour of C++ is **copy member values byte by byte**.
- Java assigns/passes by reference. No copying.
- C++ Solution: implement your own semantic by **Copy constructor** and overloading assignment operator.
- Assignment operator destroys an existing object and replaces with the data from new one, copy constructor copies data into an empty object.

# Copy Constructor

- Type is: `ClassName(const ClassName &)`
- Called when:
  - Object passed by value: `void add(ClassName a) {...}`
  - Object initialized by object: `ClassName a,b=a;`
  - Object returned as a value `ClassName getVal() {...}`
- Last one is a little tricky.
- Default behaviour exists even if it other constructors exist.

```

class List {
    struct Node { int x; Node *next} *head;
public: List() { head=NULL;}
    List(const List &); // Copy constructor
    ~List();
};

void passbyvalue(List a) {
    ...
}

List returnasvalue(List &a) {
    List b = a;
    ...
    return a;
}

...
passbyvalue(c);
...
d=returnasvalue(c)
...

```

Diagram illustrating the use of the Copy Constructor:

- A green arrow points from the parameter `a` in the `passbyvalue` function to the `List` parameter in the `returnasvalue` function, labeled "Copy Constructor".
- A green arrow points from the variable `a` in the `returnasvalue` function to the variable `b` in the same function, labeled "Copy Constructor, explicit".
- A green arrow points from the variable `c` in the `passbyvalue` function to the variable `c` in the `returnasvalue` function, labeled "Copy Constructor".

- Pass by value of objects are constructed by the copy constructor
- Return an object as a value creates a temporary object in place of return and uses it:

```
d=returnasvalue(c); ≡ {List tmp=returnasvalue(c); d=tmp; }
```

- Temporary objects are created at such expressions and deallocated at the end of the line (at ';'), destructors are called regularly.
- Explicit call to a constructor also creates such a temporary object.

```
g=Person("ali","veli");
```

- C++ compilers avoid copy constructor calls when possible, called **copy elision**.

```
List f() { List t;...; return t;} ... ; d=f(); ...
```

If possible, compiler binds local object and returned temporary object same storage → No constructor call.



# `const` Keyword

- C++ does strict type checking on constant restriction on `const`
- `const char *p` VS `char *const q`
  - 1 `p[3]='a';` ✗
  - 2 `q[3]='a';` ✓
  - 3 `p++;` ✓
  - 4 `q++;` ✗
- `const char * const p`
- `f(const ClassName &a)` makes the parameter object constant during the function scope
- `const ClassName &f()` makes the returned object reference constant in expression containing the function call
- What's beside assignment? `constant member functions`

# Constant Member Functions

- `void f(const Rational &a) { ...; a.clear(3);...;a.out();}`  
`void Rational::clear() { a=b=0;}`

What is wrong above?

- `void Rational::out() const {...; a=b=0; }`  
`const` keyword preceding the function body makes member function a constant function.
- Constant functions cannot update member variables, only can inspect them  
`a=b=0` in `out()` is invalid above
- If an object is constant, only constant member functions can be called.  
`a.clear(3);` is invalid above
- Type system of C++ prohibits those → Syntax error.

# Operator Overloading

- Not an essential feature of object oriented programming but improves readability in some cases.
- Especially usefull in implementing selector abstraction, algebra based applications.
- Do not use it when the operator is not intuitive for the context (class and the operation).
- C++ allows overloading of existing operators with same arity and precedence and only if at least one class type involves in the operator
- Operator can be implemented as a member function (first parameter is the class) or as an external function (which has at least one parameter being a class)

- All C++ operators except '.', '?:', '::', '.\*' and '->\*'
- For unary operators:
  - ① `void ClassName::operator++();`
  - ② `void operator++(ClassName &a);`
- For binary operators:
  - ① `void ClassName::operator&&(int a);`
  - ② `void operator&&(int a,ClassName &b);`
- First versions are member functions, can exist private members. Only operand in unary case, LHS in binary case is the current object
- Second versions are outside of the definition. You need `friend` declaration if they need to access private members.

```

Rational & Rational::operator+(Rational &b) {...}
Rational & Rational::operator+(int n) {...}
Rational & Rational::operator<(Rational &b) {...}
Rational & Rational::operator!() {...}
Rational & Rational::operator++() {...}
Rational & Rational::operator++(int nouse) {...}
Rational & Rational::operator double() {...}

void Hash::operator=(Hash &a) {...}
double Hash::operator[](int a) {...}
double Hash::operator[](const char a[]) {...}
Hash & Hash::operator()(const char a[]) {...}

double Pointer::operator*() {...}
void * Pointer::new(size_t size) {...}
void * Pointer::delete(void *p, size_t size) {...}

Rational a,b,c; Hash h,j; Pointer p,*q;
a+b;           a+3;           if (a<b) ... ;           !a;
++a;           a++;           x=(double)a;

h=j;           x=h[3];       x=h["ali"];           i=h("a-b");

x=*p;           q=new Pointer;           delete q;

```

```

int operator+(int a, Rational &b) {...}
Rational & operator++(Rational &b) {...}
ostream & operator<<(ostream &os, Rational &a) {...}
istream & operator>>(istream &os, Rational &a) {...}

void operator+=(Hash &a, Rational b) {...}

Rational a,b; Hash h,j;

i=i+a;
++a;
cout << a; cout << 3 << a << b ;
cin >> b;
h+=a;

```

# Friends

- When an external function or class needs to access private members, **friend** declaration is used to grant access.

```
class Rational {
    friend class Hash;
    friend ostream & operator<<(ostream &, const Rational &);
    int a,b;
public: ...
};
class Hash {
    ...
    void operator+=(Rational &a) { .. a.a; .. a.b; ...}
};
ostream & operator<<(ostream &os, const Rational &a) {
    os << a.a << "//" << a.b << '\n';
    return os;
}
```

# Implementation of Objects

```
class Person
```

char name[40]	40*sizeof(char)
int id	sizeof(int)
<del>char * getname()</del>	<del>sizeof(char *(*)())</del>
<del>void print()</del>	<del>sizeof(void (*)(*))</del>

- What is size of object? Size of member variables + sizeof member function pointers?
- No! Each object does not have to store the function information.  
Its storage is same with the structure without any member functions.
- Function membership handled by the type system:  
`Person::getname()` instead of `getname()`



- How functions get object context (which object they refer to?)?
- `Person::getname(Person *this)` instead of no parameters
- `Person a; a.getname();`  
converted to `Person::getname(&a);` internally
- All member references inside member function are converted to:  
`char *getname() {.. id=5; ... ; strlen(name);...} →`  
`char *Person::getname(Person *this) {`  
`.. this->id=5; ... ; strlen(this->name);...}`