C++ Review

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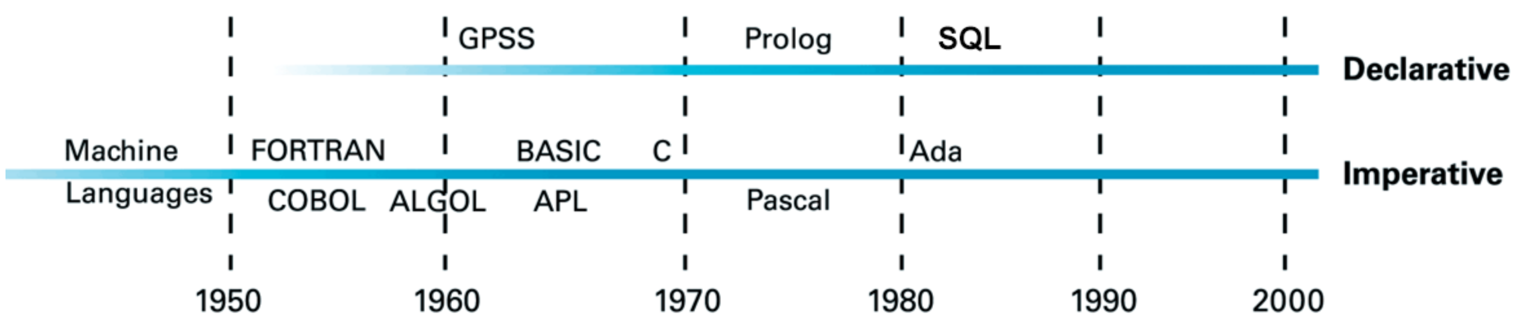
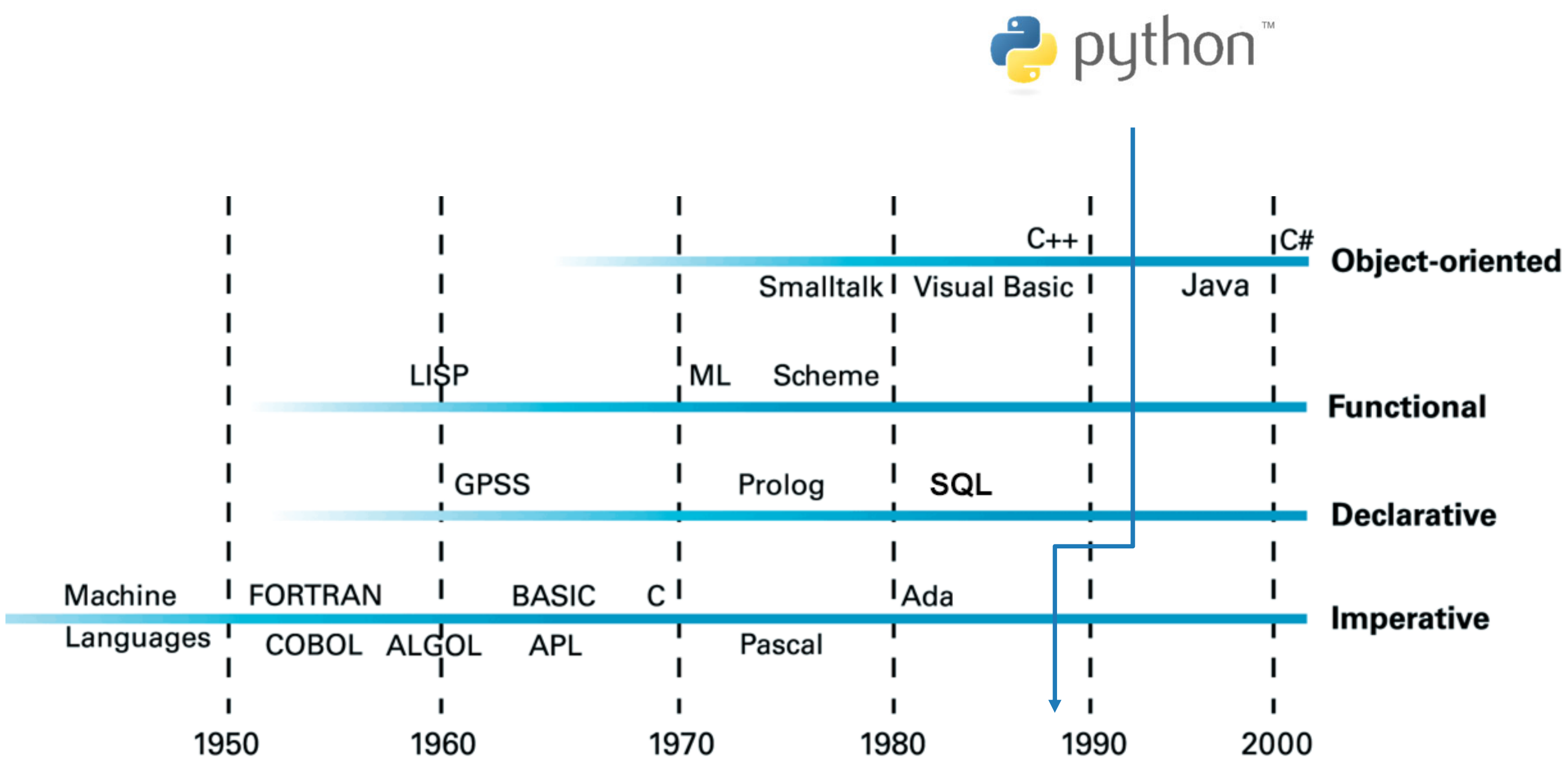
Evolution Of Programming Paradigms

- Declarative programming
  - Expresses the logic of a computation
  - Without describing its control flow
- Imperative programming
  - Uses statements that change a program's state



Evolution Of Programming Paradigms



Algorithmic Decomposition vs. Object-Oriented Decomposition

- Algorithmic Decomposition
  - Software decomposed into steps
  - Steps are implemented as functions
    - E.g., C or Pascal
  - Data structures are a secondary concern
    - Data is visible and accessible to all steps
    - No way to prevent irrelevant codes to access the data
- Object-Oriented Decomposition
  - Software decomposed into objects
    - E.g., C++
    - Interact with each other to solve the problem
  - High reusability and flexibility

Object-Oriented Programming (OOP)

- Object
  - Basic unit that does the computation
  - Contain data and procedural functions
- Object-Oriented Programming
  - Objects are fundamental building blocks
  - Each object is an instance of some class
  - Classes have inheritance relationships

C++ v.s. Java

- Object-Oriented Language (C++)
  - It supports objects
  - It requires objects to belong to a class
  - It supports inheritance
- Object-Based Language (Java)
  - It supports objects
  - It requires objects to belong to a class

History of C++

- Creator of C++ : Bjarne Stroustrup
- C++ is an enhanced version of C
- Standardization:

Year	C++ Standard	Informal name
1998	ISO/IEC 14882:1998	C++98
2003	ISO/IEC 14882:2003	C++03
2007	ISO/IEC TR 19768:2007	C++TR1
2011	ISO/IEC 14882:2011	C++11
2014	ISO/IEC 14882:2014	C++14
2017	ISO/IEC 14882:2017	C++17
2020	ISO/IEC 14882:2020	C++20

Abstraction and Encapsulation

- Data Abstraction
  - The separation between
    - Specification of a data object
    - Implementation
- Data Encapsulation (Information Hiding)
  - Conceals the implementation details from the outside world
- Benefit to large software system design

Data Type

- A collection of objects and a set of operations
- Fundamental data type in C++:
  - Basic: char, int, float, double, and many mores
  - Modifiers: short, long, signed, unsigned
- Example: int data type
  - Objects: 0, +1, -1, +2, -2, MAXINT, MININT
  - Operations: +, -, *, /, ==, <=

Grouping Data

- Examples:
  - Arrays
    - Collection of elements of the same basic data type
  - structs (C) and classes (C++)
    - Collection of elements

Example

Data Type1

Objects:
int data;

Operations:
int Value(void)
{ return data; }

void Calculate(void)
{data = 100; }

Data Type2

Objects:
float data;

Operations:
float Value(void)
{ return data; }

void Calculate(void)
{data= exp(-10); }

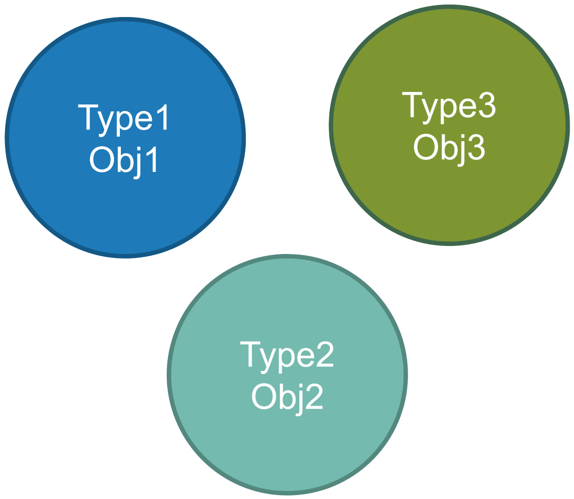
Data Type3

Objects:
Type1 data;
int data2;

Operations:
int Value(void)
{ return
data.Value()+data2; }

void Calculate(void)
{data. Calculate();
data2 = 128; }

A Software that uses ADTs




```
double Calculate1(void);
double Calculate2(void);
double Calculate3(void);
```

```
double Calculate1(void)
{ Obj1. Calculate();
  Obj2. Calculate();
  return (double)Obj1.Value()+
             (double)Obj2.Value();}

double Calculate2(void)
{ Obj2. Calculate();
  Obj3. Calculate();
  return (double)Obj2.Value()+
             (double)Obj3.Value();}
```

Advantages of ADTs

- Simplification
- Testing and debugging
  - Each object can be tested and debugged separately
- Reusability
- Flexibility
  - Could freely modify the internal implementation without affecting the rest of codes

Program Organization

- Header file (*.h)
  - Store declarations
- Hello_World.h

```
#ifndef _HELLO_WORLD_H_
#define _HELLO_WORLD_H_

void Hello_World(void);

// insert other declarations here
// …

#endif
```

- Source file (*.cpp)
  - Store source codes
- Hello_World.cpp

```
#include <iostream>
#include <Hello_World.h>

void Hello_World(void)
{
std::cout << "Hello" << std::endl;
}
```

Scope in C++

- Local scope
  - A name declared in a block
- Class scope
  - Declaration associated with a class definition
- Namespace scope
  - Declaration associated with a namespace
- File scope

Data Declaration in C++

- Constant values
  - E.g., 5, ‘a’, 4.3
- Variables
  - E.g., double income;
- Constant variables
  - The content must be fixed at declaration
  - E.g., **const int** MAX=500;
- Enumeration types
  - Declare a series of constants
  - E.g., **enum** semester {SUMMER, FALL, SPRING};

Data Declaration in C++ (Contd.)

- Pointers
  - Hold memory address of objects
  - E.g.,

```
int i = 25;
int* np;
np = &i;
```

- Reference types (C++ only)
  - Provide a alternate name for an object
  - E.g.,

```
int i=5;
int& j=i;
i = 7;
cout << j << endl;
```

Reference v.s. Pointer

- The sematic differences between reference and pointer:
  - Pointer CAN be NULL but reference CANNOT be NULL
    - reference must bind a variable at initialization

```
int * ptr = NULL;
int & ref = NULL;
```

  - Pointer CAN be changed to point different target in the program but reference variable CANNOT be changed.

```
int  x= 10, y=20;
ptr = &x ;
ptr = &y ;
int & ref = x;
&ref = y;
```

Comment

- One line comment:

```
// To increase the readability
```

- Multiple Line comment:

```
/*
   Usually comment out some functions/procedures
*/
```

Functions in C++

- A function consists of
  - A function name
  - A list of arguments (input)
  - A return type (output) or void
  - The body
- Example

```
int Max (int a, int b)
{
        if (a>b) return a;
        else return b;
}
```

Parameter Passing in C++

- Call by **value**

```
int special_add(int a , int b)
{
		a = a+5;
		return a+b;
}
```

- Value is copied into local storage
- Will not modify the original copies

Parameter Passing in C++

- Call by **pointer**

```
void swap(int *a , int *b){
        int temp=*a;
        *a=*b;
        *b=temp;
}
```

- Will modify the original objects

Function Overloading in C++

- In C++, we can have following functions:

```
int  Max(int, int);
int  Max(int, int, int);
int  Max(int*, int);
int  Max(float, int);
int  Max(int, float);
```

- It is impossible to defined two functions with the same name in C

Dynamic Memory Allocation in C++

- Dynamic Memory Allocation in C
  - malloc, delete, realloc, memset, memcopy
  - Memory leak and memory fragmentation problems

- New dynamic memory allocation mechanism
  - Using keywords "new" and "delete"
  - Make sure you use 'delete' for pointer generated by 'new'

Dynamic Memory Allocation in C++

- C

```
#include <cstdio>

int main () {

   int * x  = (int*) malloc ( sizeof(int) );

   free(x);
   return 0;
}
```

- C++

```
#include <iostream>

int main () {


   int * y =  new int ;
   delete   y ;

   // allocate an int array.
   int  * data  = new  int [10];

   /* make sure you use 'delete' for
   pointer generated by 'new'. */
   delete  [] data ;
   return 0;
}
```

http://www.cplusplus.com/reference/new/operator%20new[]/

Exceptions Handle

- Handle runtime errors or special conditions
- Provide more clear programing logic

```
#include <iostream>
using namespace std;

int main () {
  try {
    throw 20;
  }
  catch (int e) {
    cout << "An int-type exception occurred.
    Exception Nr. " << e << endl;
  }
  return 0;
}
```

```
#include <iostream>
using namespace std;

int main () {
  try {
    throw “error occurs”;
  }
  catch (char* e) {
    cout << "An char-type exception occurred.
    Exception Nr. " << e << endl;
  }
  return 0;
}
```

Exceptions Handle

- **try-catch** block
  - Each try block is followed by zero or more **catch** blocks.
  - Each **catch** block is visited sequentially until the matched block
  - Each **catch** block has a parameter whose type determine the type of exception that may be caught
- **catch (char*** e){}
  - Catch exceptions of type char*
- **catch (bad_alloc** e){}
  - Catch exceptions of type **bad_alloc** (system-defined type)
- **catch** (…){}
  - Catch all exceptions regardless of their type

http://www.cplusplus.com/doc/tutorial/exceptions/

Exceptions Handle – throw

```
int main(void)
{
    int a =0;

    func1();

    int b = a +2;
    int c  = 3;


    return 0;
}
```

```
void func1(){

   func2();

   int  a = 2;
   //....
   return ;
}
```

```
void func2(){

  throw "error!";
  std::cout<<"hi";

return ;
}
```

System

C++ Class

- Class can support data abstraction and encapsulation

```
// In the header file Rectangle.h
#ifndef RECTANGLE_H
#define RECTANGLE_H
class Rectangle {
public:    // the following members are public
           // the next four members are member functions
           Rectangle ( );        // constructor
           ~Rectangle( );        // destructor
           int GetHeight ( );    // return the height of the rectangle
           int GetWidth ( );     // return the width of the rectangle
private:   // the following members are private
           // the following members are data member
           int xLow, yLow, height, width;
           // (xLow, yLow) are the coordinates of the bottom left corner of rec.
};
#endif
```

Data Abstraction

- Specification is placed in header file (e.g., Rectangle.h)
- Implementation is placed in source file (e.g., Rectangle.cpp)

```
// In the source file Rectangle.cpp
#include "Rectangle.h"

/* The prefix "Rectangle::" identifies GetHeight() and GetWidth() are member
function of class Rectangle. It is required because the member functions are
implemented outside the class definition*/

int Rectangle::GetHeight() {return height;}
int Rectangle::GetWidth() {return width;}
```

Class Usage

```
// In a source file main.cpp
#include <iostream>
#include “Rectangle.h”

main() {
            Rectangle r, s;      // r and s are objects of class “Rectangle”
            Rectangle *t = &s;              // t is a pointer to class object s
            .
            .
            // use “.” operator to access members of class objects.
            // use “->“ operator to access members of class objects through pointers.
            If ( r.GetHigh ( ) * r.GetWidth ( ) > t→GetHeight ( ) * t→GetWidth ( ) )
               cout << “r”;
            else cout << “s”;
            cout << “has the greater area “ << endl;
}
```

Data Encapsulation

- C++

```
class  Foo{
  private:
            int  x;
  public:
            int  y;
};

int main(void){
   Foo  obj1 ;
   obj1.x = 11; // c
   obj1.y = 22; // access y
}
```

- C

```
struct  Foo{

     int  x;
     int  y;

};

int main(void){
   struct Foo
   obj1.x = 11
   obj1.y = 22; // access y
}
```

Constructors and Destructors

```
// In the source file Rectangle.cpp
#include "Rectangle.h"

// constructor
Rectangle::Rectangle (void)
{
    xLow = 0; yLow = 0;
    height = 1; width = 1;
}

// destructor
Rectangle::~Rectangle (void)
{
   xLow = yLow = height = width = 0;
}

int Rectangle::GetHeight() {return height;}
int Rectangle::GetWidth() {return width;}
```

Constructors

- A member function to initialize the data members
- Constructor is invoked when an object is created
- Must has the same name as class
- No return type or return value
- A class can have more than one constructors

Type of Constructors

- Default constructor
  - A constructor with no arguments

```
Rectangle ( );                        // default constructor
```

- Augmented constructor
  - A constructor with arguments

```
Rectangle (int, int, int, int);       // augmented constructor
```

- Copy constructor
  - Must be specified if the STL containers are used to store your class object.

```
Rectangle (const Rectangle&); // copy constructor
```

Destructor

- A member function to delete data members when the object disappears
- Destructor is **automatically** invoked when a class object is out of scope or is deleted
- Must has the same name as class with prefix “~”.
- No return type or return value
- Take no arguments
- Only one destructor in a class

Default Methods

- The compiler will generate 4 default methods, if not specified
  - Default constructor

```
Rectangle ( );                    // default constructor
```

  - Copy constructor

```
Rectangle (const Rectangle&);    // copy constructor
```

  - Destructor

```
~Rectangle ();                    // destructor
```

  - Assignment operator

```
Rectangle& operator=(const Rectangle&);       // operator "="
```

struct vs. class

- C

```
struct  MyData{

    int  id;
};

// instance struct
struct MyData   data1;
```

- C++

```
class MyData{
public:
    int id;
};

// instance object
MyData   data1;
```

"struct" in C++

- C++ - "struct"

```
struct Student{
    int   age;
public :
    int   id;
    char   name[100];
};
```

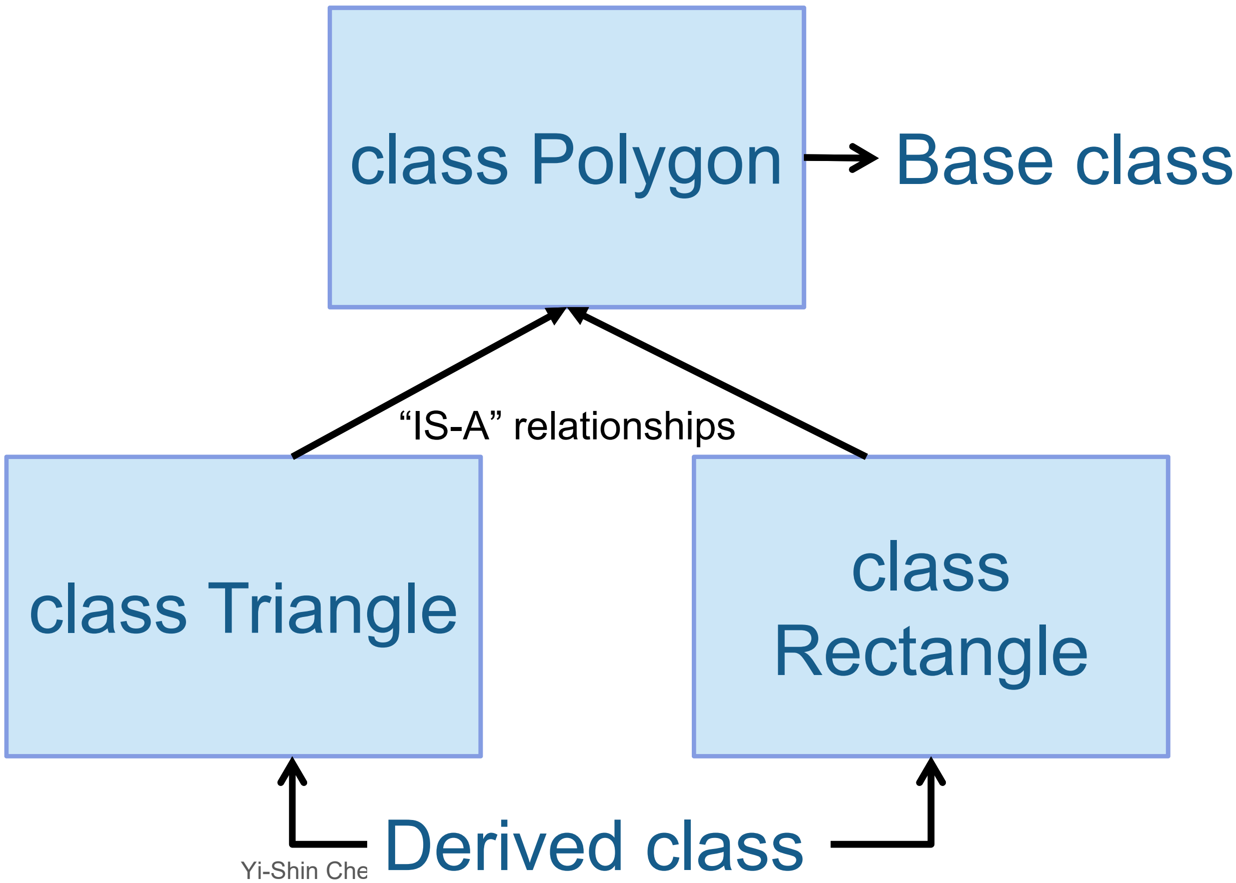
- C++ - "class"

```
class Student{
    int   age;
public:
    int   id;
    char   name[100];
};
```

Inheritance

- Relate one class object to another
- Define a “IS-A” relationships between objects
  - ***Type B*** **IS-A** data type of ***Type A*** if B is a **specialized** version of A and A is more **general** than B
- Members (data and functions) in Type A are implicitly copied to Type B.
- Reusability of codes

Class Diagram of inheritance



Access Specifier: public

- Base Class

```
class Polygon
{
private:
        int x;
protected:
        int y;
public :
        int z;

};
```

- Derived Class

```
class Triangle : public Polygon
{
private:


protected:


public :



};
```

Access Specifier: protected

- Base Class

```
class Polygon
{
private:
        int x;
protected:
        int y;
public :
        int z;
};
```

- Derived Class

```
class Triangle : protected Polygon
{
private:

protected:

public :

};
```

Access Specifier: private

- Base Class

```
class Polygon
{
private:
        int x;
protected:
        int y;
public :
        int z;

};
```

- Derived Class

```
class Triangle : private Polygon
{
private:



protected:

public :

};
```

Specialization

- Put non-common members in private block of base class
  - Derived class can not access these members
- Re-declare the members (data and functions) in the derived class (overriding)

Overriding

```
class Polygon {
public:
        …
        double CalArea ( ) { return 0.0;}
        …
};
```

```
class Triangle : public Polygon {
public:
        …
        // overriding CalArea function
        double CalArea () {
              // calculate triangle area
        }
};
```

```
Class Rectangle : public Polygon {
public:
        …
        // overriding CalArea function
        double CalArea ( ){
              // calculate rectangle area
/* if you want to access the original base class function*/
              Polygon::CalArea();
        }
};
```

Polymorphism

- Manipulate different objects through the common interface

```
class Foo
{
        public:
            virtual char* getName()
        { return "foo"; }
};
```

```
class Bar : public Foo
{
        public:
        virtual  char* getName()
        { return "Bar"; }
};
```

```
class Car : public Foo
{
        public:
       virtual char* getName()
        { return "Car"; }
};
```

```
processObj(Foo* _obj)
{… _obj->getName()…}
```

```
int main(){
        Foo* myFoo = new Foo;
        Foo* myBar = new Bar;
        Foo* myCar = new Car;

        processObj(myFoo);
        processObj(myBar);
        processObj(myCar);
}
```

Polymorphism

- Function Overloading
  - Data type is determined in compiler time

```
int main(){
	Foo myFoo;
	Bar myBar;
	Car myCar;

	processObj (myFoo);
	processObj (myBar);
	processObj (myCar);
}
```

- Dynamic Binding
  - Data type is determined in run time

```
int main(){
	Foo* myFoo = new Foo;
	Foo* myBar = new Bar;
	Foo* myCar = new Car;

	processObj(myFoo);
	processObj(myBar);
	processObj(myCar);
}
```

Dynamic Binding: Pros and Con

- Pros:
  - Ideal data abstraction.
  - Powerful mechanism of OOP (Design Pattern)
  - Widely used in large-scale software design
- Con:
  - Decreasing performance
    - Additional memory to store virtual function table
    - Additional runtime cost to access virtual function table

References

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