C++

程式語言（二）

Introduction to Programming (II)

Friend Functions & Friend Classes

Joseph Chuang-Chieh Lin

Dept. CSE, NTOU

Platform/IDE

- Dev-C++

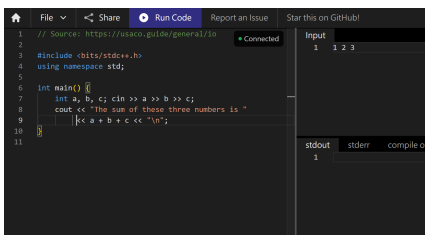
https://www.pngegg.com/en/search?q=Dev-C

- Codeblocks

https://icons8.com/icons/set/code-blocks

- OnlineGDB (https://www.onlinegdb.com/)

- Real-Time Collaborative Online IDE (https://ide.usaco.guide/)



Textbooks (We focusing on C++11)

- ***Learn C++ Programming by Refactoring* (由重構學習 C++ 程式設計). Pang-Feng Liu (劉邦鋒). NTU Press. 2023.**
- ***C++ Primer. 5th Edition.* Stanley B. Lippman, Josée Lajoie, Barbara E. Moo. 2019.**
- *Effective C++*. Scott Meyers. O'Reilly. 2016.
- *Thinking in C++. Vol. 1: Introducing to Standard C++*. 2nd Edition. Bruce Eckel. Prentice Hall PTR. 2000.

Useful Resources

- Tutorialspoint
  - https://www.tutorialspoint.com/cplusplus/index.htm
  - Online C++ Compiler
- Programiz
  - https://www.programiz.com/cpp-programming
- LEARN C++
  - https://www.learncpp.com/
- MIT OpenCourseWare - Introduction to C++
  - https://ocw.mit.edu/courses/6-096-introduction-to-c-january-iap-2011/pages/lecture-notes/
- Learning C++ Programming
  - https://www.programiz.com/cpp-programming
- GeeksforGeeks
  - https://www.geeksforgeeks.org/c-plus-plus/

Friend Functions

Friend Functions

Refer to the material at https://www.programiz.com/cpp-programming/friend-function-class

- A **friend function** can access the **private** and **protected** data of a class.
- We declare a friend function using the **`friend`** keyword **inside** the body of the class.

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

class Distance {
    private:
        int meter;

        // friend function
        friend int addFive(Distance);

    public:
        Distance() : meter(0) {}

};
```

```
// friend function definition
int addFive(Distance d) {

    //accessing private members from the friend function
    d.meter += 5;
    return d.meter;
}

int main() {
    Distance D;
    cout << "Distance: " << addFive(D);
    return 0;
}
```

Exercise

https://onlinegdb.com/wvkTzVLw5

- Try to make the friend function be "protected" or "public".
- See what we will get.

Another Example (Accessing two classes)

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

// forward declaration
class ClassB;

class ClassA {

public:
     // constructor to initialize numA to 12
     ClassA() : numA(12) {}

private:
     int numA;
     // friend function declaration
     friend int add(ClassA, ClassB);
};
```

```
class ClassB {

public:
     // constructor to initialize numB to 1
     ClassB() : numB(1) {}

private:
     int numB;

     // friend function declaration
     friend int add(ClassA, ClassB);
};

// access members of both classes
int add(ClassA objectA, ClassB objectB) {
    return (objectA.numA + objectB.numB);
}

int main() {
    ClassA objectA;
    ClassB objectB;
    cout << "Sum: " << add(objectA, objectB);
    return 0;
}
```

Friend Classes

Friend Classes

Refer to the material at https://www.programiz.com/cpp-programming/friend-function-class

- Take a whole class as a friend.

```
class ClassB;

class ClassA {
   // ClassB is a friend class of ClassA
    friend class ClassB;
   ... .. ...
}

class ClassB {
   ... .. ...
}
```

- When a class is declared a friend class, all the member functions of the friend class become friend functions.

Example

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

// forward declaration
class ClassB;

class ClassA {
private:
    int numA;

    // friend class declaration
    friend class ClassB;

public:
    // constructor to initialize numA to 12
    ClassA() : numA(12) {}
};
```

```
class ClassB {
private:
    int numB;

public:
    // constructor to initialize numB to 1
    ClassB() : numB(1) {}

    // member function to add numA
    // from ClassA and numB from ClassB
    int add() {
        ClassA objectA;
        return objectA.numA + numB;
    }
};
```

```
int main() {
    ClassB objectB;
    cout << "Sum: " << objectB.add();
    return 0;
}
```

Another Example

```
#include <iostream>

using namespace std;

class Box {
   double width;

   public:
      friend void printWidth(Box box);
      void setWidth( double wid );
};

// Member function definition
void Box::setWidth( double wid ) {
   width = wid;
}
```

```
void printWidth( Box box ) {
   cout << "Width of box : " << box.width
        <<endl;
}

// Main function for the program
int main() {
   Box box;
   box.setWidth(10.0);
   // Use friend function to print the width.
   printWidth(box);
   return 0;
}
```

An Example for Book Sales

https://onlinegdb.com/PSz0YMg0R

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

// Below we define the base class
class Quote {
    friend bool book_compare(Quote &item1, Quote &item2);
public:
    Quote() = default;
    Quote(const std::string &book, double sales_price):
        bookNo(book), price(sales_price) { }
    std::string isbn() const { return bookNo; }
    //returns the total sales price for the specified number of items
    virtual double net_price(std::size_t n)
        { return n * price; }
    virtual ~Quote() = default; // dynamic binding for the destructor
private:
    std::string bookNo;
protected:
    double price = 0.0;
};

//Below we define a class derived from the base class Quote
class Bulk_quote : public Quote {
public:
    Bulk_quote() = default;
    Bulk_quote(const std::string &book, double p, std::size_t qty, double disc):
        Quote(book, p), min_qty(qty), discount(disc) { }
    double net_price(std::size_t) override;
private:
    std::size_t min_qty = 0; // minimum purchase for the discount to apply
    double discount = 0.0; // the discount to apply
    //std::size_t total = 0; // a acount for the total sold volumes
};
```

```cpp
double Bulk_quote::net_price(size_t cnt)  {
    if (cnt >= min_qty)
        return cnt * (1-discount) * price;
    else
        return cnt * price;
}

bool book_compare(Quote &item1, Quote &item2) {
    return item1.price > item2.price;
}

int main()
{
    Quote item("NTOU is Love", 100.0);
    std::cout << "BOOK: " << item.isbn();
    std::cout << ", total cost: " << item.net_price(10) << std::endl;
    Bulk_quote bulk("NTOU Forever", 100.0, 5, 0.2);
    std::cout << "BOOK: " << bulk.isbn();
    std::cout << ", total cost: " << bulk.net_price(10) << std::endl;
    if (book_compare(item, bulk))
        std::cout << bulk.isbn() << " is cheaper!" << std::endl;
    else
        std::cout << bulk.isbn() << " is cheaper!" << std::endl;
    return 0;
}
```

Friend Function Can NOT be Inherited

https://onlinegdb.com/SzMrngR-02

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

class MyBaseClass {
   protected:
      int x;
   public:
      MyBaseClass() {
         x = 20;
      }
      friend void display();
};
class MyDerivedClass : public MyBaseClass {
   private:
      int y;
   public:
      MyDerivedClass() {
         x = 40;
      }
};
```

```
void display() {
   MyDerivedClass derived;
   cout << "The value of x of Base class is: "
        << derived.x << endl;
   cout << "The value of y of Derived class is: "
        << derived.y << endl;
}
```

```
int main() {
   display();
   return 0;
}
```

Exercise

```
class rectangle {
public:
     typedef double unit;
     unit area();
     void set(unit wd, unit ht);
private:
     unit width;
     unit height;
};
```

```
class triangle {
public:
     typedef int unit;
     unit area();
     void set(unit wd, unit ht);
private:
     unit width;
     unit height;
};
```

```
int main() {// DO NOT modify main()
     rectangle::unit x1, y1;
    rectangle obj1;
    cin >> x1 >> y1;
    triangle::unit x2, y2;
     triangle obj2;
     cin >> x2 >> y2;
    obj1.set(x1,y1);
    obj2.set(x2,y2);
     cout << area_sum(obj1, obj2) << endl;
     return 0;
}
```

```
Sample input:
2 5
3 6
```

```
Sample output:
19
```

Supplementary:

Can a constructor be "*private*"?

Create an object using a private constructor...

```
class MyClass {
private:
    MyClass() {}   // private constructor
};

// In main():
MyClass obj;  // Error: 'MyClass::MyClass()' is private
```

Scenarios (some design patterns)

- Singleton pattern
  - Ensure **only one object** is created.
- Static-only **utility** class
  - Prevent anyone from creating an instance.

```
class MathUtils {
private:
    MathUtils() {} // Prevent instantiation
public:
    static int square(int x) { return x * x; }
};
```

- Base class constructor as **protected**.
  - So that **only the derived classes** can call it.

Motivation for “Singleton”

- **Multiple** components of the system need access to **the same instance**.
- We don't want multiple copies, because that would lead to inconsistencies or waste of resources.
  - Logging to a file
  - Database connections
  - ...

Example: Logger

```
class Logger {
public:
    void log(string msg) { /* write to a log file */
}
};
```

```
Logger log1;
Logger log2;

log1.log("System started");
log2.log("User logged in");
```

- If each `Logger` object writes to its own file, your logs get scattered.
- We lose centralized tracking

Example: Logger

https://onlinegdb.com/ssmsm44ww

https://onlinegdb.com/aNnFWR4yZ

```
class Logger {
private:
    // Private constructor
    Logger() { cout << "[Logger created]" << endl;}

    // Private copy constructor and
     // assignment operator
    Logger(const Logger&) {
        cout << "[Copy constructor called]"
             << endl;
    }
    Logger& operator=(const Logger&) {
        cout << "[Assignment operator called]"
             << endl;
        return *this;
    }
    // Static instance pointer
    static Logger* instance;
```

```
public:
    // Public method to access the
     // instance
    static Logger* getInstance() {
        if (instance == nullptr) {
            instance = new Logger();
        }
        return instance;
    }

    void log(const string& message) {
        cout << "[LOG]: " << message
             << endl;
    }
};
// Remember to define the static member //
outside the class
Logger* Logger::instance = nullptr;
```

Example: Logger (x move constructor)

https://onlinegdb.com/WtqtrF5-B

```
class Logger {
private:
    // Private constructor
    Logger() { cout << "[Logger created]" << endl;}

    // Private copy constructor, move constructor
     // and assignment operator
    Logger(const Logger&) {
        cout << "[Copy constructor called]" << endl;
    }
    Logger& operator=(const Logger&) {
        cout << "[Assignment operator called]" << endl;
        return *this;
    }
    Logger(Logger&&) {// not working since it's private
         cout << "[Move constructor called]" << endl;
     }
    Logger& operator=(Logger&&) {
         cout << "[Assignment operator called]"<< endl;
         return *this;
     }
    // Static instance pointer
    static Logger* instance;
```

```
public:
    // Public method to access the
     // instance
    static Logger* getInstance() {
        if (instance == nullptr) {
            instance = new Logger();
        }
        return instance;
    }

    void log(const string& message) {
        cout << "[LOG]: " << message
             << endl;
    }
};
// Remember to define the static
// member outside the class
Logger* Logger::instance = nullptr;
```

Example: Logger

```
[Logger created]
[LOG]: System started
[LOG]: User logged in
logger1 and logger2 are the same instance.
```

```
int main() {
    Logger* logger1 = Logger::getInstance();
    logger1->log("System started");

    Logger* logger2 = Logger::getInstance();
    logger2->log("User logged in");

    // Check if logger1 and logger2 are the same object
    if (logger1 == logger2) {
        cout << "logger1 and logger2 are the same instance."
             << endl;
    }
}
```

Example: Logger (cleaner)

```
class Logger {
private:
    // Private constructor
    Logger() { cout << "[Logger created]" << endl;}

    // 'delete' the copy and move constructors and
    // the use of assignment
    Logger(const Logger&) = delete;
    Logger& operator=(const Logger&) = delete;
    Logger(Logger& operator=(const Logger&) = delete;
    Logger& operator=(Logger&&) = delete;

    // Static instance pointer:
    // static Logger* instance;
```

https://onlinegdb.com/sp0wcNBNe

```
public:
    // create the instance once and
    // reuse it forever
    static Logger* getInstance() {
        static Logger instance;
        return instance;
    }

    void log(const string& message) {
        cout << "[LOG]: " << message
             << endl;
    }
};
// Remember to define the static
// member outside the class
Logger* Logger::instance = nullptr;
```

Example: Logger
(cleaner case)

```
[Logger created]
[LOG]: System started
[LOG]: User logged in
logger1 and logger2 are the same instance.
```

```
int main() {
    Logger& logger1 = Logger::getInstance();
    Logger1.log("System started");

    Logger& logger2 = Logger::getInstance();
    Logger2.log("User logged in");

    // Check if logger1 and logger2 are the same object
    if (&logger1 == &logger2) {
        cout << "logger1 and logger2 are the same instance."<< endl;
    }
}
```

Example: Logger

- Effect achieved:

Prevent external creation	⇨	**private constructor**
Ensure only one instance	⇨	**static** (pointer) `Logger::instance`
Controlled access	⇨	`getInstance` returns that one object
Safe from accidental copies	⇨	`delete` (or private) copy constructor & assignment

- Compile-time errors:

```
Logger x = *Logger::getInstance();  // copy
Logger y;     // direct constructor
```

Example: Logger

- We can also use friend function to invoke the private constructor.
  - But it's usually not recommended.

```
class Logger {
private:
    // Private constructor
    Logger() { cout << "[Logger created]" << endl;}
    ...

    // grant this free function full access:
    friend Logger* createLogger();
};

// friend factory can invoke private constructor:
Logger* createLogger() {
    return new Logger();
}
```

Discussions & Questions