Data Structure Program Assignment #4
(Due: 12:00 PM (noon), April 12, 2025)

Template Bag Class and Inheritance

Instructor: Jiann-Jone Chen

● Introduction

Templates in C++ allow for the creation of parameterized types, making it easier to reuse both classes and functions. In this project, you are required to utilize templates to implement various container classes, such as Bag, Queue, and Stack. To promote code reuse and a cleaner design, inheritance will also be applied in structuring these container classes.

As demonstrated in lecture, template functions can be effectively used in the implementation of stack and queue classes, allowing container classes to operate generically with different data types.

The **Bag** class will serve as a **base class**, from which other container classes like **Stack** and **Queue** can be derived. Below is the definition of the template-based **Bag** class:

● Steps

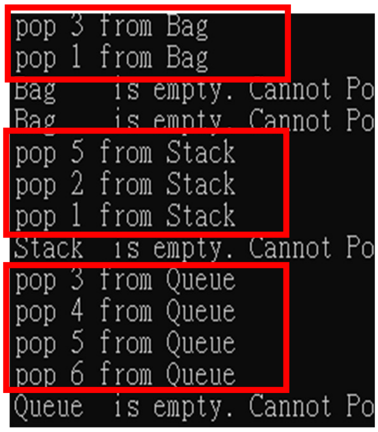
1. Design the base class, Bag Class

As shown, basic member functions (IsEmpty(), IsFull(), Empty(), Full()) and data members (*array, capacity, top, name[10]) are defined in this base class, so derived classes, Stack and Queue, can reuse them to eliminate the time-consuming redesign process. Since the data are stored and accessed through the pointer, the T *array is defined in the Bag class. A friend function

```
friend ostream& operator<<<>(ostream&, const Bag <T>&);
```

is designed in the Bag class to print out the data stored in the array of a derived class.

A member function `void message(const T& x);` is declared to deal with the message printing. For example, when you pop( ) a value x=5 from the stack class, the program had to print out pop 5 from Stack. As shown on the right figure.



```
pop 3 from Bag
pop 1 from Bag
Bag    is empty. Cannot Po
Bag    is empty. Cannot Po
pop 5 from Stack
pop 2 from Stack
pop 1 from Stack
Stack  is empty. Cannot Po
pop 3 from Queue
pop 4 from Queue
pop 5 from Queue
pop 6 from Queue
Queue  is empty. Cannot Po
```

```
#include <iostream>
#include <string.h>
#include <iomanip>
using namespace std;

template <class T>
class Bag {
     friend    ostream& operator<<<>(ostream&, const Bag <T>&);
public:
     Bag(int BagSize) :MaxSize(BagSize), name("Bag"), top(0) {
          array = new T[MaxSize];
     };
     ~Bag() {delete[] array; };   // destructor
     virtual int  Size() const;
     virtual bool IsEmpty() const;
     virtual bool IsFull() const;
     virtual void Push(const T&);
     virtual T* Pop(T &);
protected:
     T *array;
     int MaxSize;
     int top;   // position of the top element
     char name[20];
     void Empty() {
      cout <<"   "<< setw(6) << left << name << " is empty. Cannot Pop()\n";  };
     void Full(const T& x) {
      cout <<"   "<< setw(6) << left << name << " is full for " << x << endl; };
     void message(const T& x);
};

template <class T>
ostream& operator<<<>(ostream& os, const Bag <T>& b) {
     os << "   All Data in "<<right<<setw(6)<<b.name<< '['<<b.MaxSize<<"] are: ";
     for (int i = 0; i < b.MaxSize; i++)
          os << "(" << i << ") " << b.array[i] << setw(3) << " ";

     os << "\n   Valid data among them are: ";
     for (int i = 0; i < b.top; i++)
          os << "(" << i << ") " << b.array[i] << setw(3) << " ";
     cout << "\n\n";
     return os;
}
```

2. Design a Derived Class: a Stack Class

In a Stack class, the Push() function is the same as that in the Bag class, but the Pop() function is different. (In lecture notes, it is the delete() function).   That’s why only the Pop() function is re-designed.

```
#include "bag.h"

template <class T>
class Stack:public Bag<T> {

public:
    Stack(int StackCapacity) :Bag(StackCapacity) {
        strcpy(name, "Stack");
    };
    ~Stack() {};
    T* Pop(T &); // delete the top-most element from a stack
};
```

3. Design a derived Class: the Queue Class

In the Queue class, we adopt a circular queue structure to store the data to avoid frequent data shift operations. Both Push() and Pop() functions have to be re-designed to implement the required data operations. In addition, the operator overloading function

```
friend ostream& operator<<<>(ostream&, const Queue <T>&);
```

had to be re-designed to print out the data stored in the circular queue.

```
#include "bag.h"
template <class T>
class Queue:public Bag<T> {
    friend    ostream& operator<<<>(ostream&, const Queue <T>&);

public:
    Queue(int QueueSize):Bag(QueueSize) {
        front = rear = -1;
        strcpy(name, "Queue");
    };
    ~Queue() {};
    T* Pop(T&);          // delete the element from queue
    void Push(const T&);
private:
    int rear, front; // circular list implementation
};
```

4. The main program, main.cpp, is shown below.

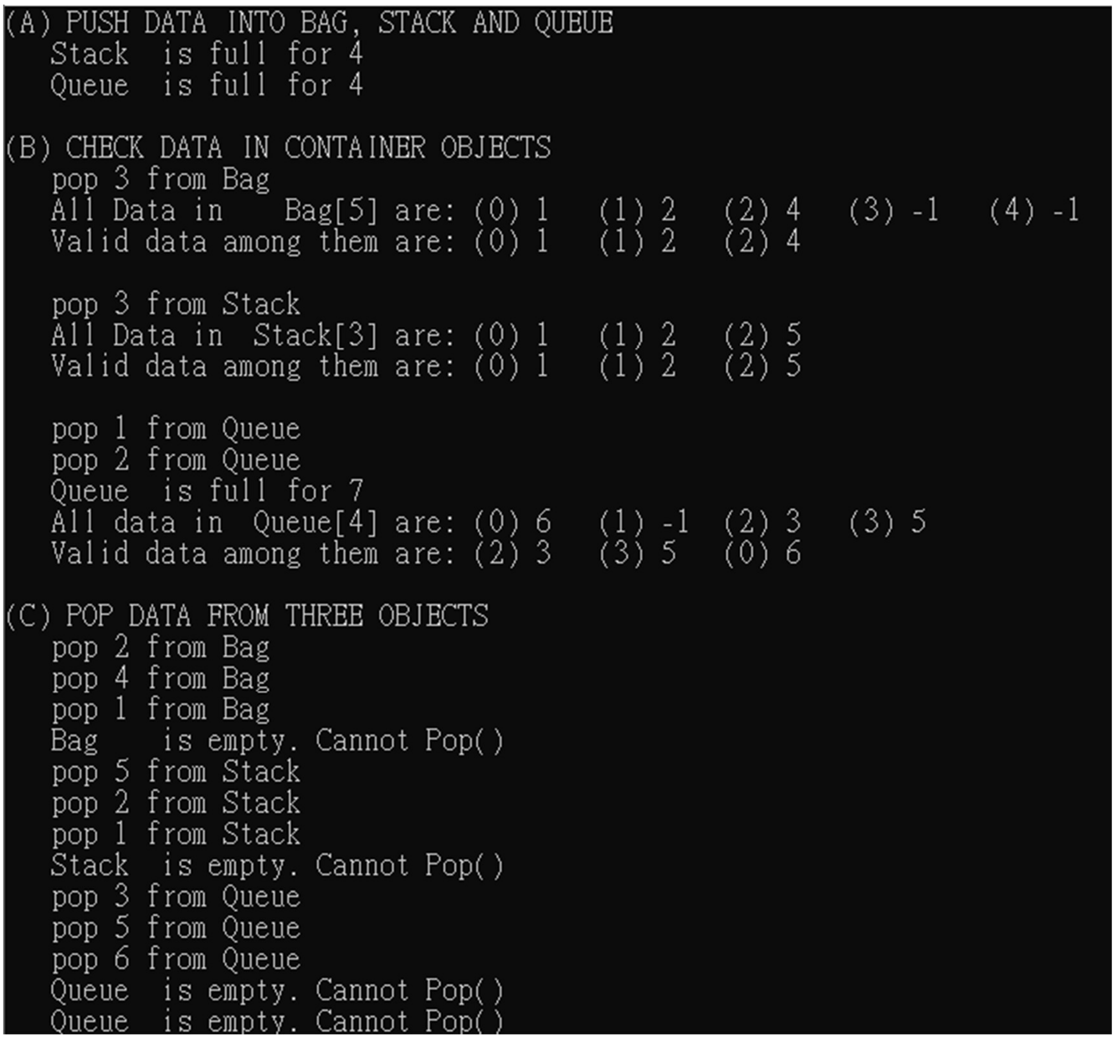
```
// solved program
#include "stack.h"
#include "bag.h"
#include "queue.h"
#include "deque.h"
int main(){
     Bag<int> b(5);      // uses Bag constructor to create array of size 3
     Stack<int> s(3);    // uses Stack constructor to create array of size 3
     Queue<int> q(4);    // circular queue needs one more pace
     int i = 0, x[8] = { 1, 2, 3, 4, 5, 6, 7, 8 }, t;
     cout << "(A) PUSH DATA INTO BAG, STACK AND QUEUE\n";
          while(i < 4) {
               b.Push(x[i]);    // use Bag::Push
               s.Push(x[i]);    // Stack::Push not defined, use Bag::Push
               q.Push(x[i++]);    // Queue::Push override Bag::Push for circular
list
          }
          cout << "\n(B) CHECK DATA IN CONTAINER OBJECTS\n";
          b.Pop(t); cout << b;
          s.Pop(t); s.Push(x[4]);  cout << s;
          q.Pop(t); q.Pop(t);
          q.Push(x[4]); q.Push(x[5]); q.Push(x[6]);
          cout << q;

          cout << "(C) POP DATA FROM THREE OBJECTS\n";
          i = 0;  while (i < 4) b.Pop(x[i++]);
          i = 0;  while (i < 4) s.Pop(x[i++]);
          i = 0;  while (i < 5) q.Pop(x[i++]);

          cout << "(D) DOUBLE ENDED QUEUE\n";

     // BONUS Parts
     Deque <int> dq(4);
          dq.Popr(t);
          dq.Pushf(3); dq.Pushr(2);
          dq.Pushf(4); dq.Pushr(1);
          dq.Pushf(5);
          dq.Popr(t);     dq.Popf(t);
          cout << dq;
     return 0;
};
```

The execution results are shown below:



```
(A) PUSH DATA INTO BAG, STACK AND QUEUE
   Stack  is full for 4
   Queue  is full for 4

(B) CHECK DATA IN CONTAINER OBJECTS
   pop 3 from Bag
   All Data in    Bag[5] are: (0) 1   (1) 2   (2) 4   (3) -1   (4) -1
   Valid data among them are: (0) 1   (1) 2   (2) 4

   pop 3 from Stack
   All Data in  Stack[3] are: (0) 1   (1) 2   (2) 5
   Valid data among them are: (0) 1   (1) 2   (2) 5

   pop 1 from Queue
   pop 2 from Queue
   Queue  is full for 7
   All data in  Queue[4] are: (0) 6   (1) -1  (2) 3   (3) 5
   Valid data among them are: (2) 3   (3) 5   (0) 6

(C) POP DATA FROM THREE OBJECTS
   pop 2 from Bag
   pop 4 from Bag
   pop 1 from Bag
   Bag    is empty. Cannot Pop()
   pop 5 from Stack
   pop 2 from Stack
   pop 1 from Stack
   Stack  is empty. Cannot Pop()
   pop 3 from Queue
   pop 5 from Queue
   pop 6 from Queue
   Queue  is empty. Cannot Pop()
   Queue  is empty. Cannot Pop()
```

5. A demo project is provided for you to quickly start designing the program. Click the bag.sln file to start the programming.

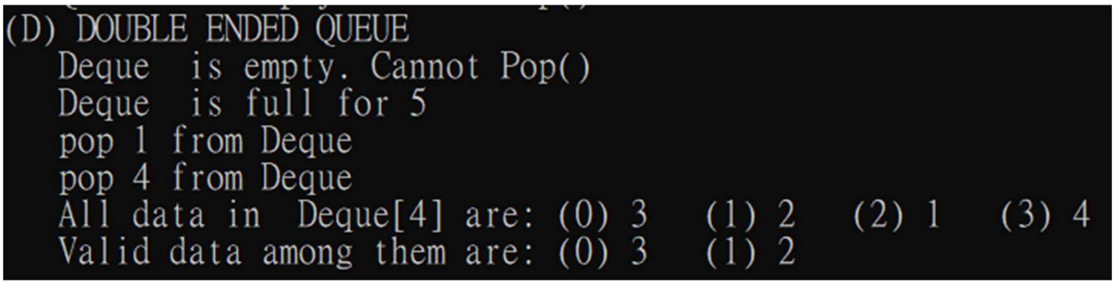
- **Requirement (85%)**
  1. Use your student ID to Name the directory of your project so the TA could recompile and verify your programs.
  2. Write a short report to describe
     (1) What is all about the program?
     (2) Describe your program by writing notes for each instruction.
     (3) How do you improve this program? List your contributions.

- Bonus: (15%)
  1. In our lecture, a circular queue with capacity n can only utilize n-

1 item space instead of n. Can you modify the algorithm to fully utilize all available space?

2. You are encouraged to modify the queue class to enable push and pop from both sides, i.e., a double-ended queue class (Deque) with Pushf(), Pushr(), Popf(), and Popr() functions, in which Pushf() means Push from the front and Popr() means Pop from the rear. When the following instructions are added, execution results look like in the following back figure.

```
        cout << "(D) DOUBLE ENDED QUEUE\n";
    Deque <int> dq(4);
        dq.Popr(t);
        dq.Pushf(3); dq.Pushr(2);
        dq.Pushf(4); dq.Pushr(1);
        dq.Pushf(5);
        dq.Popr(t);  dq.Popf(t);
        cout << dq;
```



```
(D) DOUBLE ENDED QUEUE
   Deque  is empty. Cannot Pop()
   Deque  is full for 5
   pop 1 from Deque
   pop 4 from Deque
   All data in  Deque[4] are: (0) 3   (1) 2   (2) 1   (3) 4
   Valid data among them are: (0) 3   (1) 2
```

- Note: For this homework, you can discuss with other classmates about the program design instead of copying programs. Don’t share your program with others If you finished the project very early, Otherwise, the credits will also be shared by students who submit the same program contents.