第二课 栈、队列、堆

林沐

内容概述

1.7道经典**栈、队列、堆**的相关题目

- 例1:使用队列实现栈 (easy) (栈、队列)
- 例2:使用栈实现队列 (easy) (栈、队列)
- 例3:包含min函数的栈 (easy) (栈)
- 例4:合法的出栈序列 (medium) (栈、队列)
- 例5:简单的计算器(hard) (栈)
- 例6:数组中第K大的数(easy) (堆)
- 例7:寻找中位数(hard) (堆)

2.详细讲解题目**解题方法**、**代码实现**

预备知识:STL stack (栈)

栈，先进后出的线性表。

```
#include <stdio.h>
#include <stack>
int main(){
    std::stack<int> S;
    if (      1      ){
        printf("S is empty!");
    }
    S.push(5);
    S.push(6);
            2

    printf("S.top = %d\n", S.top());
    S.pop();
            3
    printf("S.top = %d\n", S.top());
    printf("S.size = %d\n", S.size());
    return 0;
}
```

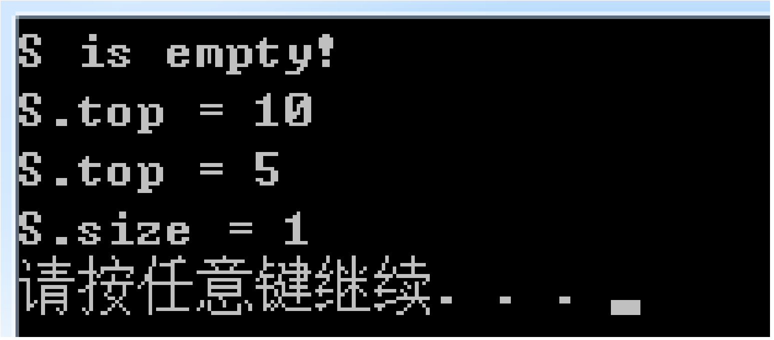
S.top()：取出栈顶

S.empty()：判断栈是否为空

S.push(x)：将x添加至栈

S.pop()：弹出栈顶

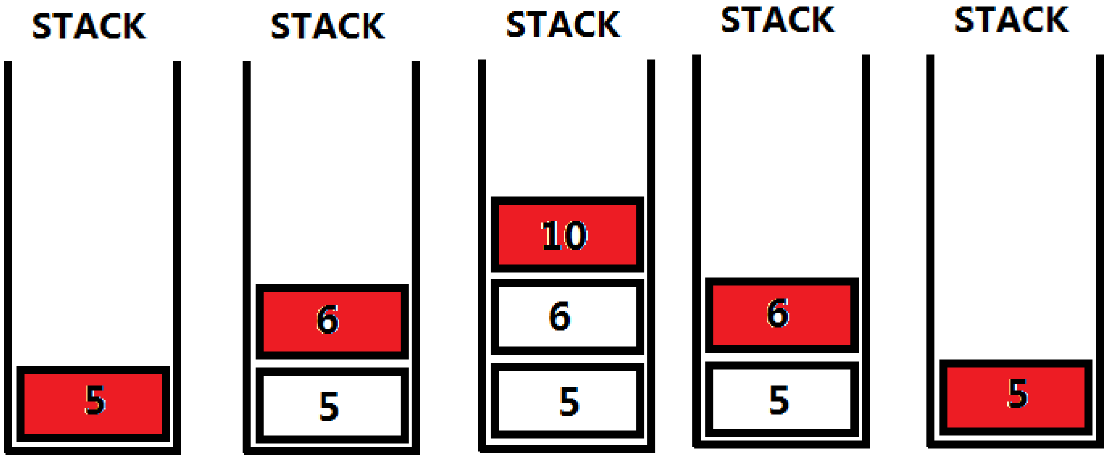
S.size()：栈的存储元素个数

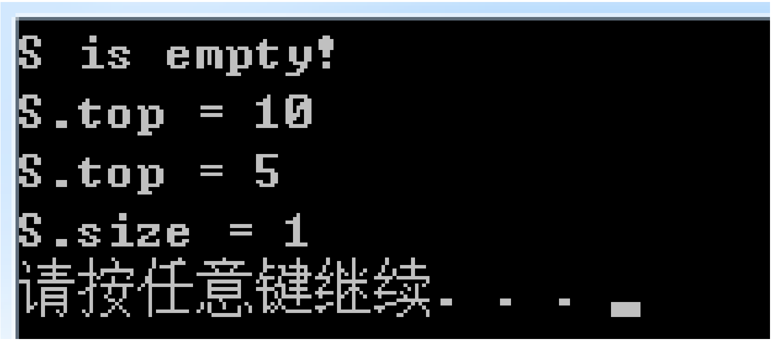


```
S is empty!
S.top = 10
S.top = 5
S.size = 1
请按任意键继续. . .
```

预备知识:STL stack (栈)

```
#include <stdio.h>
#include <stack>
int main(){
    std::stack<int> S;
    if (S.empty()){
        printf("S is empty!");
    }
    S.push(5);
    S.push(6);
    S.push(10);

    printf("S.top = %d\n", S.top());
    S.pop();
    S.pop();
    printf("S.top = %d\n", S.top());
    printf("S.size = %d\n", S.size());
    return 0;
}
```





```
S is empty!
S.top = 10
S.top = 5
S.size = 1
请按任意键继续. . . _
```

预备知识:STL queue(队列)

队列，先进先出的线性表。

```
#include <stdio.h>
#include <queue>
int main(){
    std::queue<int> Q;
    if (Q.empty()){
        printf("Q is empty!\n");
    }
                1
    Q.push(6);
    Q.push(10);
    printf("Q.front = %d\n", Q.front());
    Q.pop();
                2
    printf("Q.front = %d\n", Q.front());
                3
    printf("Q.back = %d\n", Q.back());
    printf("Q.size = %d\n", Q.size());
    return 0;
}
```

Q.empty(): 判断队列是否为空

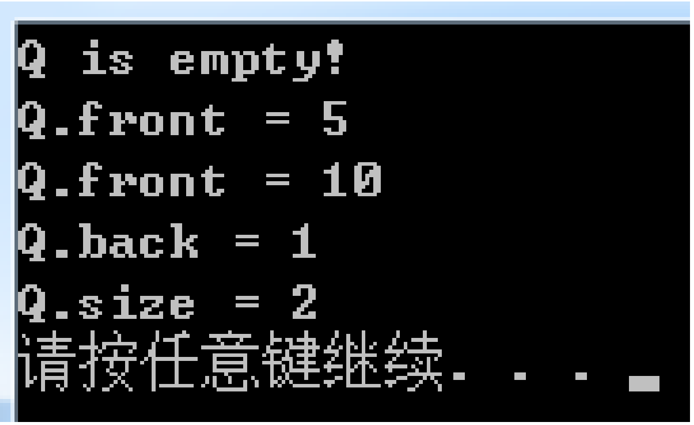
Q.front(): 返回队列头部元素

Q.back(): 返回队列尾部元素

Q.pop(): 弹出队列头部元素

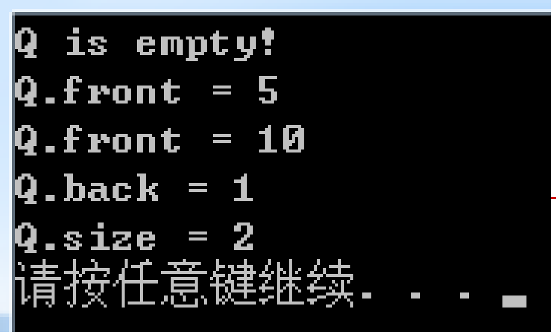
Q.push(x): 将x添加至队列

Q.size(): 返回队列的存储元素的个数



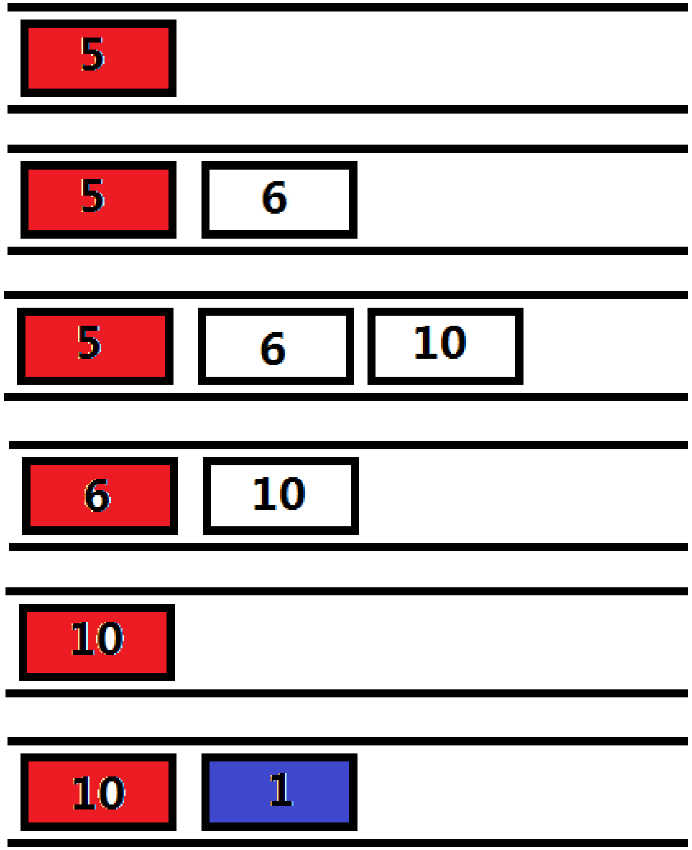
```
Q is empty!
Q.front = 5
Q.front = 10
Q.back = 1
Q.size = 2
请按任意键继续. . .
```

预备知识:STL queue(队列)



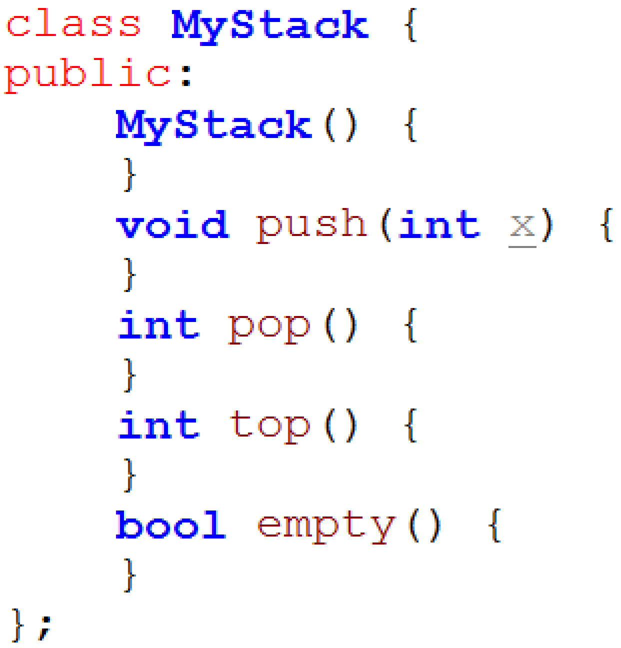
```
Q is empty!
Q.front = 5
Q.front = 10
Q.back = 1
Q.size = 2
请按任意键继续. . .
```

```
#include <stdio.h>
#include <queue>
int main(){
    std::queue<int> Q;
    if (Q.empty()){
        printf("Q is empty!\n");
    }
          Q.push(5);
    Q.push(6);
    Q.push(10);
    printf("Q.front = %d\n", Q.front());
    Q.pop();
          Q.pop();
    printf("Q.front = %d\n", Q.front());
          Q.push(1);
    printf("Q.back = %d\n", Q.back());
    printf("Q.size = %d\n", Q.size());
    return 0;
}
```



例1:使用队列实现栈

设计一个**栈**，支持如下操作，这些操作的算法复杂度需要是**常数级，O(1)**，**栈**的内部存储数据的结构为**队列**，队列的方法只能包括push、peek(front)、pop、size、empty等**标准的队列方法**



```
class MyStack {
public:
    MyStack() {
    }
    void push(int x) {
    }
    int pop() {
    }
    int top() {
    }
    bool empty() {
    }
};
```

1.**push(x)**：将元素x压入栈中

2.**pop()**：弹出(移除)栈顶元素

3.**top()**：返回栈顶元素

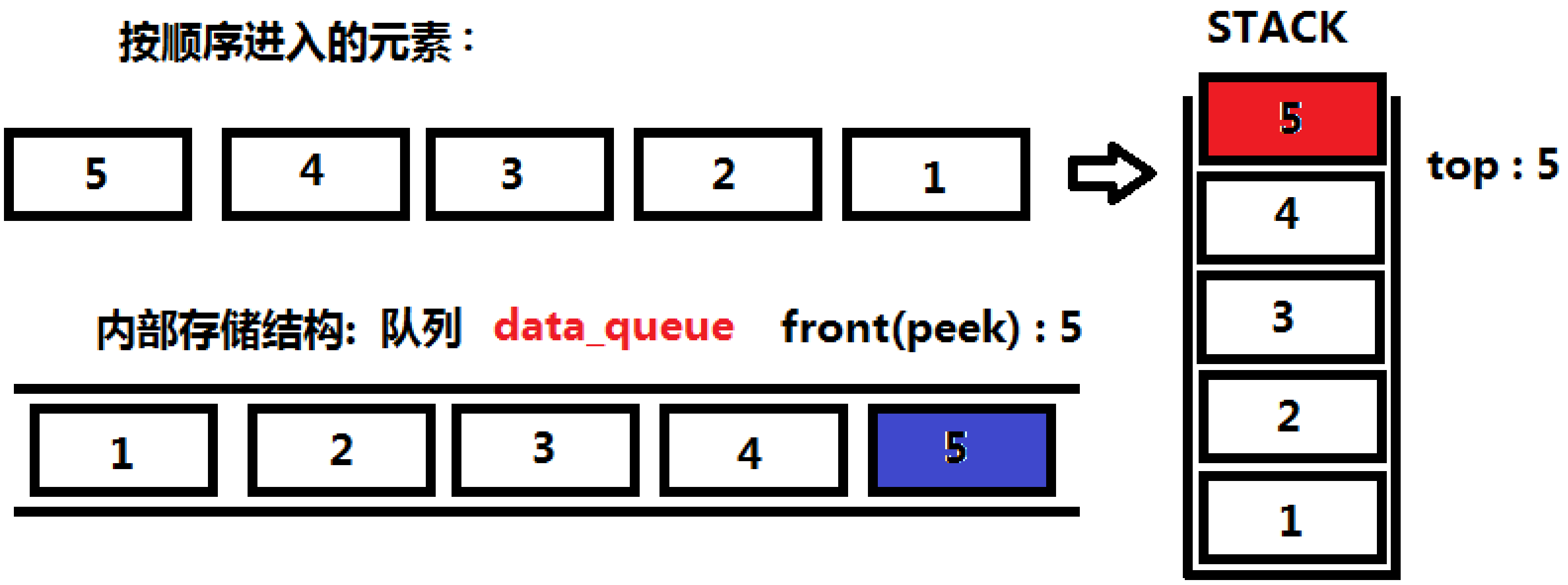
4.**empty()**：判断栈是否是空

选自 **LeetCode 225. Implement Stack using Queues**

https://leetcode.com/problems/implement-stack-using-queues/description/

难度:**Easy**

例1:思考



1.**push(x)** ：？ ？ ？ **(思考半分钟)**

2.**pop()** ：弹出(移除)栈顶元素，即弹出(移除)队列头部元素

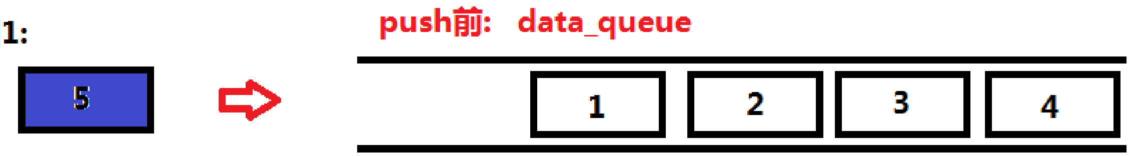
3.**top()**：返回栈顶元素，即返回队列头部元素(front)

4.**empty()** :判断队列是否是空，即判断队列是否为空

例1:思路

方案: 在STACK push元素时，利用临时队列调换元素次序

图1:



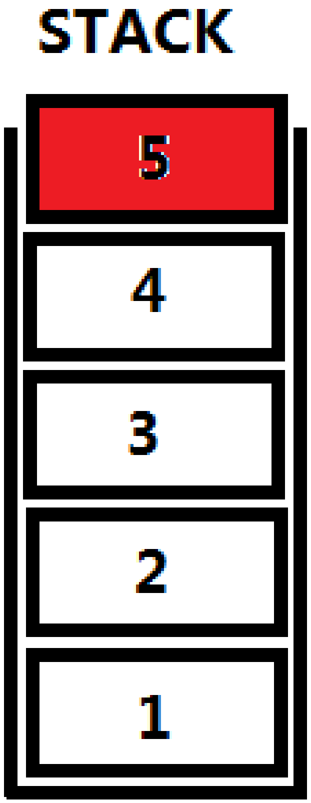


图2: 将新元素push进入 临时队列 temp_queue

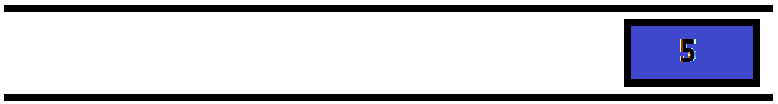


图3: 将原队列内容push进入 临时队列 temp_queue

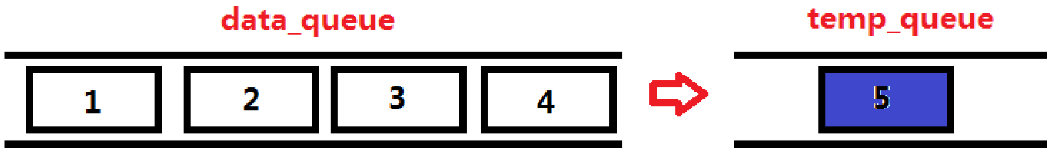


图4: 将临时队列 temp_queue 元素 push进入数据队列data_queue

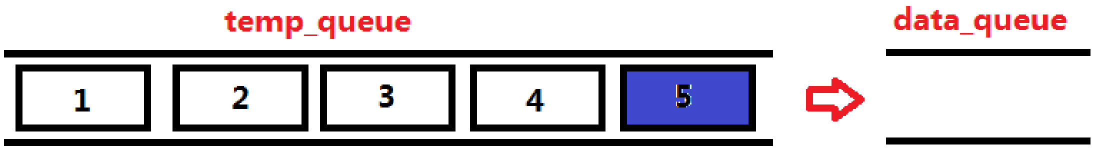
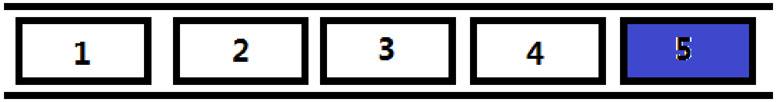


图5: 最终data queue结果:



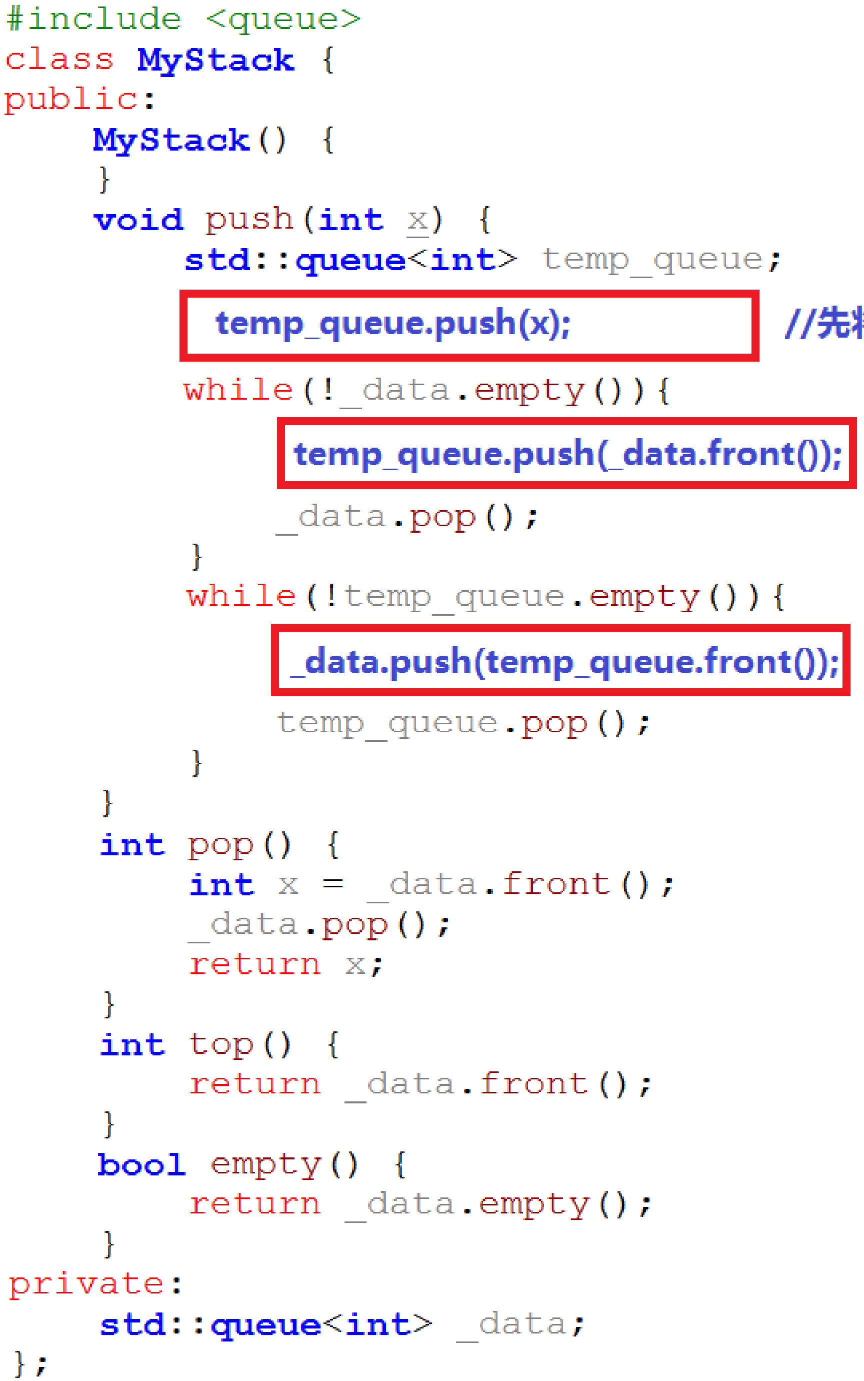
例1:实现，课堂练习

```
#include <queue>
class MyStack {
public:
    MyStack() {
    }
    void push(int x) {
        std::queue<int> temp_queue;
        [            1            ]
        while(!_data.empty()){
            [            2            ]
            _data.pop();
        }
        while(!temp_queue.empty()){
            [            3            ]
            temp_queue.pop();
        }
    }
    int pop() {
        int x = _data.front();
        _data.pop();
        return x;
    }
    int top() {
        return _data.front();
    }
    bool empty() {
        return _data.empty();
    }
private:
    std::queue<int> _data;
};
```

3分钟时间填写代码，

有问题随时提出！

例1:实现



```
#include <queue>
class MyStack {
public:
    MyStack() {
    }
    void push(int x) {
        std::queue<int> temp_queue;
        temp_queue.push(x);
        while(!_data.empty()){
            temp_queue.push(_data.front());
            _data.pop();
        }
        while(!temp_queue.empty()){
            _data.push(temp_queue.front());
            temp_queue.pop();
        }
    }
    int pop() {
        int x = _data.front();
        _data.pop();
        return x;
    }
    int top() {
        return _data.front();
    }
    bool empty() {
        return _data.empty();
    }
private:
    std::queue<int> _data;
};
```

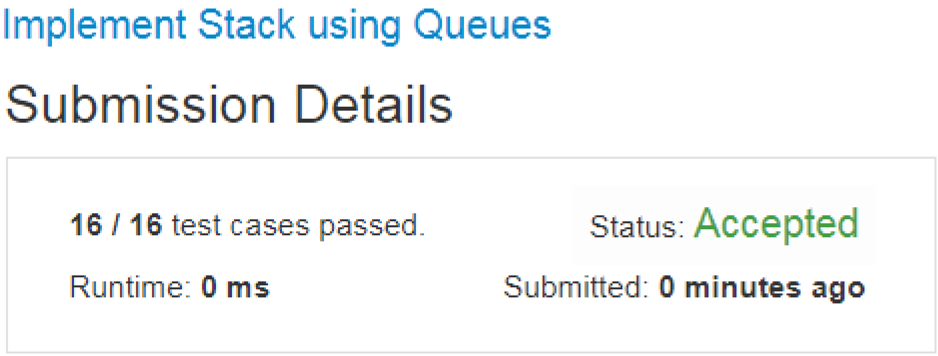
//先将新元素push进入temp_queue

//将数据队列元素导入临时队列

//将临时队列元素再导入数据队列

例1:测试与leetcode提交结果

```
int main(){
    MyStack S;
    S.push(1);
    S.push(2);
    S.push(3);
    S.push(4);
    printf("%d\n", S.top());
    S.pop();
    printf("%d\n", S.top());
    S.push(5);
    printf("%d\n", S.top());
    return 0;
}
```



Implement Stack using Queues

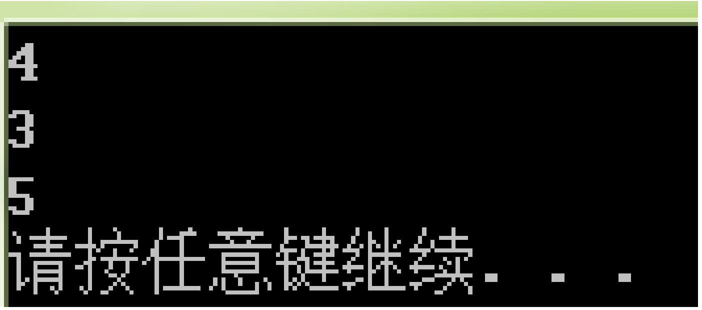
Submission Details

16 / 16 test cases passed.

Status: Accepted

Runtime: **0 ms**

Submitted: **0 minutes ago**



```
4
3
5
请按任意键继续. . .
```

例2:使用栈实现队列

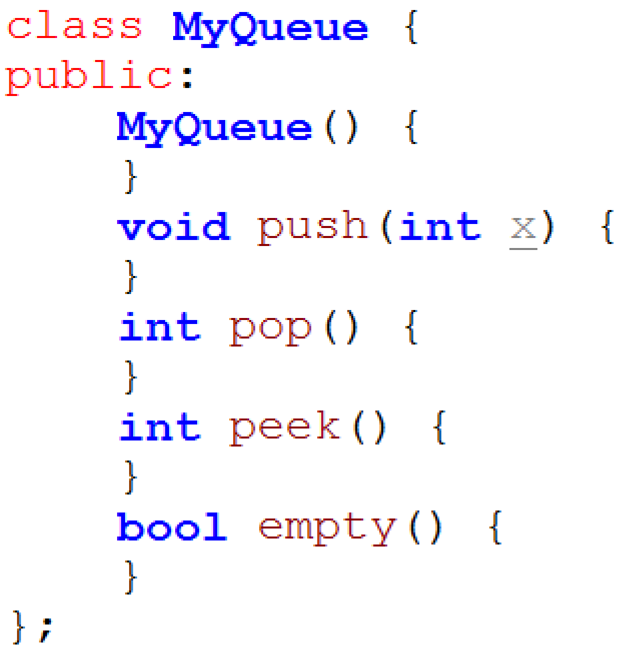
设计一个**队列**，**队列**支持如下操作，这些操作的算法复杂度需要是**常数级，O(1)**，**队列**的内部存储数据的结构为**栈**，栈的方法只能包括push、top、pop、size、empty等**标准的栈方法**

1.**push(x)** : 将元素x压入队列中

2.**pop()** : 弹出(移除)队列头部元素

3.**peek()** : 返回队列头部元素(即为front)

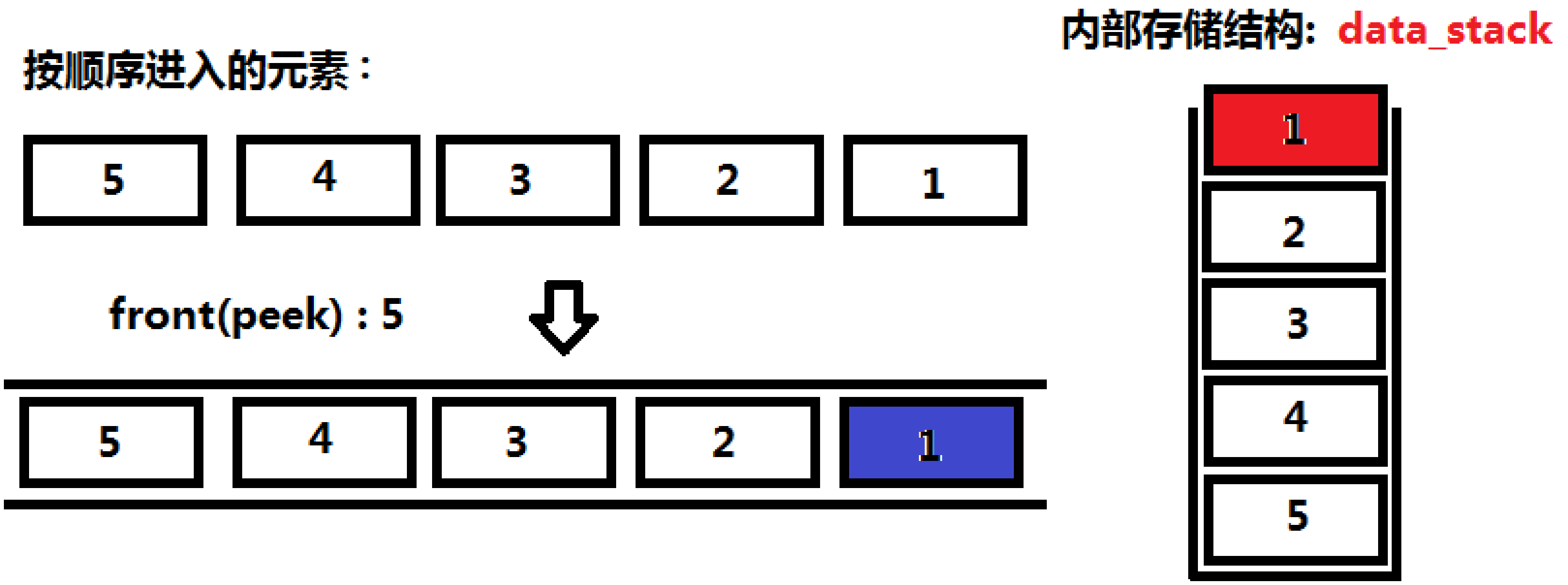
4.**empty()** : 判断队列是否是空



```
class MyQueue {
public:
    MyQueue() {
    }
    void push(int x) {
    }
    int pop() {
    }
    int peek() {
    }
    bool empty() {
    }
};
```

选自 **LeetCode 232. Implement Queue using Stacks**
https://leetcode.com/problems/implement-queue-using-stacks/description/
难度:**Easy**

例2:思考



1.**push(x)** ：？ ？ ？ **(思考半分钟)**

2.**pop()** :弹出(移除)队列头部元素，即弹出(移除)栈头部元素

3.**peek()** :返回队列头部元素(即为front)，即返回栈顶元素(top)

4.**empty()** :判断队列是否是空，即判断栈是否为空

例2:思路

方案: 在 队列 push元素时，利用临时 栈 调换元素次序

图1:

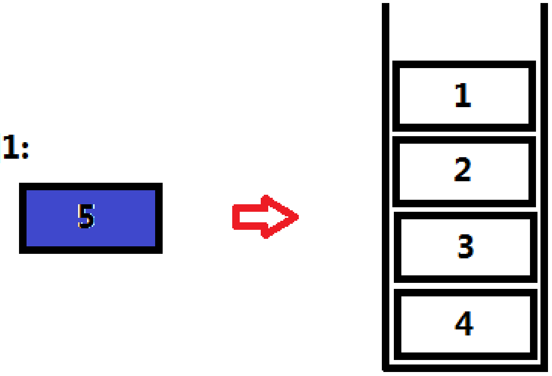


图2: 将原数据栈内容 push 进入 临时栈 temp_stack

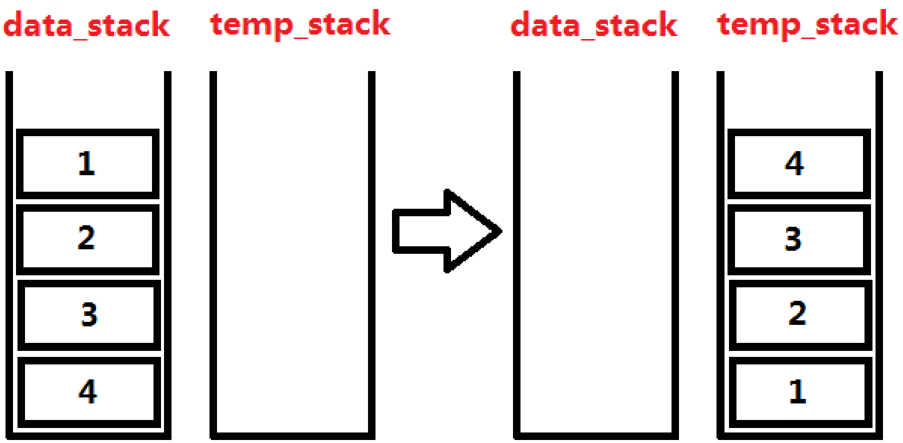


图3:将新数据 push 进入 临时栈 temp_stack

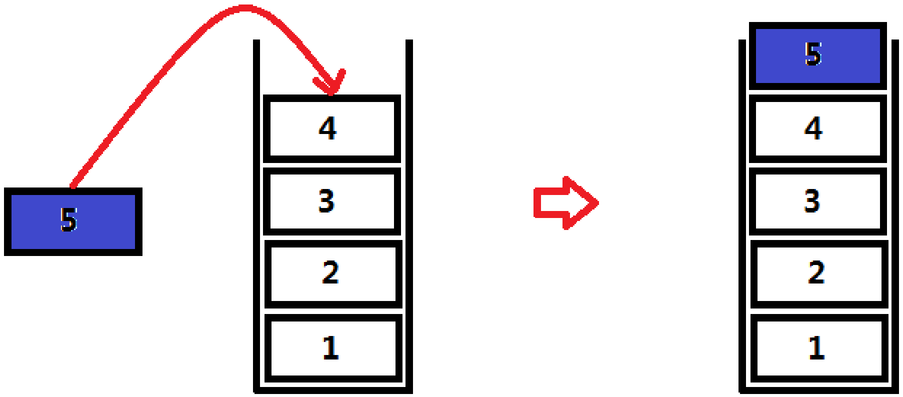
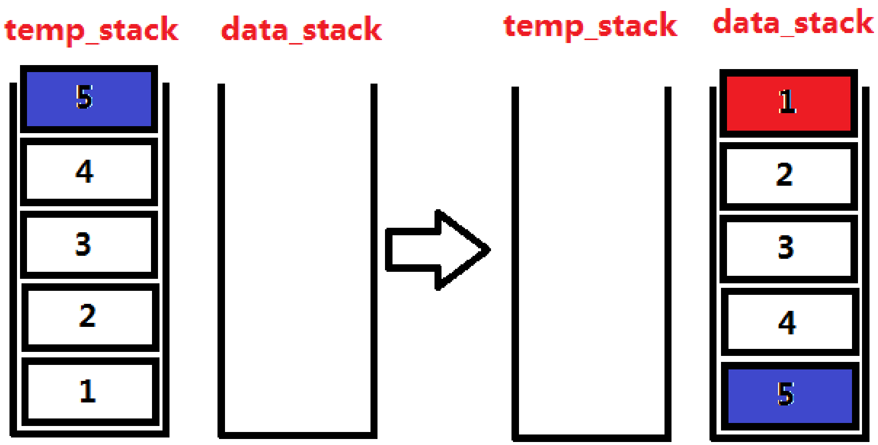
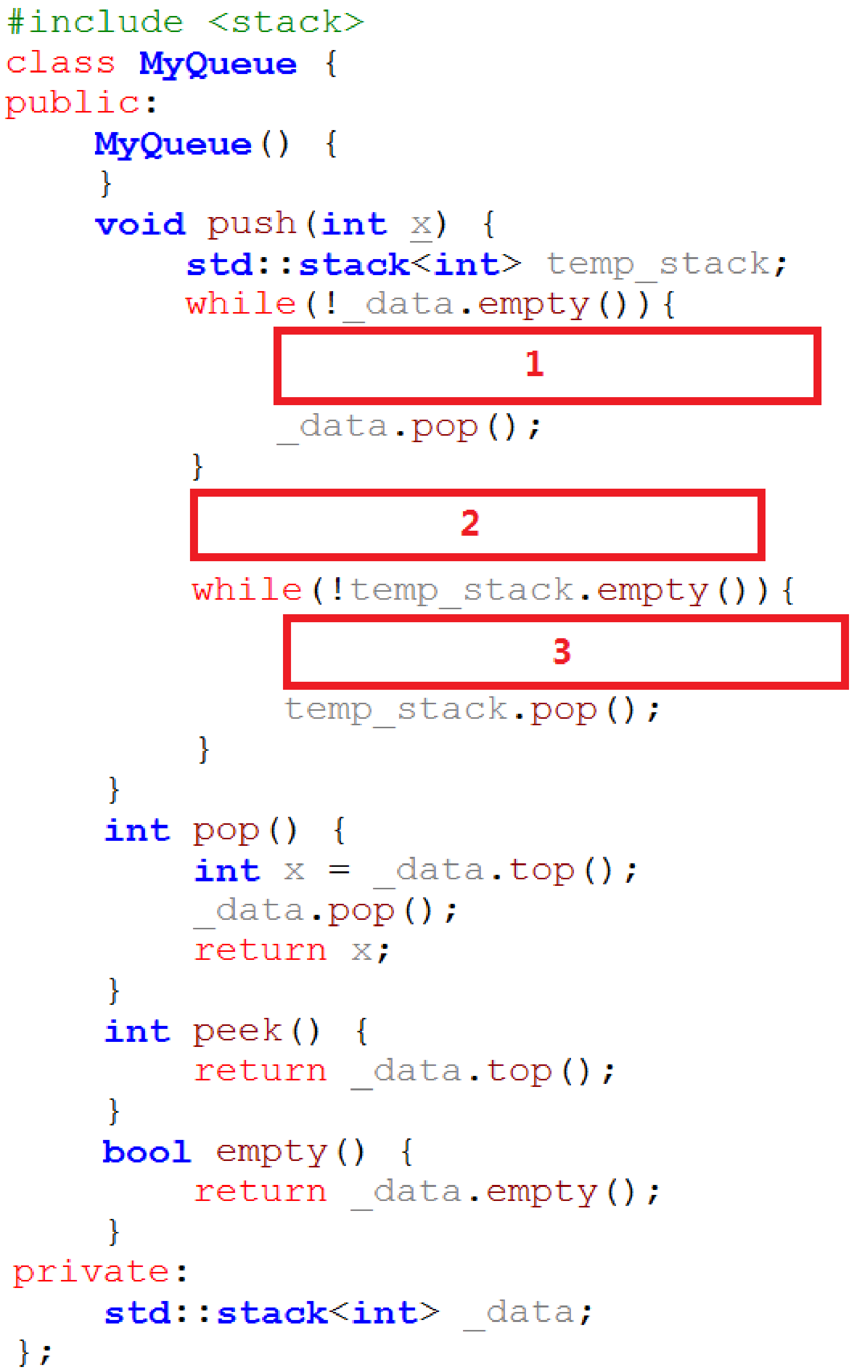


图4:将临时栈temp_stack 中的元素push进入 数据栈data_stack



例2:实现，课堂练习

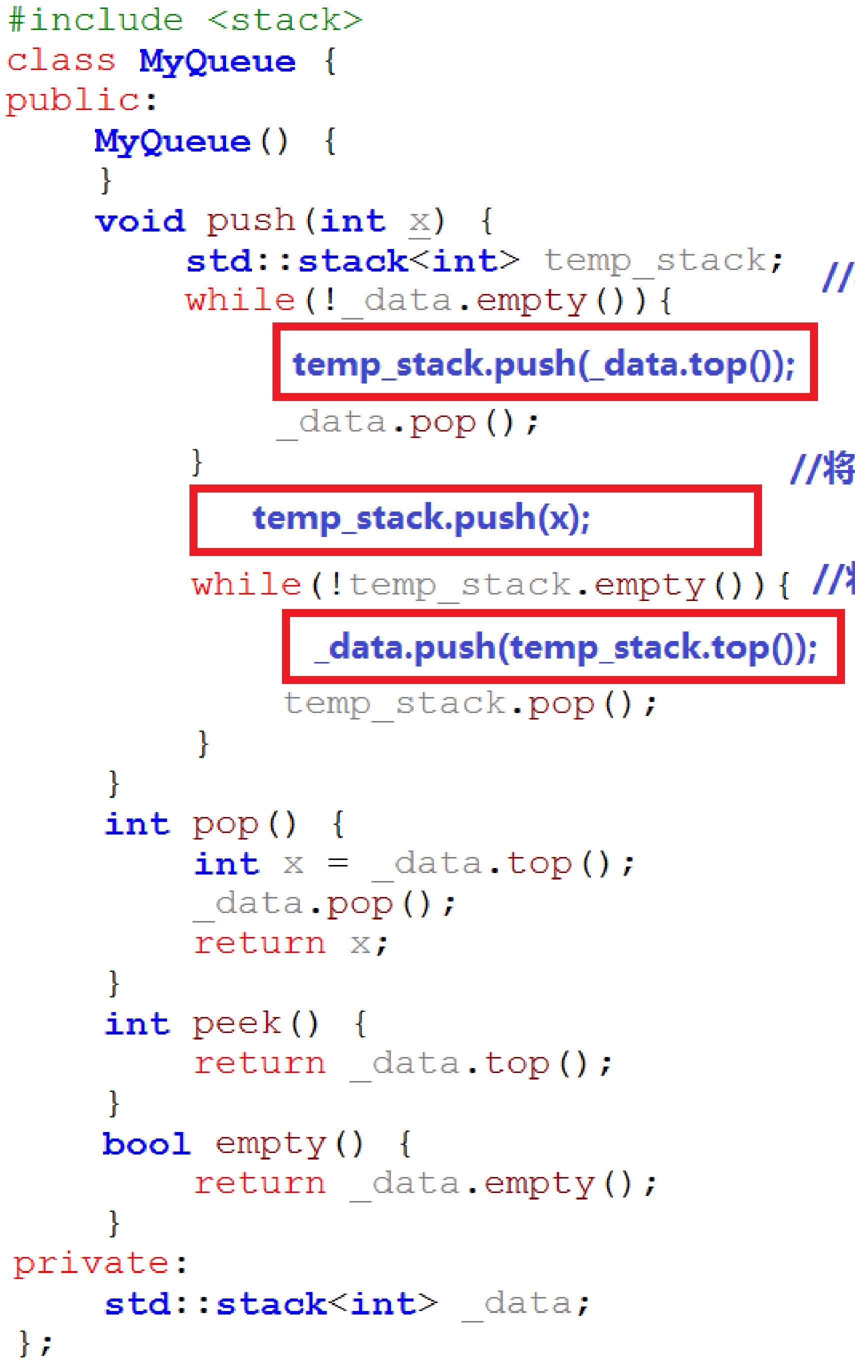


```
#include <stack>
class MyQueue {
public:
    MyQueue() {
    }
    void push(int x) {
        std::stack<int> temp_stack;
        while(!_data.empty()){
                    1
            _data.pop();
        }
                2
        while(!temp_stack.empty()){
                    3
            temp_stack.pop();
        }
    }
    int pop() {
        int x = _data.top();
        _data.pop();
        return x;
    }
    int peek() {
        return _data.top();
    }
    bool empty() {
        return _data.empty();
    }
private:
    std::stack<int> _data;
};
```

3分钟时间填写代码，

有问题随时提出！

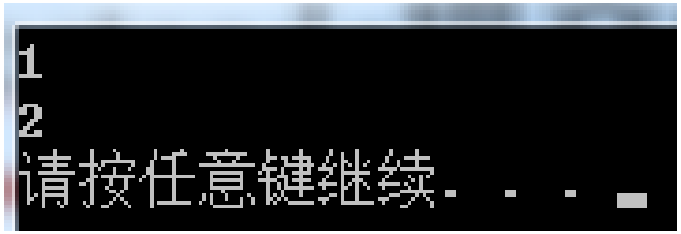
例2:实现



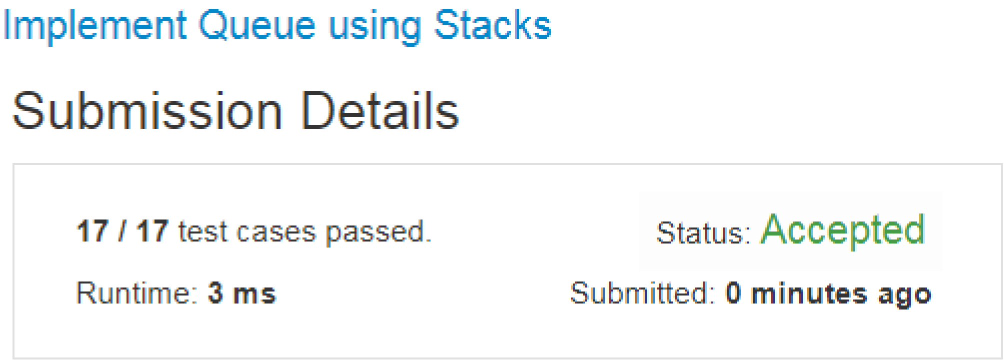
```cpp
#include <stack>
class MyQueue {
public:
    MyQueue() {
    }
    void push(int x) {
        std::stack<int> temp_stack;   //将数据栈中的元素push到临时栈中
        while(!_data.empty()){
            temp_stack.push(_data.top());
            _data.pop();
        }                             //将新元素push到临时栈中
        temp_stack.push(x);
        while(!temp_stack.empty()){   //将临时栈中的元素push到数据栈中
            _data.push(temp_stack.top());
            temp_stack.pop();
        }
    }
    int pop() {
        int x = _data.top();
        _data.pop();
        return x;
    }
    int peek() {
        return _data.top();
    }
    bool empty() {
        return _data.empty();
    }
private:
    std::stack<int> _data;
};
```

例2:测试与leetcode提交结果

```
int main(){
    MyQueue Q;
    Q.push(1);
    Q.push(2);
    Q.push(3);
    Q.push(4);
    printf("%d\n", Q.peek());
    Q.pop();
    printf("%d\n", Q.peek());
    return 0;
}
```



```
1
2
请按任意键继续. . . _
```



Implement Queue using Stacks

Submission Details

17 / 17 test cases passed.

Status: Accepted

Runtime: **3 ms**

Submitted: **0 minutes ago**

例3:包含min函数的栈

设计一个**栈**，支持如下操作，这些操作的算法复杂度需要是**常数级，O(1)**

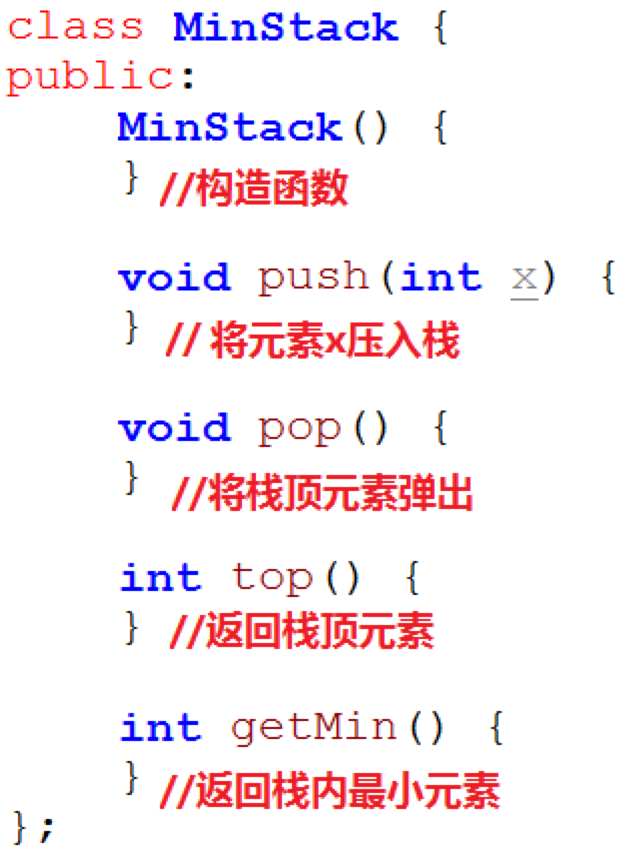
1.**push(x)** : 将元素x压入栈中

2.**pop()** : 弹出(移除)栈顶元素

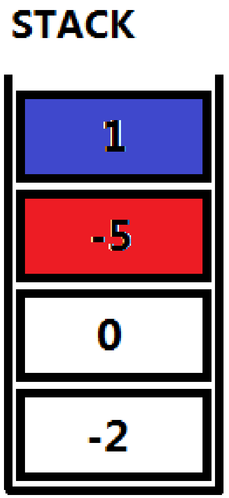
3.**top()** : 返回栈顶元素

4.**getMin()** : 返回栈内最小元素

选自 **LeetCode 155. Min Stack**
https://leetcode.com/problems/min-stack/description/
难度:**Easy**



```
class MinStack {
public:
    MinStack() {
    } //构造函数

    void push(int x) {
    } // 将元素x压入栈

    void pop() {
    } //将栈顶元素弹出

    int top() {
    } //返回栈顶元素

    int getMin() {
    } //返回栈内最小元素
};
```



top() 返回 1
getMin() 返回 -5

例3:思考，1个变量记录最小值?

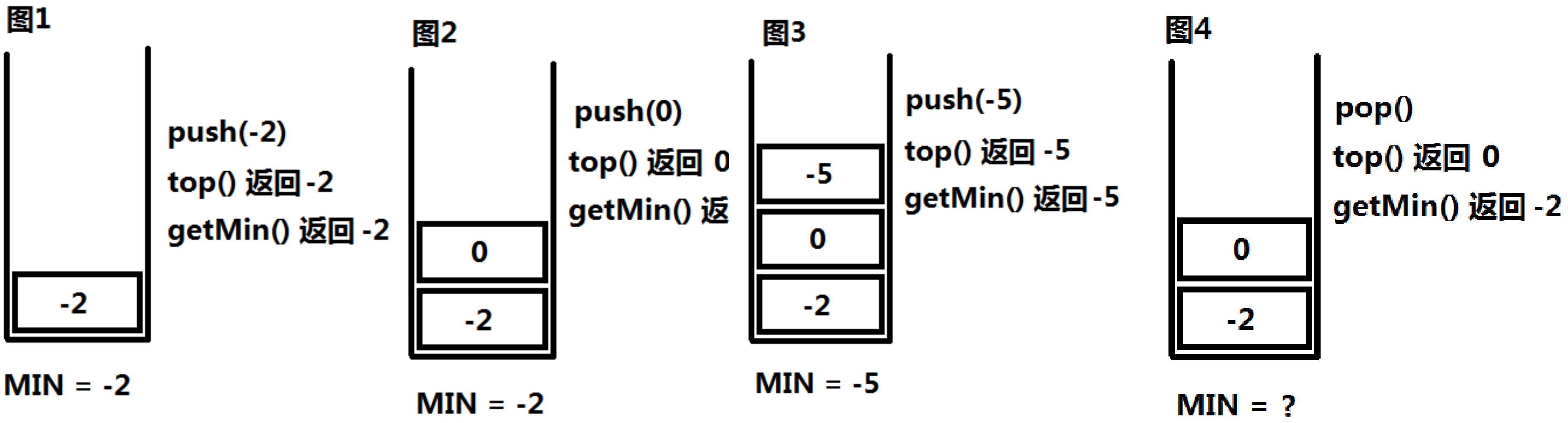


图1

push(-2)

top() 返回 -2

getMin() 返回 -2

MIN = -2

图2

push(0)

top() 返回 0

getMin() 返

MIN = -2

图3

push(-5)

top() 返回 -5

getMin() 返回 -5

MIN = -5

图4

pop()

top() 返回 0

getMin() 返回 -2

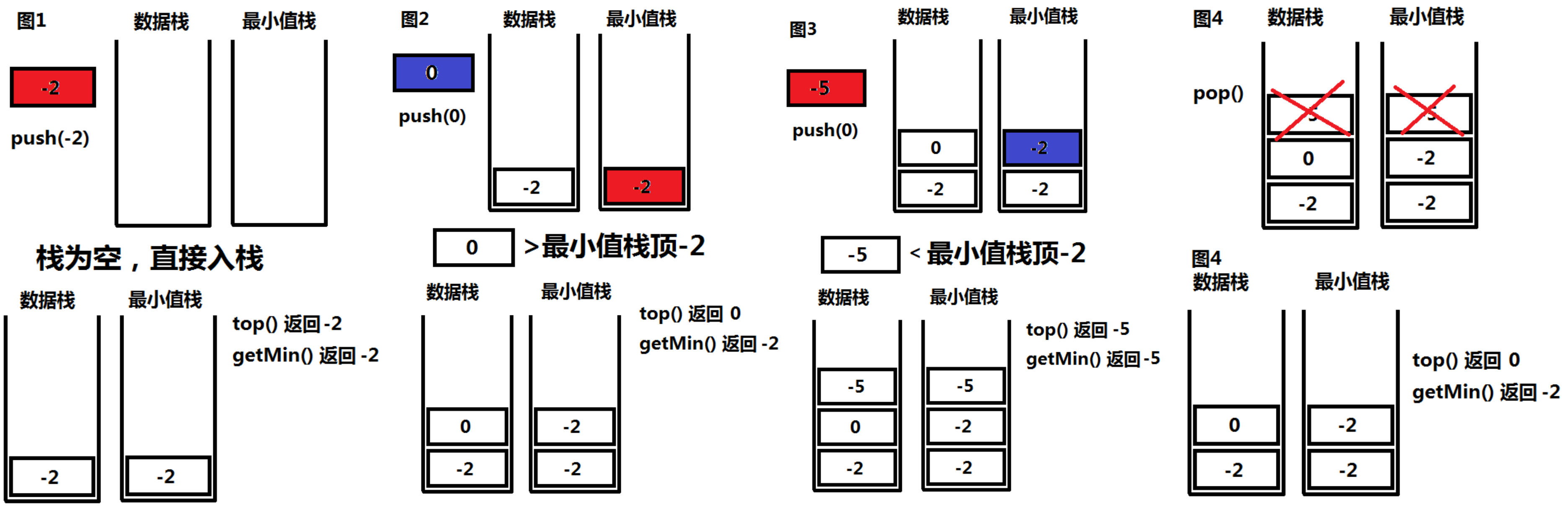
MIN = ?

结论:

1.1个变量MIN无法完成记录栈中**所有状态**下的最小值。

2.栈的**每个状态**，都需要有一个变量记录最小值。

例3:用另一个栈，存储各个状态最小值



top() 返回 -2
getMin() 返回 -2

top() 返回 0
getMin() 返回 -2

top() 返回 -5
getMin() 返回 -5

top() 返回 0
getMin() 返回 -2

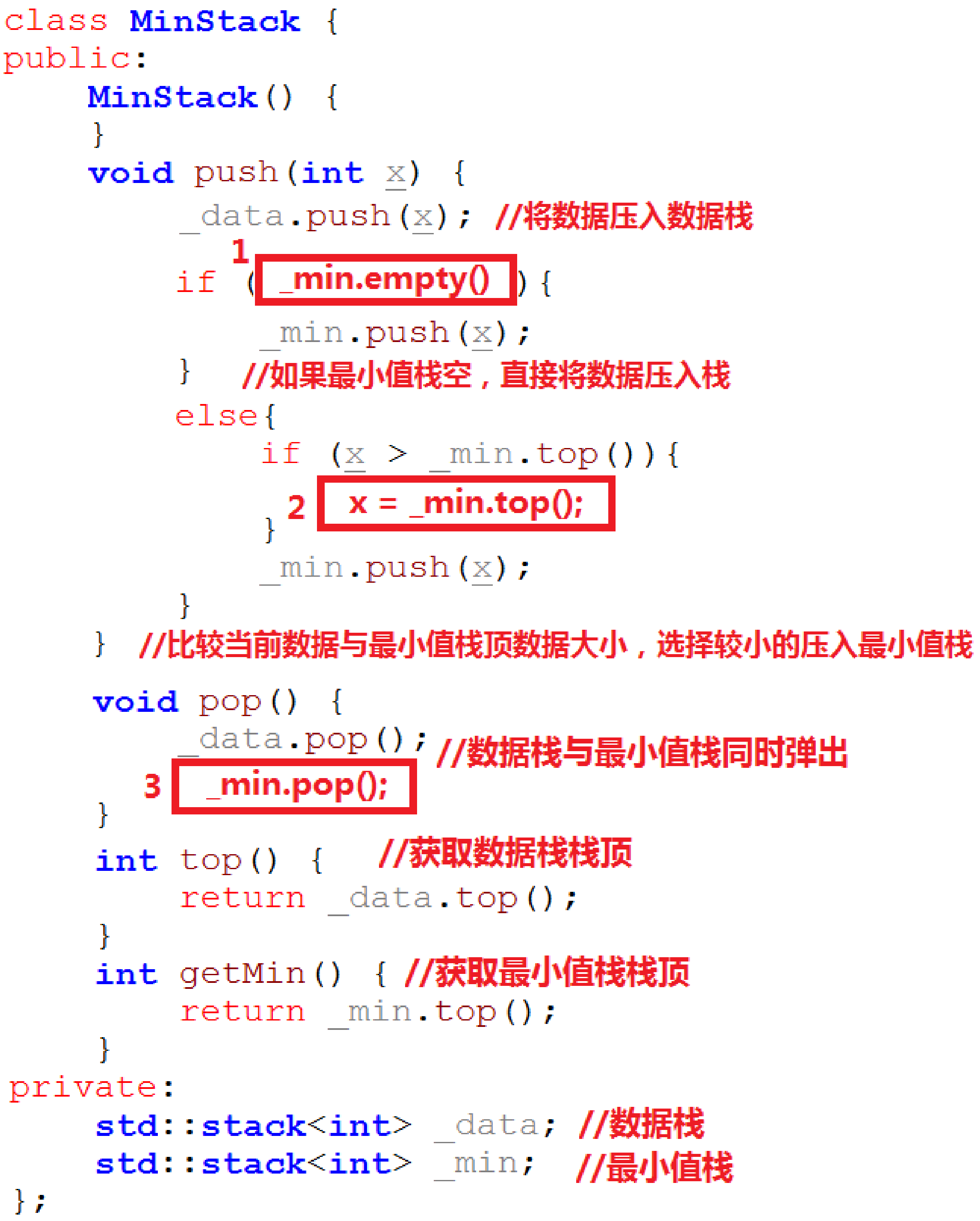
例3:实现，课堂练习

```
class MinStack {
public:
    MinStack() {
    }
    void push(int x) {
        _data.push(x); //将数据压入数据栈

        if ( 1 ){
            _min.push(x);
        }  //如果最小值栈空，直接将数据压入栈
        else{
            if (x > _min.top()){
                  2
            }
            _min.push(x);
        }
    }  //比较当前数据与最小值栈顶数据大小，选择较小的压入最小值栈

    void pop() {
        _data.pop(); //数据栈与最小值栈同时弹出
          3
    }
    int top() {   //获取数据栈栈顶
        return _data.top();
    }
    int getMin() { //获取最小值栈栈顶
        return _min.top();
    }
private:
    std::stack<int> _data; //数据栈
    std::stack<int> _min;  //最小值栈
};
```

3分钟时间填写代码，

有问题随时提出！

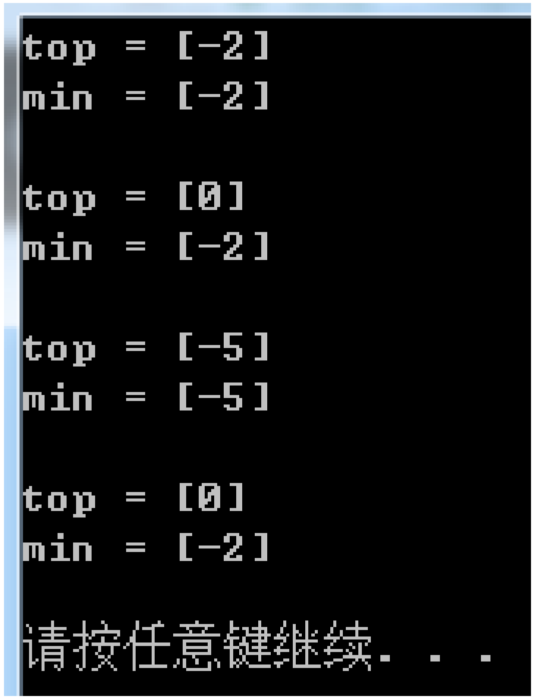
例3:实现



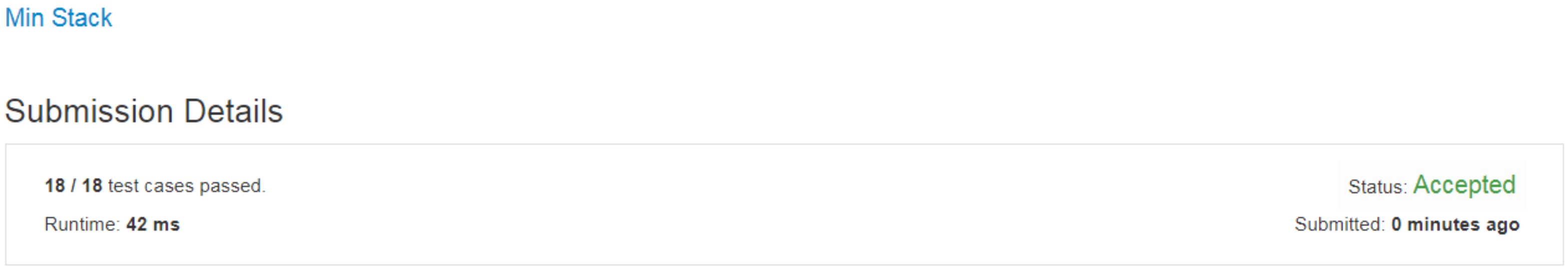
```
class MinStack {
public:
    MinStack() {
    }
    void push(int x) {
        _data.push(x); //将数据压入数据栈
           1
        if ( _min.empty() ) {
            _min.push(x);
        }  //如果最小值栈空，直接将数据压入栈
        else{
            if (x > _min.top()){
              2  x = _min.top();
            }
            _min.push(x);
        }
    }  //比较当前数据与最小值栈顶数据大小，选择较小的压入最小值栈
    void pop() {
        _data.pop(); //数据栈与最小值栈同时弹出
      3  _min.pop();
    }
    int top() {   //获取数据栈栈顶
        return _data.top();
    }
    int getMin() { //获取最小值栈栈顶
        return _min.top();
    }
private:
    std::stack<int> _data; //数据栈
    std::stack<int> _min;  //最小值栈
};
```

例3:测试与leetcode提交结果

```
int main(){
    MinStack minStack;
    minStack.push(-2);
    printf("top = [%d]\n", minStack.top());
    printf("min = [%d]\n\n", minStack.getMin());
    minStack.push(0);
    printf("top = [%d]\n", minStack.top());
    printf("min = [%d]\n\n", minStack.getMin());
    minStack.push(-5);
    printf("top = [%d]\n", minStack.top());
    printf("min = [%d]\n\n", minStack.getMin());
    minStack.pop();
    printf("top = [%d]\n", minStack.top());
    printf("min = [%d]\n\n", minStack.getMin());
    return 0;
}
```



```
top = [-2]
min = [-2]

top = [0]
min = [-2]

top = [-5]
min = [-5]

top = [0]
min = [-2]

请按任意键继续. . .
```



Min Stack

Submission Details

18 / 18 test cases passed.

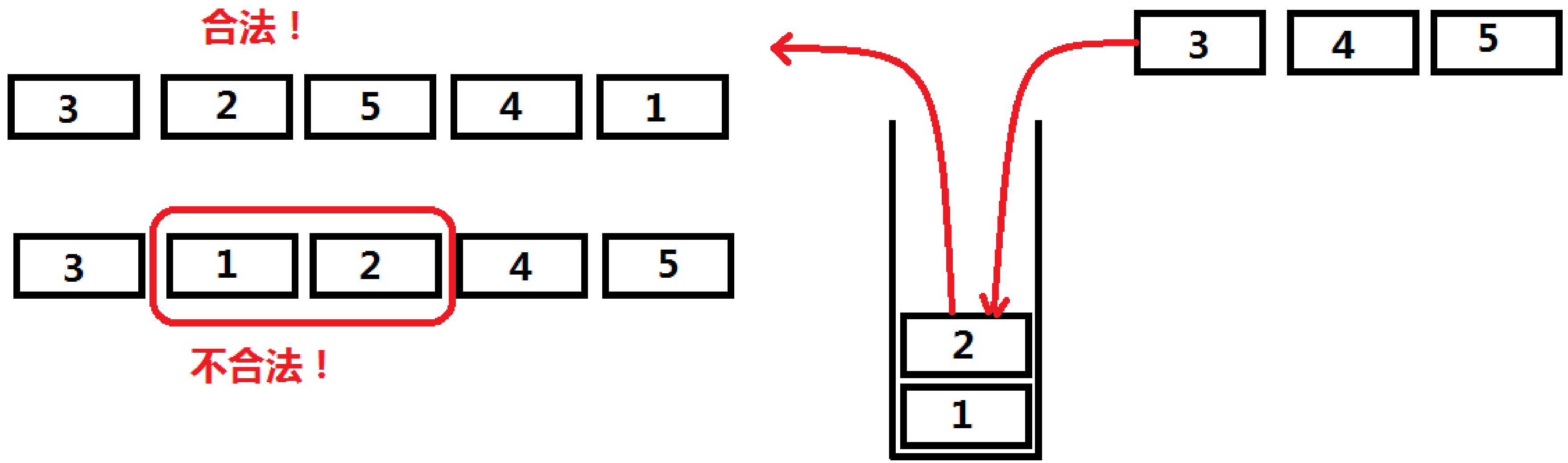
Runtime: 42 ms

Status: Accepted

Submitted: 0 minutes ago

例4:合法的出栈序列

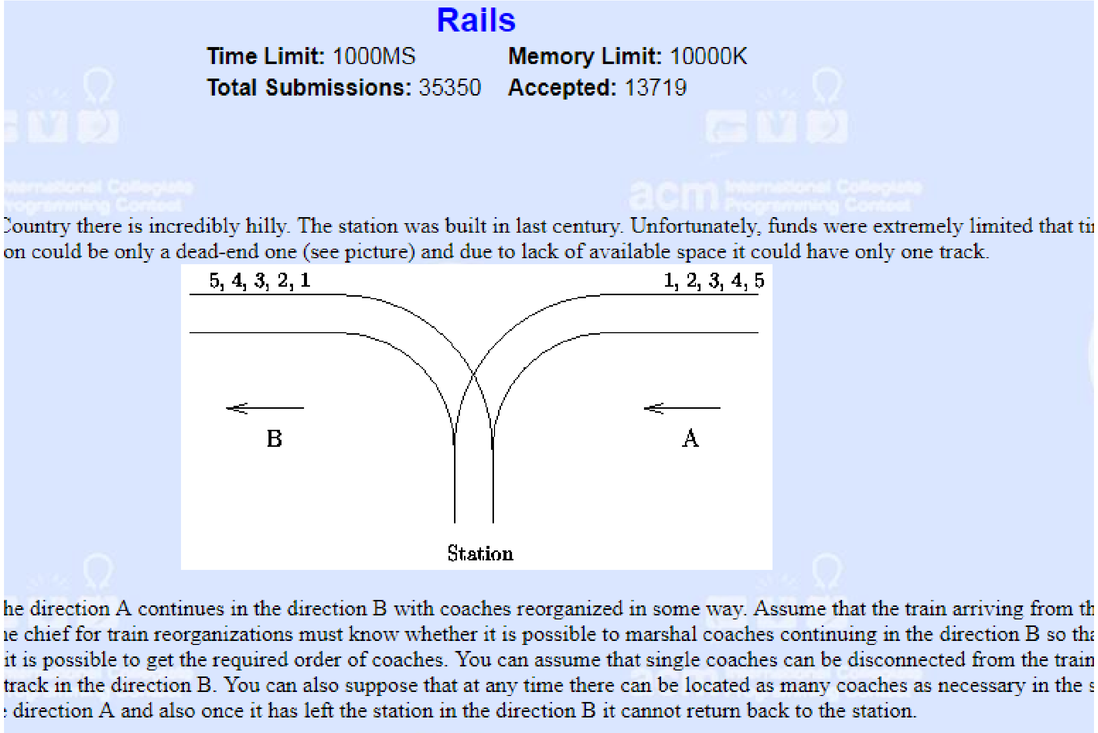
已知从1至n的**数字序列，按顺序**入栈，每个数字入栈后即可出栈，也可在栈中停留，等待后面的数字入栈出栈后，该数字再出栈，求该数字序列的**出栈序列**是否合法？



选自 **poj 1363 Rails**
http://poj.org/problem?id=1363
难度:**Medium**

例4: poj 1363 Rails 原题介绍与poj简介

POJ 即“**北京大学程序在线评测系统**”（Peking University Online Judge）的缩写，主要收录**ACM** 国际大学生程序设计竞赛、**NOI** 青少年信息学奥林匹克竞赛等各类程序设计竞赛题目，当前共有3000多道。



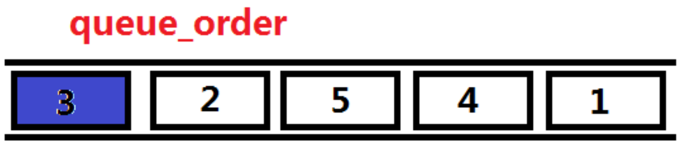
Rails

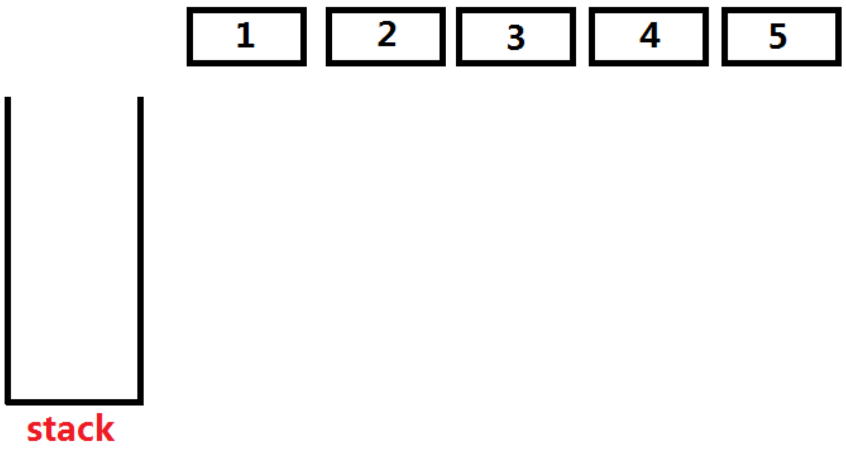
Time Limit: 1000MS **Memory Limit:** 10000K
Total Submissions: 35350 **Accepted:** 13719

:ountry there is incredibly hilly. The station was built in last century. Unfortunately, funds were extremely limited that ti
on could be only a dead-end one (see picture) and due to lack of available space it could have only one track.

he direction A continues in the direction B with coaches reorganized in some way. Assume that the train arriving from th
ie chief for train reorganizations must know whether it is possible to marshal coaches continuing in the direction B so tha
it is possible to get the required order of coaches. You can assume that single coaches can be disconnected from the train
track in the direction B. You can also suppose that at any time there can be located as many coaches as necessary in the s
: direction A and also once it has left the station in the direction B it cannot return back to the station.

例4: 思路:使用栈与队列模拟入栈、出栈过程





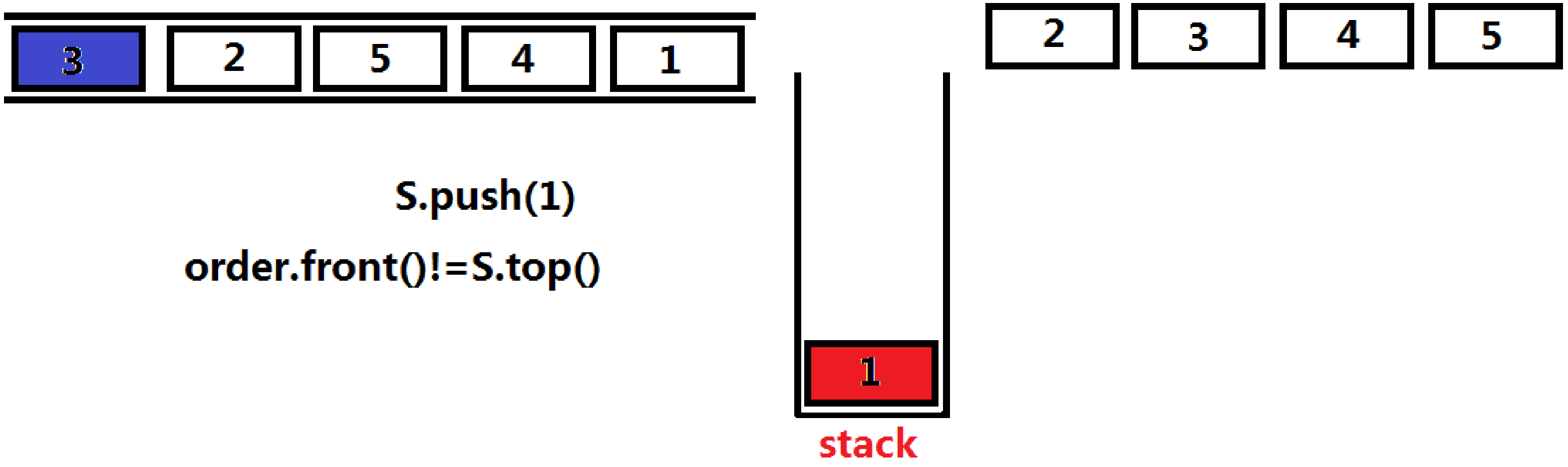
1.出栈结果存储在队列order中

2.按元素顺序，将元素push进入栈

3.每push一个元素，即检查是否与队列首部元素相同若相同则弹出队列首元素，弹出栈顶元素，直到两元素不同结束

4.若最终栈为空，说明序列合法，否则不合法

图1: queue_order

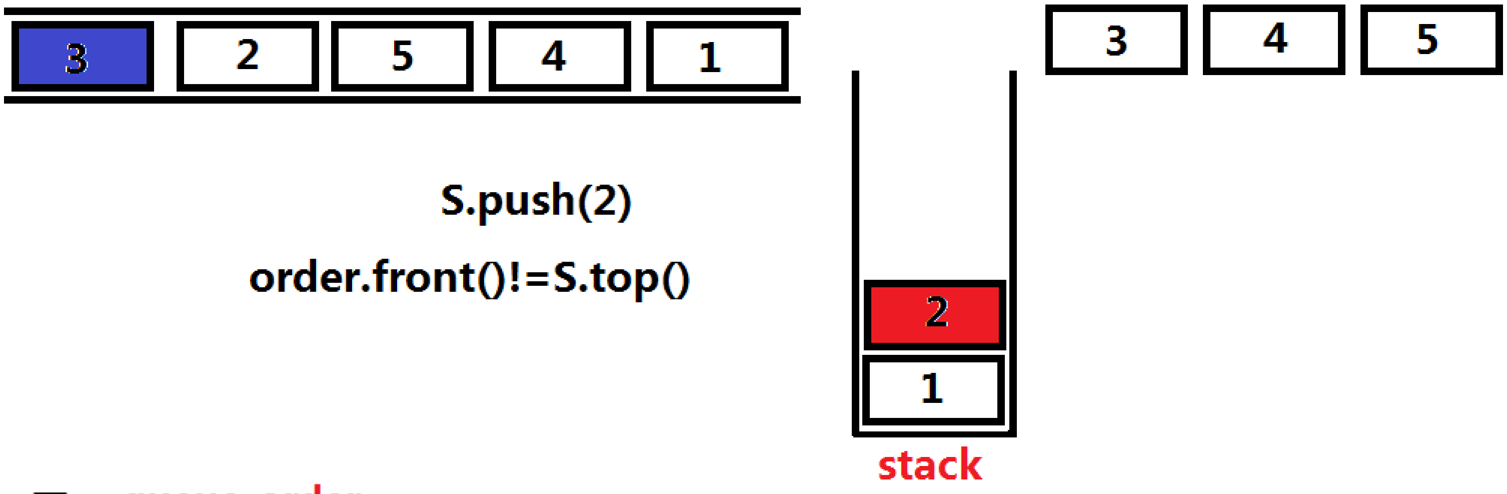


S.push(1)

order.front()!=S.top()

例4: 思路:使用栈与队列模拟入栈、出栈过程

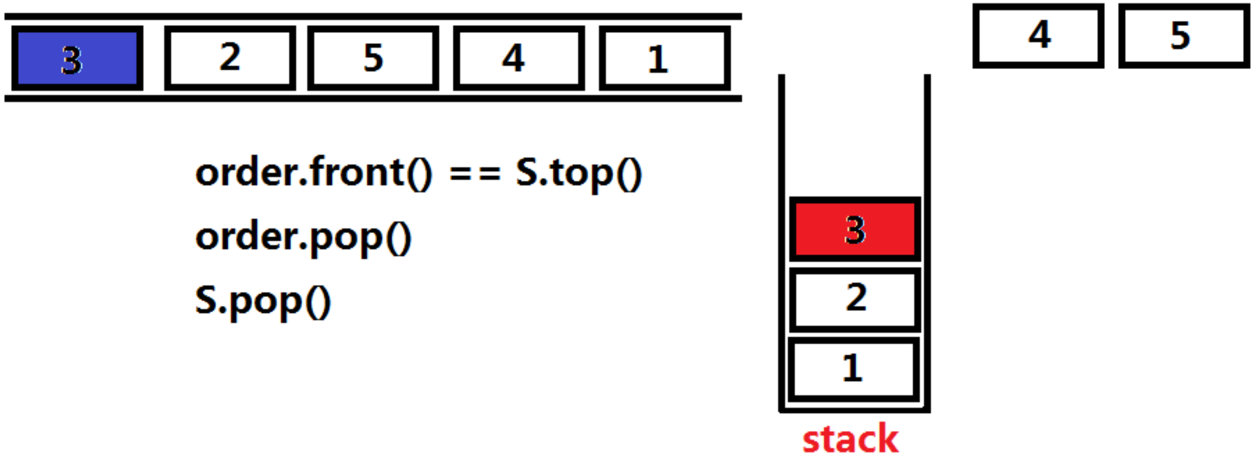
图2: queue_order



S.push(2)

order.front()!=S.top()

图3: queue_order



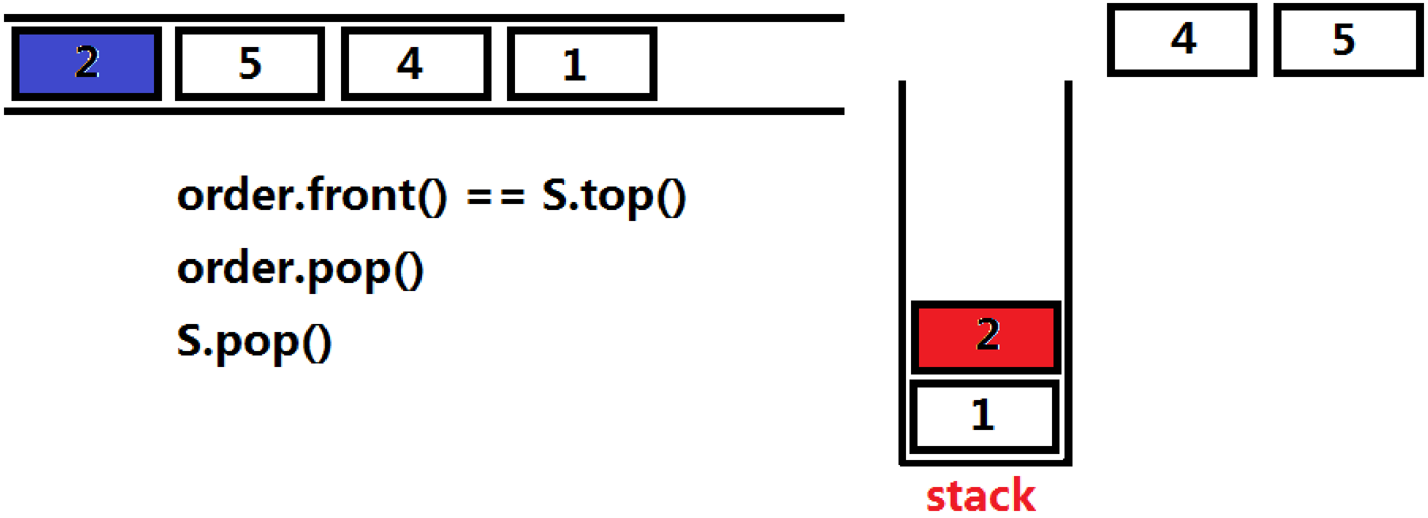
order.front() == S.top()

order.pop()

S.pop()

例4: 思路:使用栈与队列模拟入栈、出栈过程

图4: queue_order

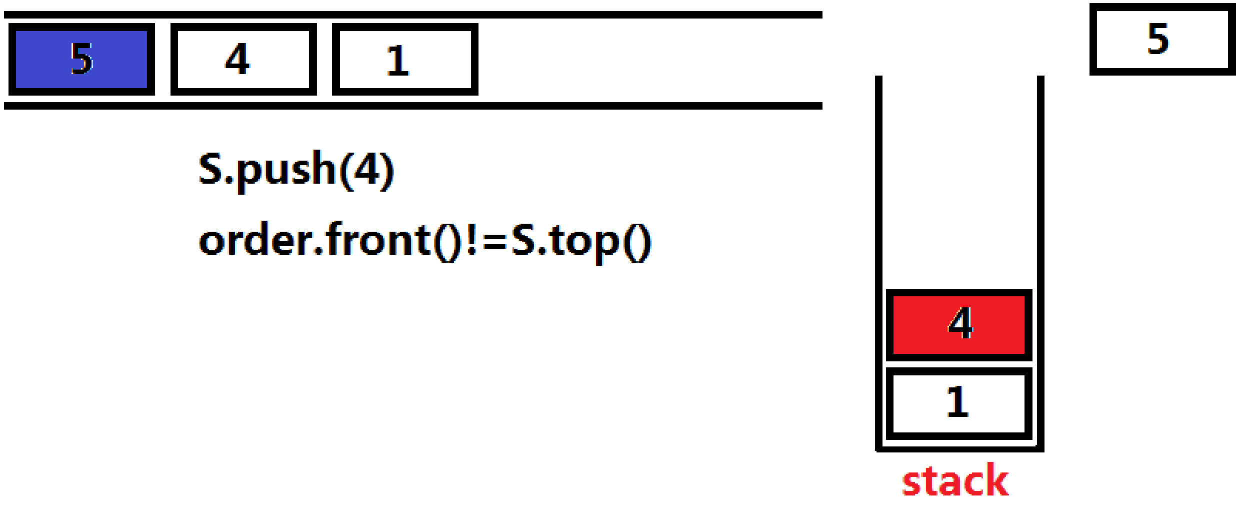


order.front() == S.top()

order.pop()

S.pop()

图5: queue_order

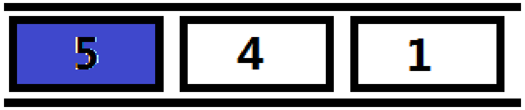


S.push(4)

order.front()!=S.top()

例4: 思路:使用栈与队列模拟入栈、出栈过程

图6: queue_order



order.front() == S.top()

order.pop()

S.pop()

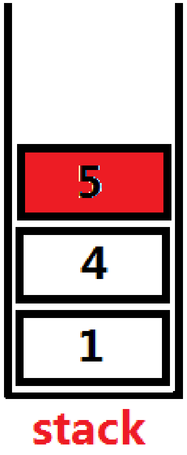
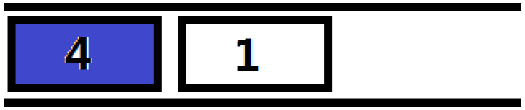


图7: queue_order



order.front() == S.top()

order.pop()

S.pop()

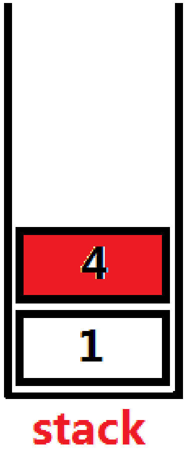
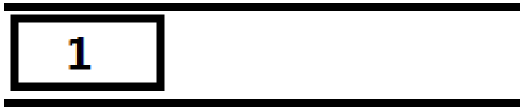


图8: queue_order



order.front() == S.top()

order.pop()

S.pop()

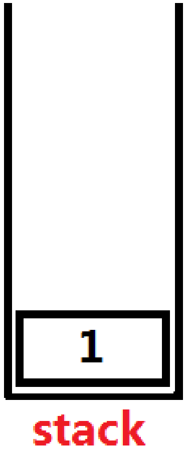
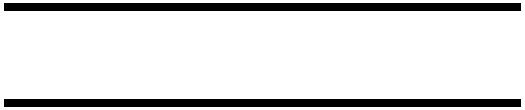
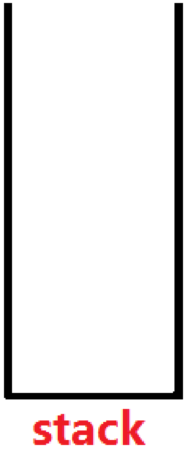


图9: queue_order

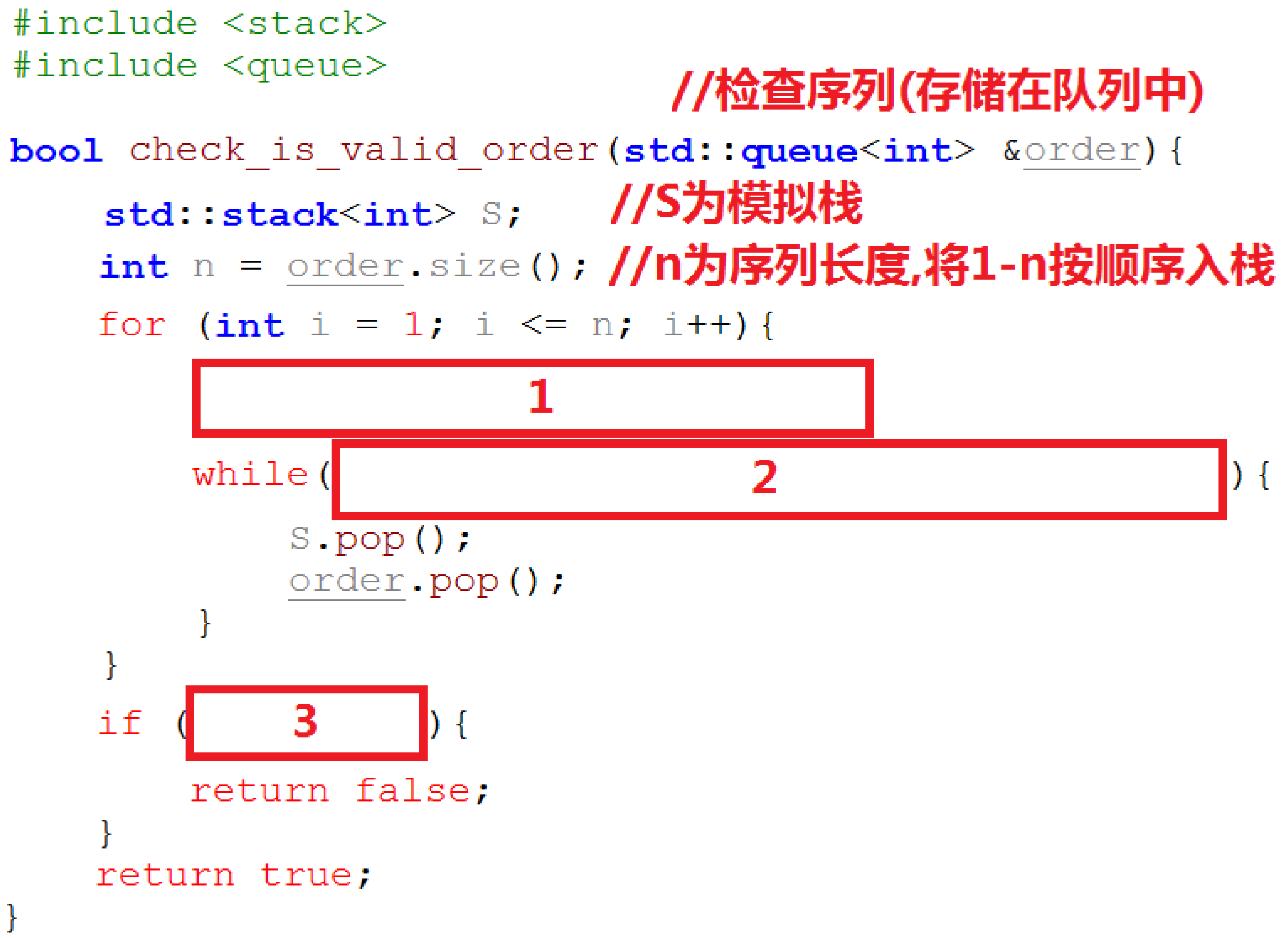


S.empty()

故:order序列合法！



例4:实现，课堂练习

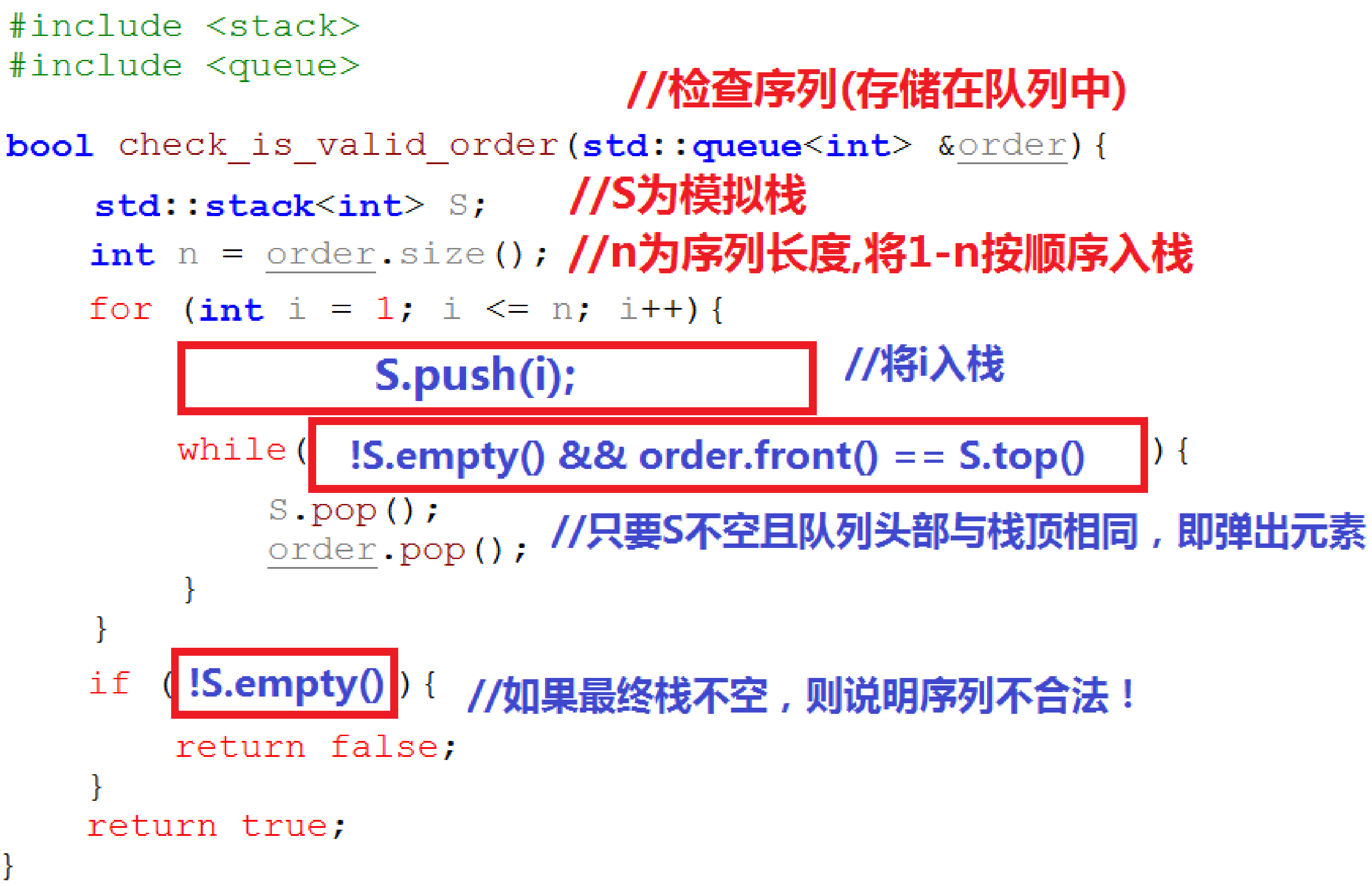


```
#include <stack>
#include <queue>
                              //检查序列(存储在队列中)
bool check_is_valid_order(std::queue<int> &order){
    std::stack<int> S;    //S为模拟栈
    int n = order.size(); //n为序列长度,将1-n按顺序入栈
    for (int i = 1; i <= n; i++){
        [         1         ]
        while([         2         ]){
            S.pop();
            order.pop();
        }
    }
    if ([  3  ]){
        return false;
    }
    return true;
}
```

3分钟时间填写代码，

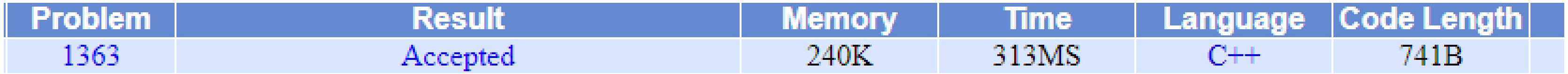
有问题随时提出！

例4:实现



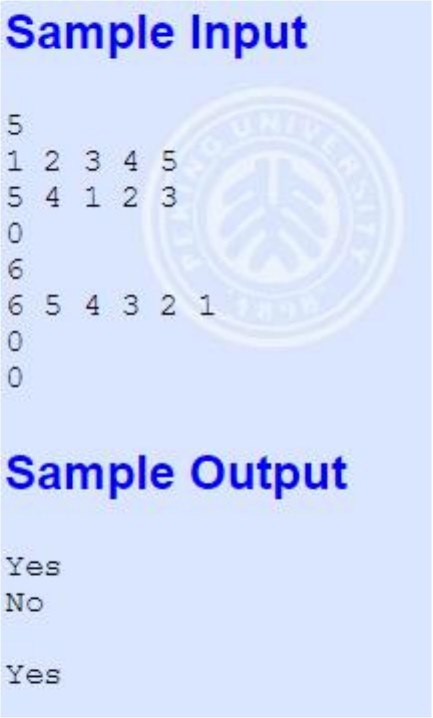
```
#include <stack>
#include <queue>
                                              //检查序列(存储在队列中)
bool check_is_valid_order(std::queue<int> &order){
    std::stack<int> S;        //S为模拟栈
    int n = order.size();     //n为序列长度,将1-n按顺序入栈
    for (int i = 1; i <= n; i++){
        S.push(i);            //将i入栈
        while(!S.empty() && order.front() == S.top()){
            S.pop();
            order.pop();      //只要S不空且队列头部与栈顶相同，即弹出元素
        }
    }
    if (!S.empty()){          //如果最终栈不空，则说明序列不合法！
        return false;
    }
    return true;
}
```

例4:poj测试与提交



Problem	Result	Memory	Time	Language	Code Length
1363	Accepted	240K	313MS	C++	741B

```
int main(){
    int n;
    int train;
    scanf("%d", &n);
    while(n){
        scanf("%d", &train);
        while (train){
            std::queue<int> order;
            order.push(train);
            for (int i = 1; i < n; i++){
                scanf("%d", &train);
                order.push(train);
            }
            if (check_is_valid_order(order)){
                printf("Yes\n");
            }
            else{
                printf("No\n");
            }
            scanf("%d", &train);
        }
        printf("\n");
        scanf("%d", &n);
    }
    return 0;
}
```



Sample Input

```
5
1 2 3 4 5
5 4 1 2 3
0
6
6 5 4 3 2 1
0
0
```

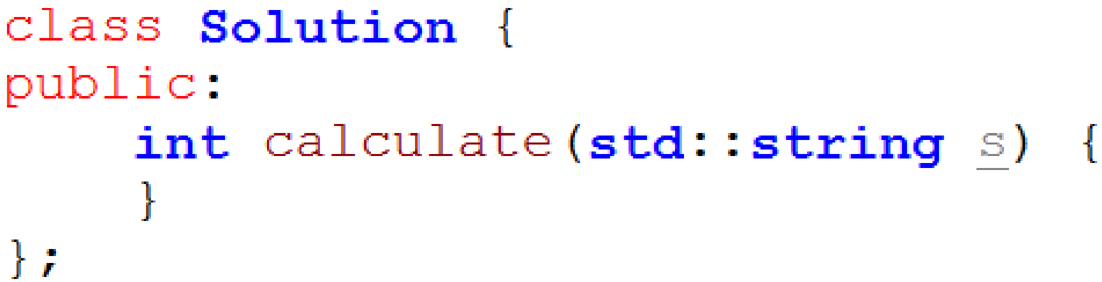
Sample Output

```
Yes
No

Yes
```

例5:简单的计算器

设计一个**计算器**，输入一个**字符串存储**的数学表达式，可以计算包括 “(“、”)”、 ”+”、 ”-”四种符号的**数学表达式**，输入的数学表达式字符串**保证是合法的**。输入的数学表达式中可能存在空格字符。

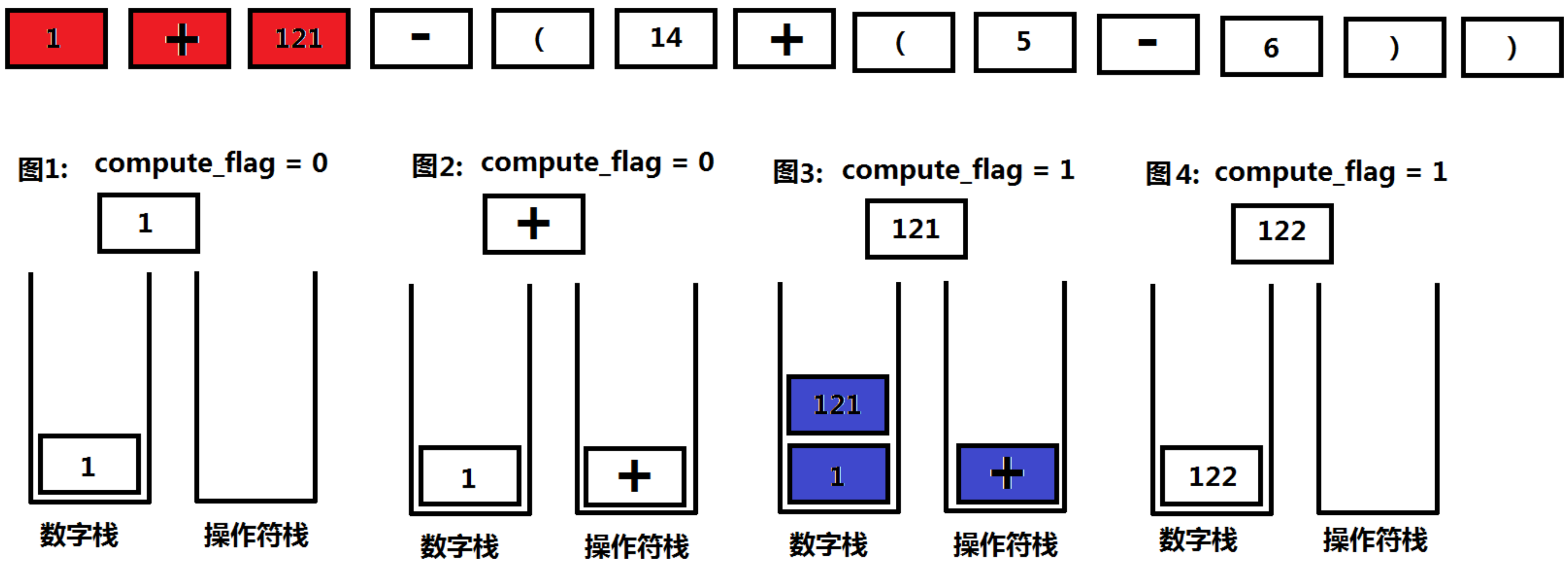
如计算:
“(1 + 1)" = 2
"1+121 - (14+ (5-6)) = 109



```
class Solution {
public:
    int calculate(std::string s) {
    }
};
```

选自 **LeetCode 224. Basic Calculator**
https://leetcode.com/problems/basic-calculator/description/
难度:**Hard**

例5:计算思路



1 + 121 - (14 + (5 - 6))

图1: compute_flag = 0

1

1

数字栈 操作符栈

图2: compute_flag = 0

+

1

数字栈

+

操作符栈

图3: compute_flag = 1

121

121

1

数字栈

+

操作符栈

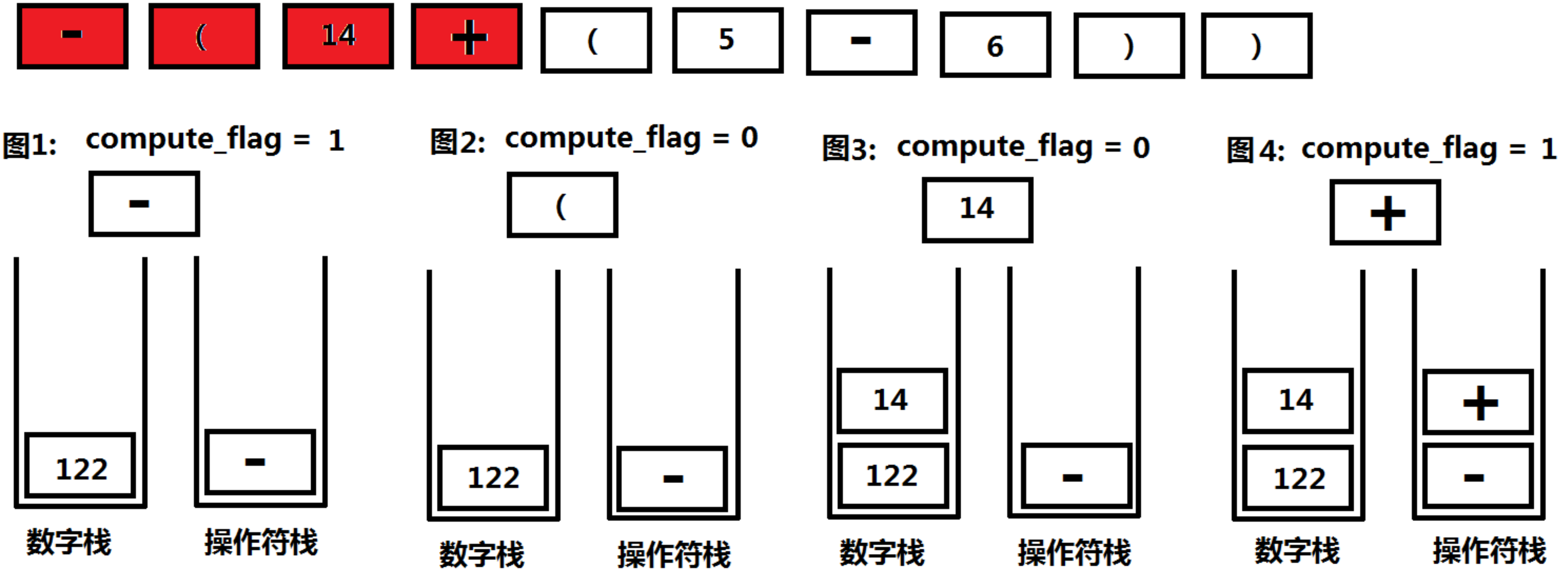
图4: compute_flag = 1

122

122

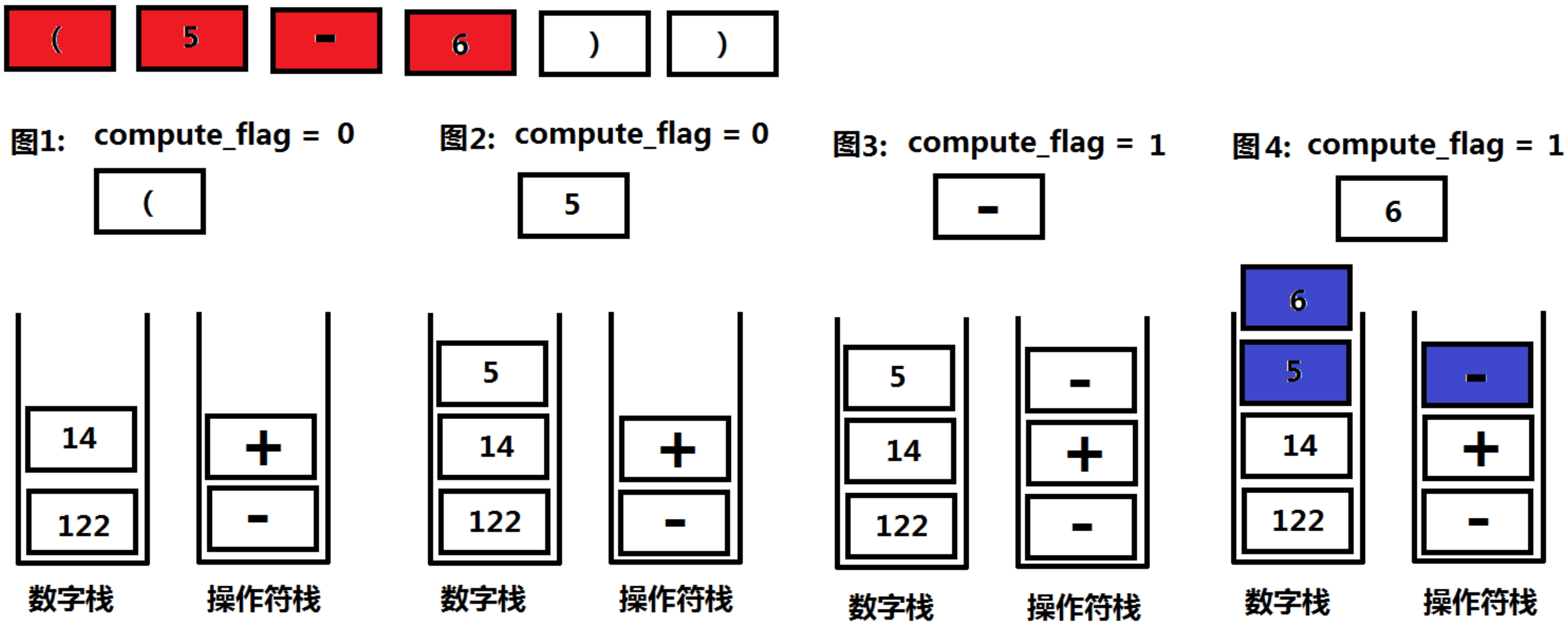
数字栈 操作符栈

例5:计算思路

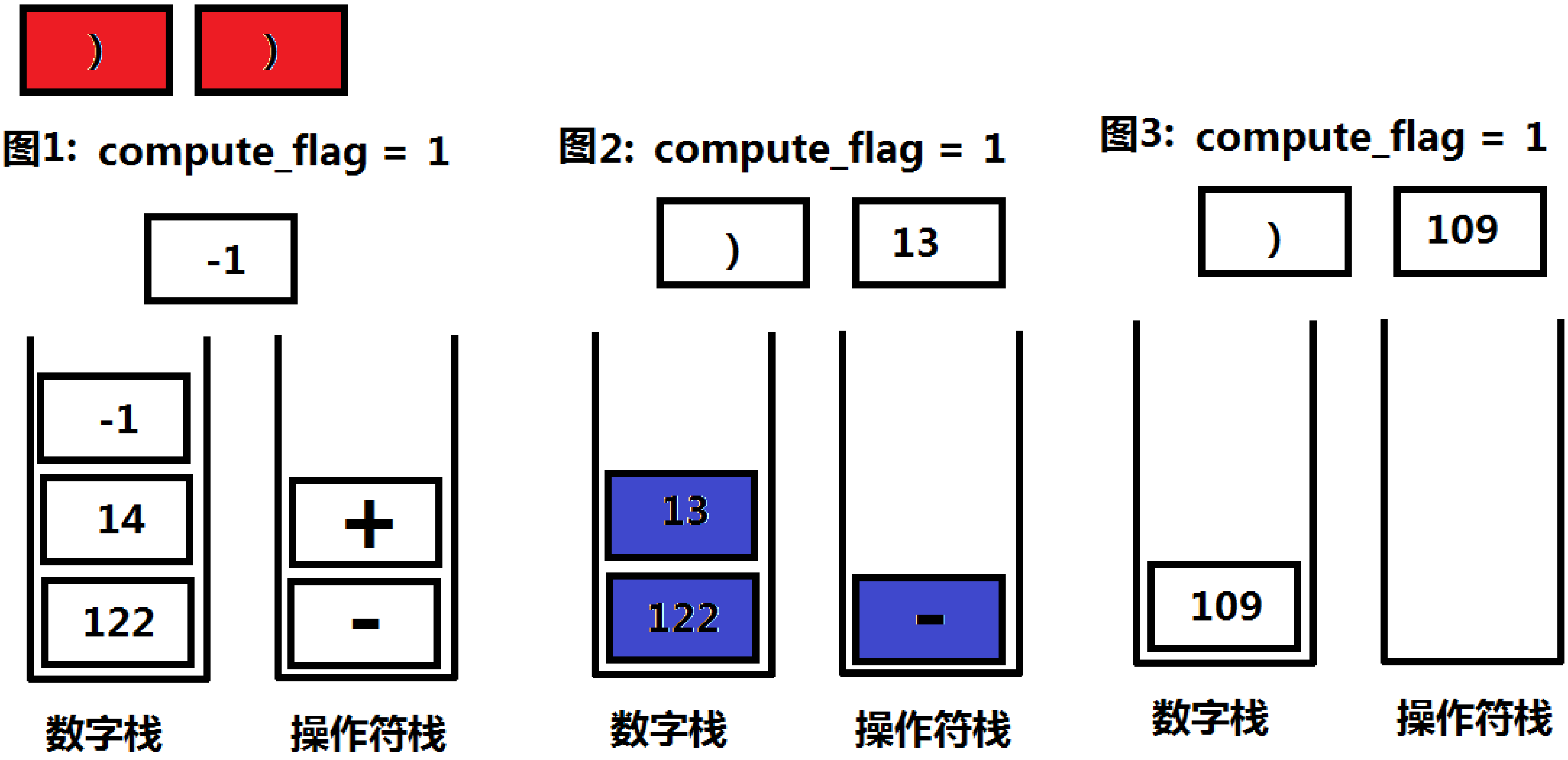


-
(
14
+
(
5
-
6
)
)
图1: compute_flag = 1
-
122
-
数字栈
操作符栈
图2: compute_flag = 0
(
122
-
数字栈
操作符栈
图3: compute_flag = 0
14
14
122
-
数字栈
操作符栈
图4: compute_flag = 1
+
14
122
+
-
数字栈
操作符栈

例5:计算思路

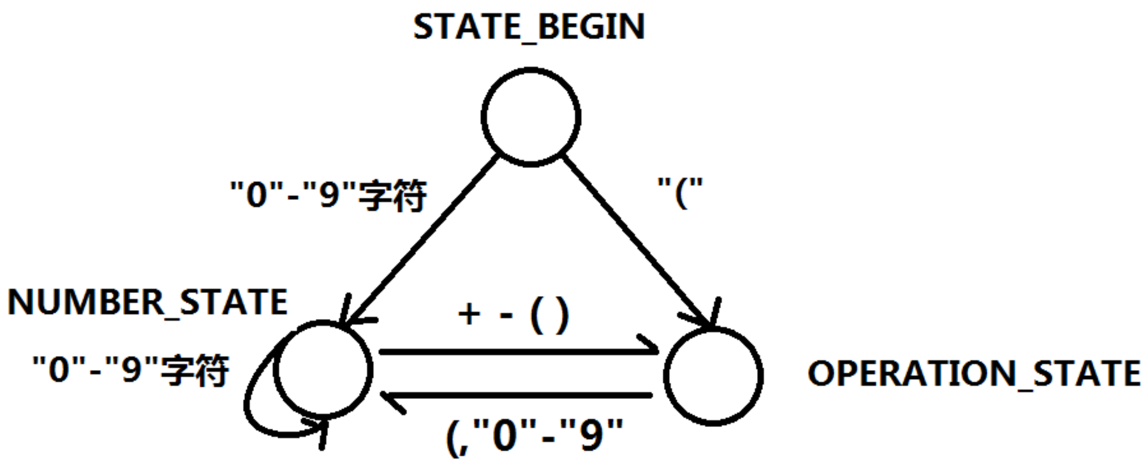

(
5
-
6
)
)
图1: compute_flag = 0
(
14
122
+
-
数字栈
操作符栈
图2: compute_flag = 0
5
5
14
122
+
-
数字栈
操作符栈
图3: compute_flag = 1
-
5
14
122
-
+
-
数字栈
操作符栈
图4: compute_flag = 1
6
6
5
14
122
-
+
-
数字栈
操作符栈

例5:计算思路


)
)
图1: compute_flag = 1
-1
-1
14
122
+
-
数字栈
操作符栈
图2: compute_flag = 1
)
13
13
122
-
数字栈
操作符栈
图3: compute_flag = 1
)
109
109
数字栈
操作符栈

例5:字符串处理思路

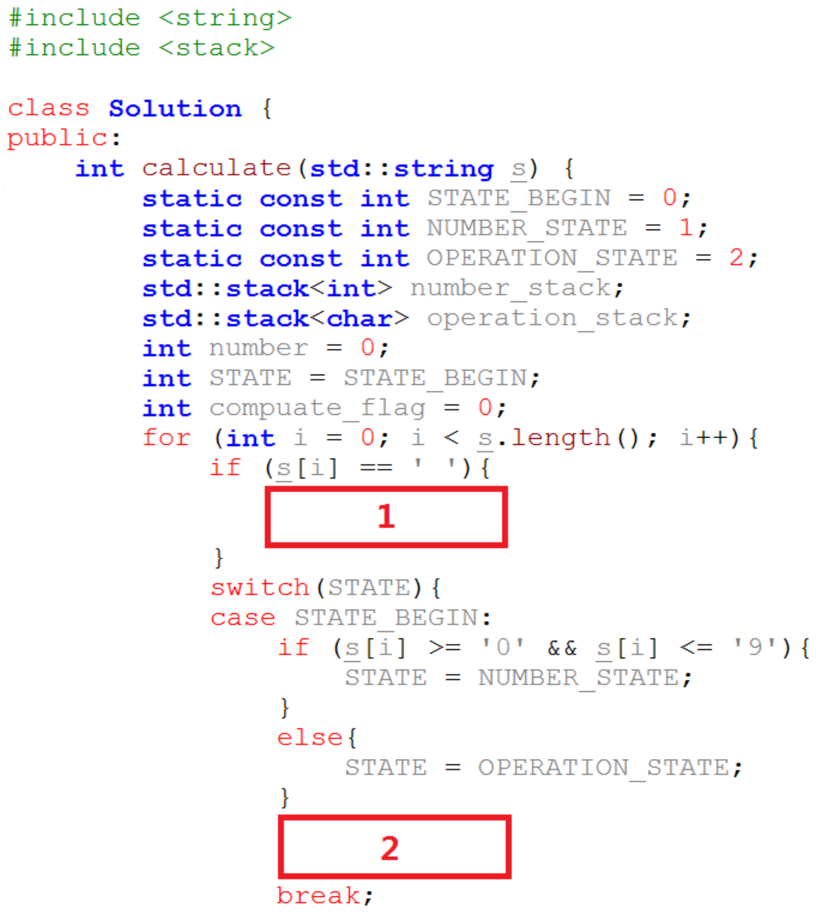
s = 1+121 - (14+(5-6))



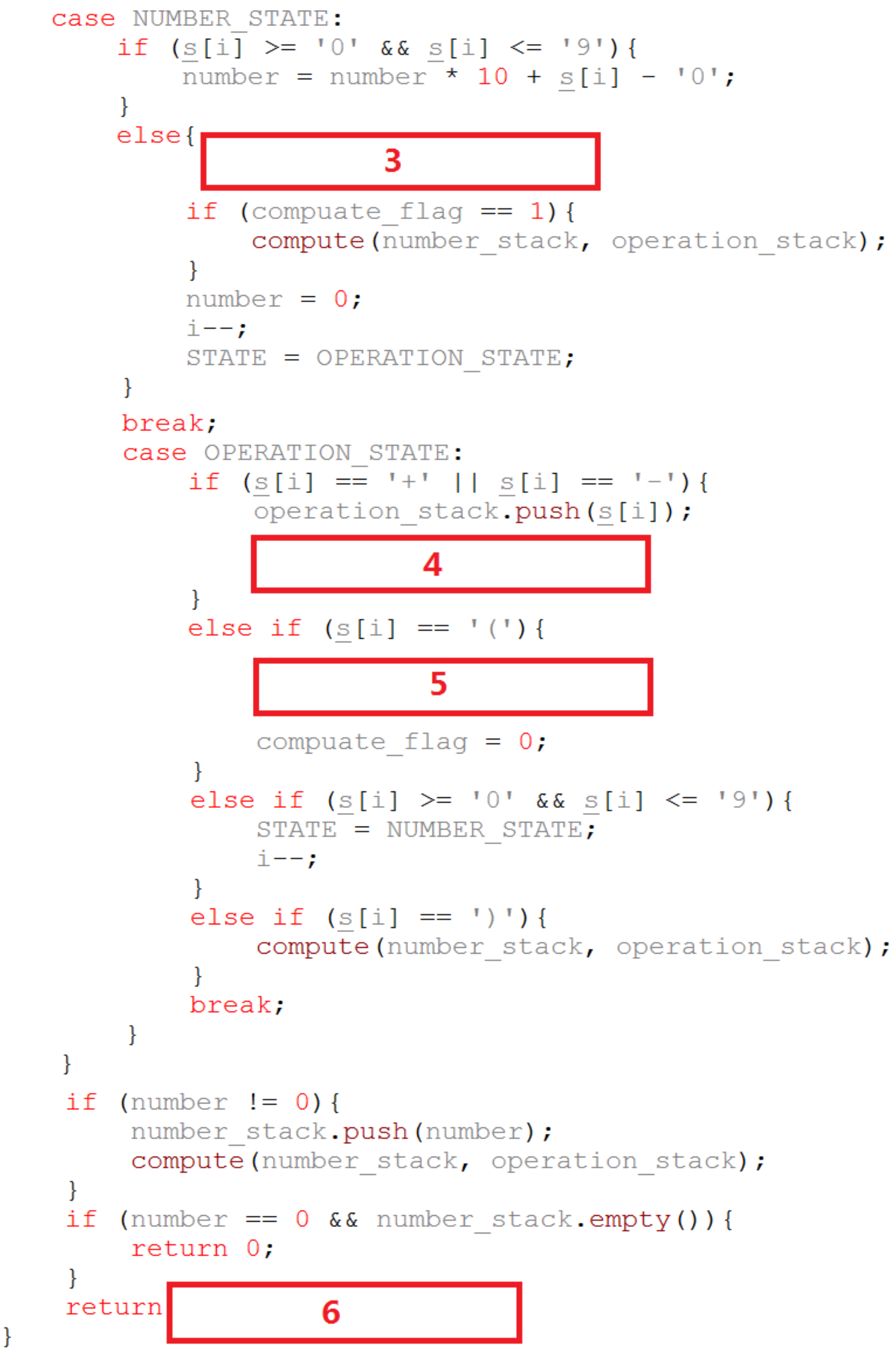
如果为数字字符:
number = number * 10 + ch - '0';
否则:
根据compute_flag进行计算
并切换至OPERATION_STATE

如果 + -
operation_stack.push
compute_flag = 1
如果 (
compute_flag = 0
切换至NUMBER_STATE
如果)
进行计算
如果0-9
切换至NUMBER_STATE

例5:实现，课堂练习

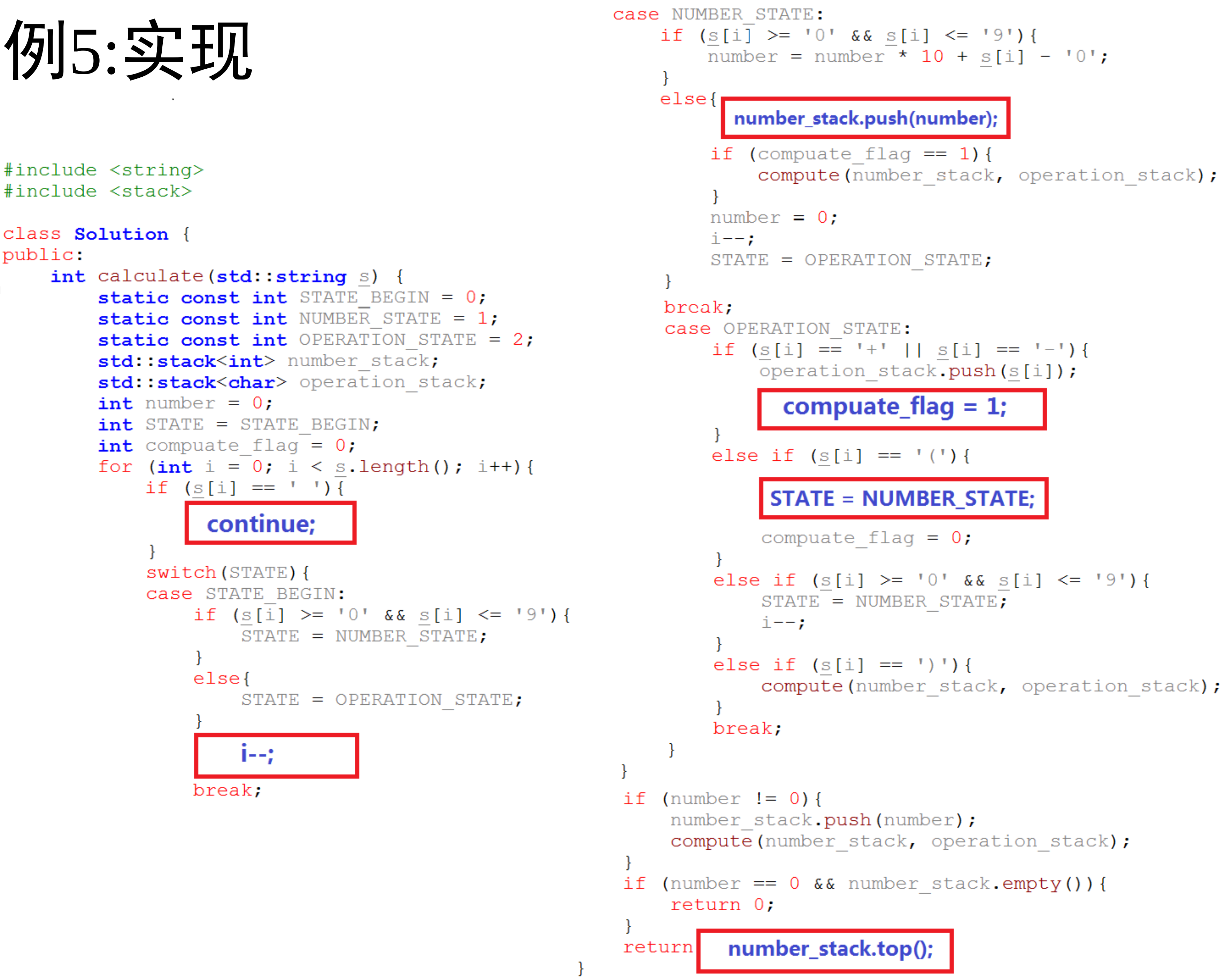


```
#include <string>
#include <stack>

class Solution {
public:
    int calculate(std::string s) {
        static const int STATE_BEGIN = 0;
        static const int NUMBER_STATE = 1;
        static const int OPERATION_STATE = 2;
        std::stack<int> number_stack;
        std::stack<char> operation_stack;
        int number = 0;
        int STATE = STATE_BEGIN;
        int compuate_flag = 0;
        for (int i = 0; i < s.length(); i++){
            if (s[i] == ' '){
                  1
            }
            switch(STATE){
            case STATE_BEGIN:
                if (s[i] >= '0' && s[i] <= '9'){
                    STATE = NUMBER_STATE;
                }
                else{
                    STATE = OPERATION_STATE;
                }
                  2
                break;
```



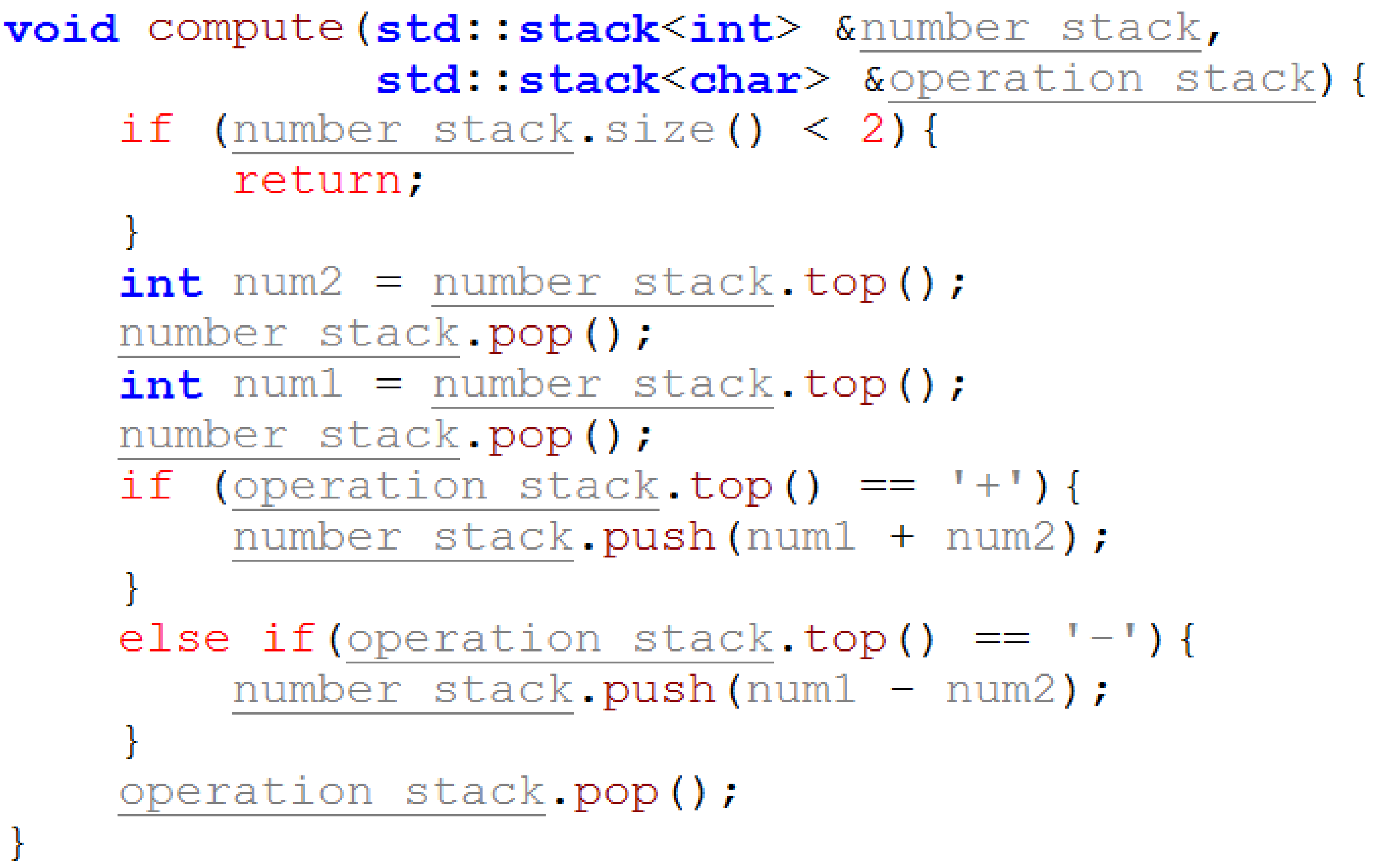
```
            case NUMBER_STATE:
                if (s[i] >= '0' && s[i] <= '9'){
                    number = number * 10 + s[i] - '0';
                }
                else{         3
                    if (compuate_flag == 1){
                        compute(number_stack, operation_stack);
                    }
                    number = 0;
                    i--;
                    STATE = OPERATION_STATE;
                }
                break;
            case OPERATION_STATE:
                if (s[i] == '+' || s[i] == '-'){
                    operation_stack.push(s[i]);
                          4
                }
                else if (s[i] == '('){
                          5
                    compuate_flag = 0;
                }
                else if (s[i] >= '0' && s[i] <= '9'){
                    STATE = NUMBER_STATE;
                    i--;
                }
                else if (s[i] == ')'){
                    compute(number_stack, operation_stack);
                }
                break;
            }
        }
        if (number != 0){
            number_stack.push(number);
            compute(number_stack, operation_stack);
        }
        if (number == 0 && number_stack.empty()){
            return 0;
        }
        return        6
    }
```

例5:实现



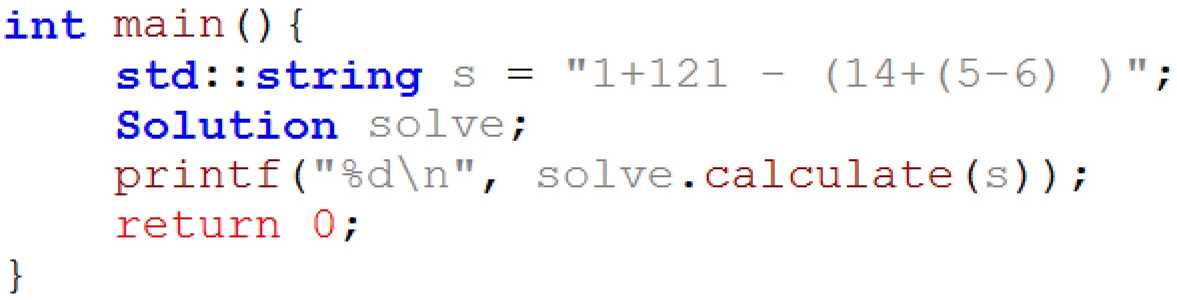
```
#include <string>
#include <stack>

class Solution {
public:
    int calculate(std::string s) {
        static const int STATE_BEGIN = 0;
        static const int NUMBER_STATE = 1;
        static const int OPERATION_STATE = 2;
        std::stack<int> number_stack;
        std::stack<char> operation_stack;
        int number = 0;
        int STATE = STATE_BEGIN;
        int compuate_flag = 0;
        for (int i = 0; i < s.length(); i++){
            if (s[i] == ' '){
                continue;
            }
            switch(STATE){
            case STATE_BEGIN:
                if (s[i] >= '0' && s[i] <= '9'){
                    STATE = NUMBER_STATE;
                }
                else{
                    STATE = OPERATION_STATE;
                }
                i--;
                break;
            case NUMBER_STATE:
                if (s[i] >= '0' && s[i] <= '9'){
                    number = number * 10 + s[i] - '0';
                }
                else{
                    number_stack.push(number);
                    if (compuate_flag == 1){
                        compute(number_stack, operation_stack);
                    }
                    number = 0;
                    i--;
                    STATE = OPERATION_STATE;
                }
                brcak;
            case OPERATION_STATE:
                if (s[i] == '+' || s[i] == '-'){
                    operation_stack.push(s[i]);
                    compuate_flag = 1;
                }
                else if (s[i] == '('){
                    STATE = NUMBER_STATE;
                    compuate_flag = 0;
                }
                else if (s[i] >= '0' && s[i] <= '9'){
                    STATE = NUMBER_STATE;
                    i--;
                }
                else if (s[i] == ')'){
                    compute(number_stack, operation_stack);
                }
                break;
            }
        }
        if (number != 0){
            number_stack.push(number);
            compute(number_stack, operation_stack);
        }
        if (number == 0 && number_stack.empty()){
            return 0;
        }
        return number_stack.top();
    }
```

例5:计算函数

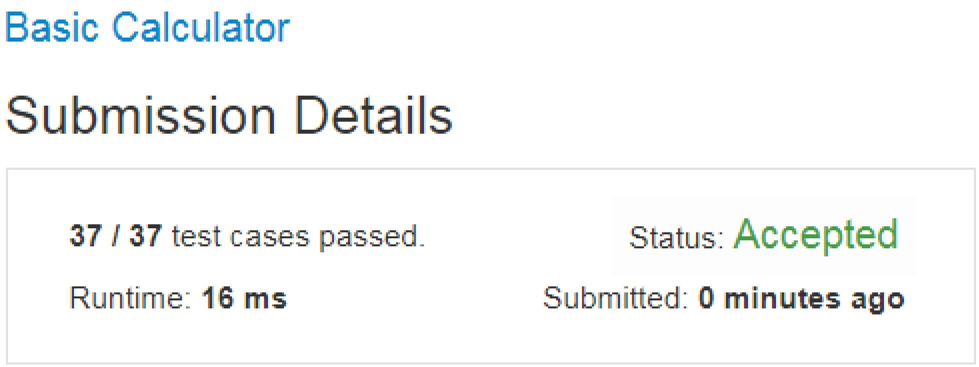


```
void compute(std::stack<int> &number_stack,
                    std::stack<char> &operation_stack){
    if (number_stack.size() < 2){
        return;
    }
    int num2 = number_stack.top();
    number_stack.pop();
    int num1 = number_stack.top();
    number_stack.pop();
    if (operation_stack.top() == '+'){
        number_stack.push(num1 + num2);
    }
    else if(operation_stack.top() == '-'){
        number_stack.push(num1 - num2);
    }
    operation_stack.pop();
}
```

例5:测试与leetcode提交结果



```
int main(){
    std::string s = "1+121 - (14+(5-6) )";
    Solution solve;
    printf("%d\n", solve.calculate(s));
    return 0;
}
```



Basic Calculator

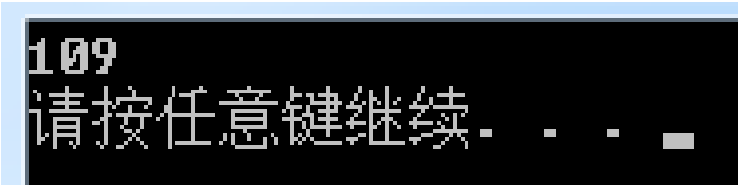
Submission Details

37 / 37 test cases passed.

Status: Accepted

Runtime: **16 ms**

Submitted: **0 minutes ago**

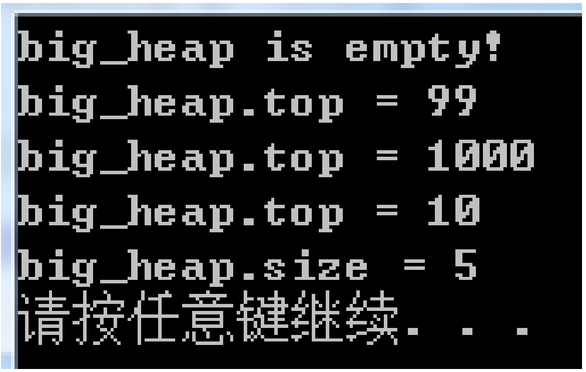


```
109
请按任意键继续. . .
```

预备知识:STL优先级队列(二叉堆)

二叉堆，最小(大)值先出的完全二叉树。

```
#include <stdio.h>
#include <queue>
int main(){
    std::priority_queue<int> big_heap;  //默认构造是最大堆
    std::priority_queue<int, std::vector<int>,  //最小堆构造方法
                        std::greater<int> > small_heap;
    std::priority_queue<int, std::vector<int>,
                        std::less<int> > big_heap2;  //最大堆构造方法
    if (big_heap.empty()){
        printf("big_heap is empty!\n");
    }
    int test[] = {6, 10, 1, 7, 99, 4, 33};
    for (int i = 0; i < 7; i++){
        big_heap.push(test[i]);
    }
    printf("big_heap.top = %d\n", big_heap.top());
                 1
    printf("big_heap.top = %d\n", big_heap.top());
    for (int i = 0;   2   ; i++){
               3
    }
    printf("big_heap.top = %d\n", big_heap.top());
    printf("big_heap.size = %d\n", big_heap.size());
    return 0;
}
```



```
big_heap is empty!
big_heap.top = 99
big_heap.top = 1000
big_heap.top = 10
big_heap.size = 5
请按任意键继续. . .
```

big_heap.empty()：判断堆是否为空

big_heap.pop()：弹出堆顶元素(最大值)

big_heap.push(x)：将元素x添加至二叉堆

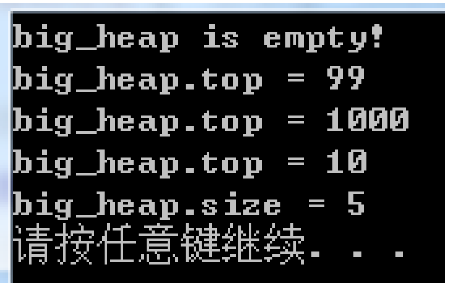
big_heap.top()：返回堆顶元素(最大值)

big_heap.size()：返回堆中元素个数

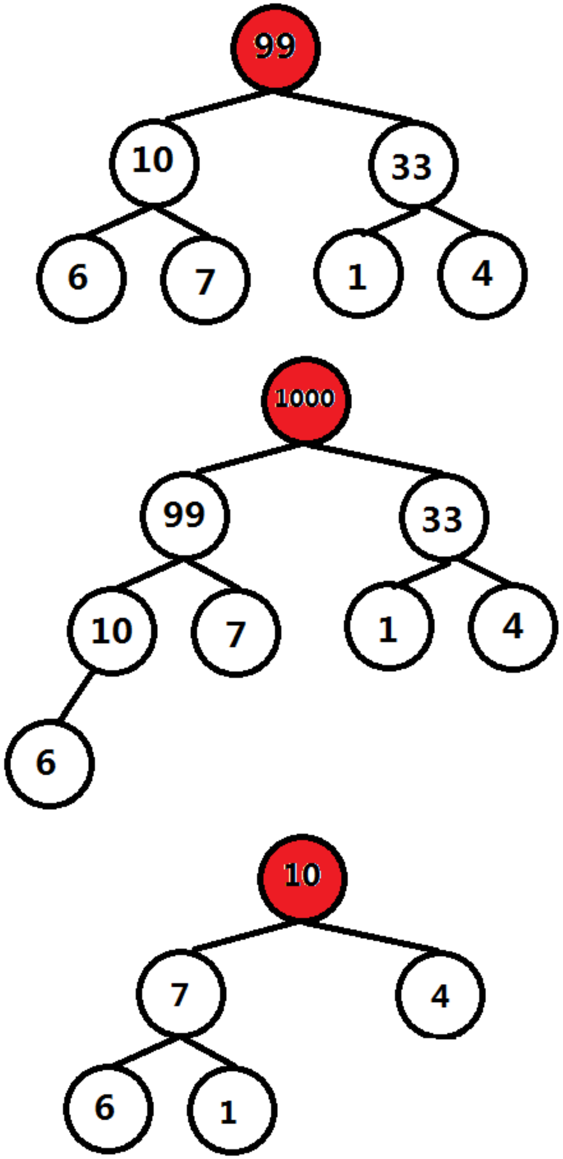
小象学院
ChinaHadoop.cn

预备知识:STL优先级队列

```
#include <stdio.h>
#include <queue>
int main(){
    std::priority queue<int> big_heap; //默认构造是最大堆
    std::priority queue<int, std::vector<int>, //最小堆构造方法
                    std::greater<int> > small_heap;
    std::priority queue<int, std::vector<int>,
                    std::less<int> > big_heap2;  //最大堆构造方法

    if (big_heap.empty()){
        printf("big_heap is empty!\n");
    }
    int test[] = {6, 10, 1, 7, 99, 4, 33};
    for (int i = 0; i < 7; i++){
        big_heap.push(test[i]);
    }
    printf("big_heap.top = %d\n", big_heap.top());
     big_heap.push(1000);
    printf("big_heap.top = %d\n", big_heap.top());
    for (int i = 0; i < 3 ; i++){
        big_heap.pop();
    }
    printf("big_heap.top = %d\n", big_heap.top());
    printf("big_heap.size = %d\n", big_heap.size());
    return 0;
}
```



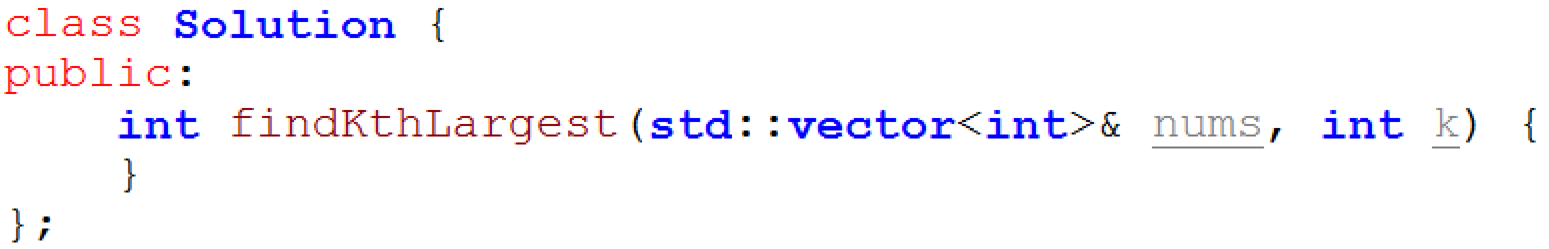
```
big_heap is empty!
big_heap.top = 99
big_heap.top = 1000
big_heap.top = 10
big_heap.size = 5
请按任意键继续. . .
```



例6:数组中第K大的数

已知一个**未排序**的**数组**，求这个数组中**第K大**的数字。

如，array = [3,2,1,5,6,4]， k = 2，return 5



```
class Solution {
public:
    int findKthLargest(std::vector<int>& nums, int k) {
    }
};
```

选自 **LeetCode 215. Kth Largest Element in an Array**
https://leetcode.com/problems/kth-largest-element-in-an-array/description/
难度:**Easy**

例6:思路

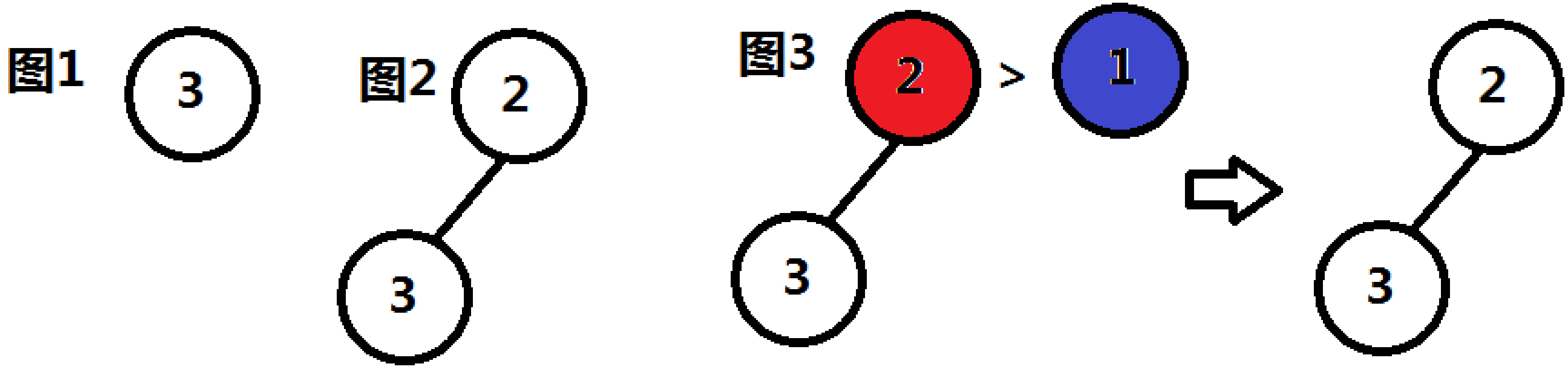
维护一个**K大小**的**最小堆**，堆中元素个数小于K时，新元素**直接**进入堆；否则，当堆顶**小于**新元素时，弹出堆顶，将**新元素加入**堆。

解释:

由于堆是**最小堆**，堆顶是堆中**最小**元素，**新元素**都会保证**比堆顶小**(否则新元素替换堆顶)，故堆中K个元素是已扫描的元素里**最大的K个**；堆顶即为**第K大**的数。

设数组长度为N，求第K大的数，时间复杂度 : N * logK

如，array = [3,2,1,5,6,4] ：



例6:思路

如，array = [3,2,1,5,6,4] ：

图4

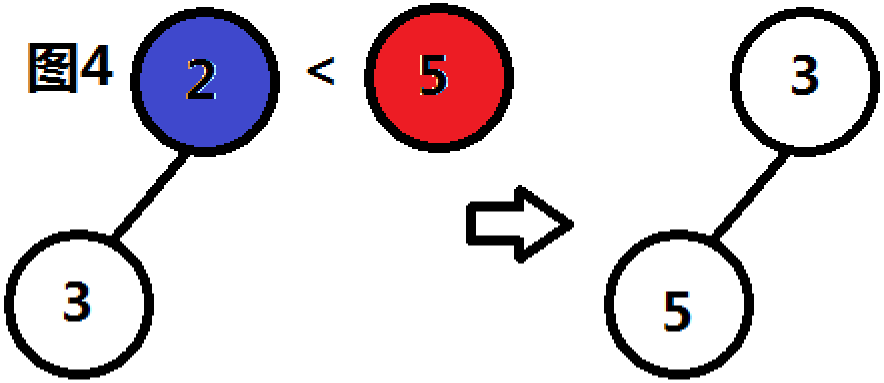


图5

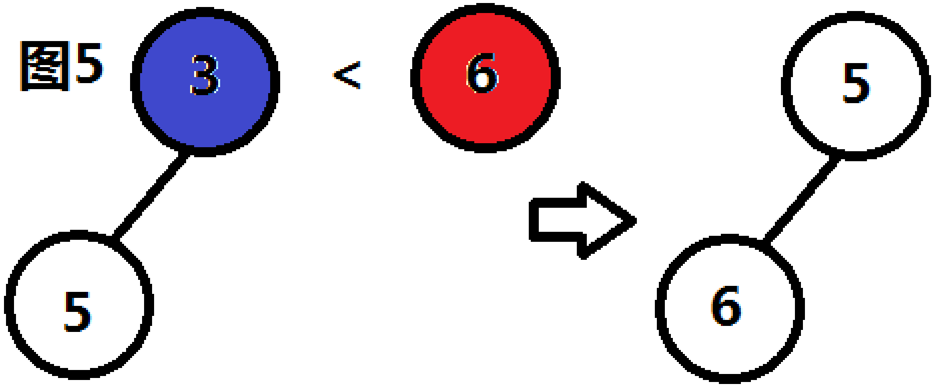
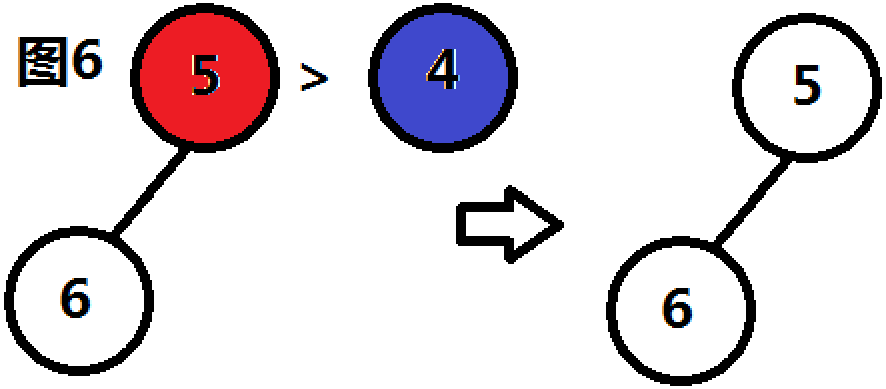
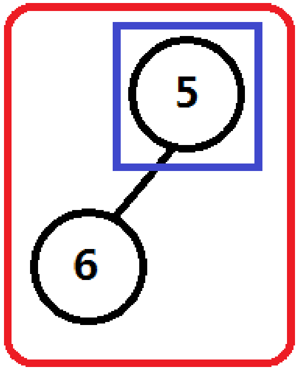


图6



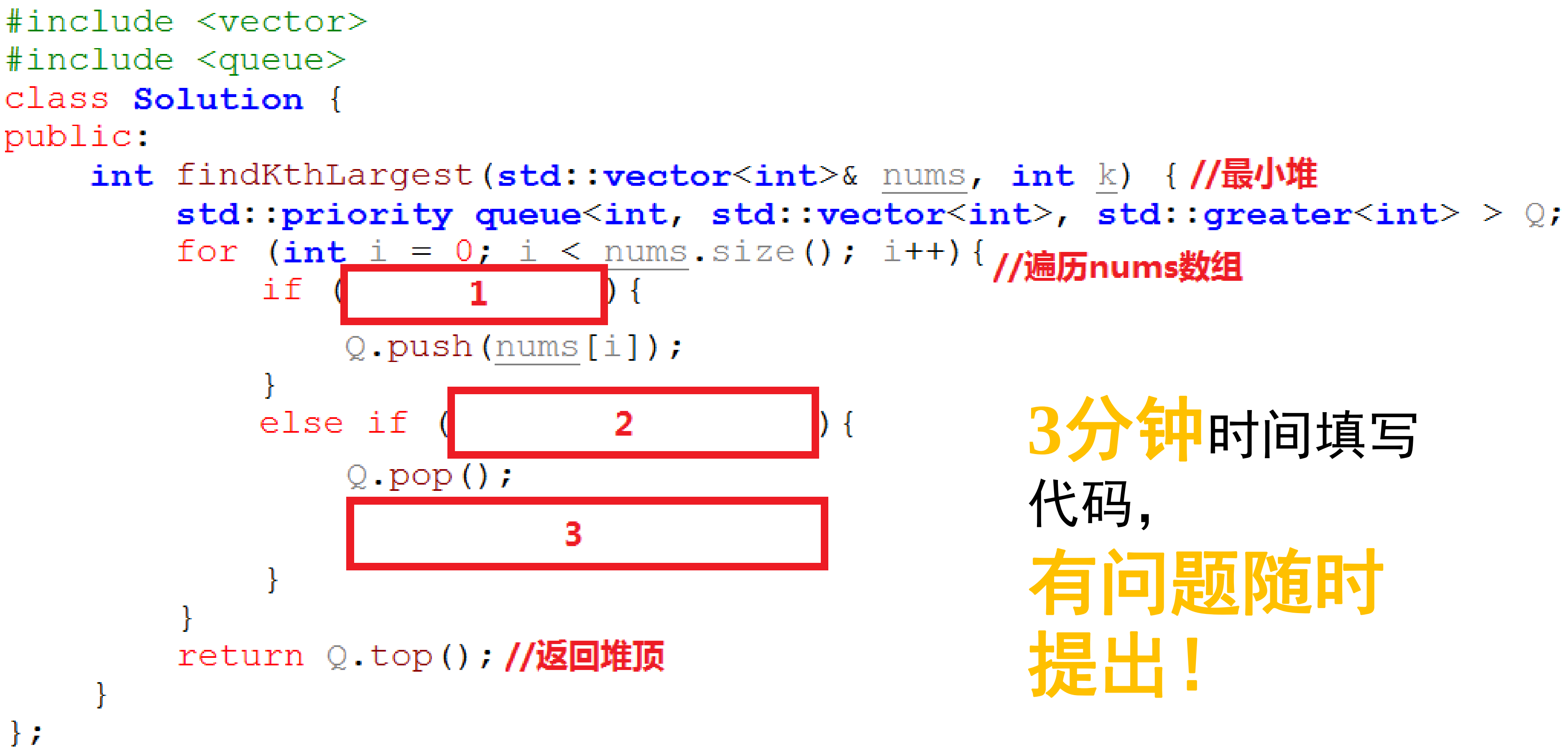
6(N)个数中最大的2(K)个



2(K)个数中最小的，

即6(N)个数第2(K)大的

例6:实现，课堂练习

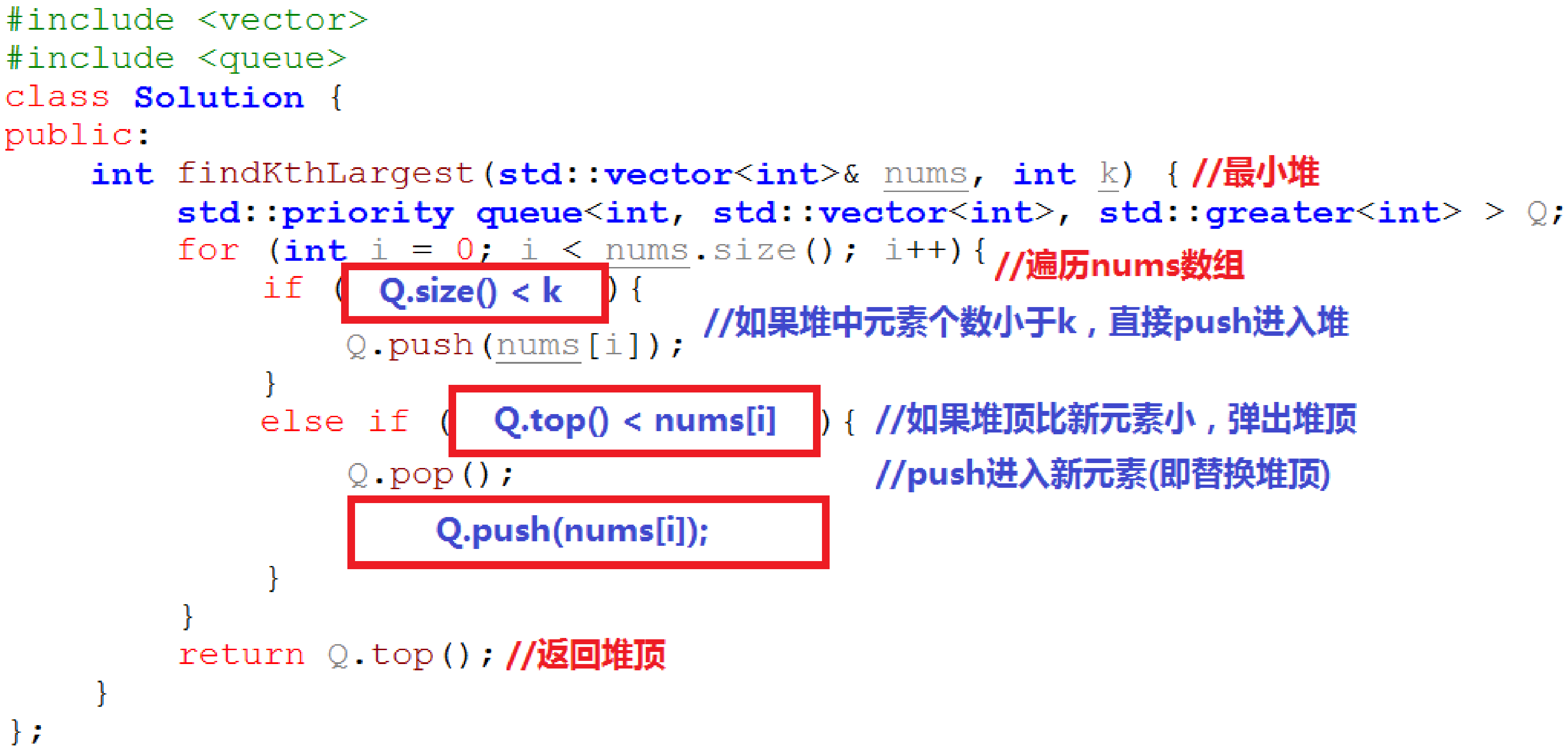


```
#include <vector>
#include <queue>
class Solution {
public:
    int findKthLargest(std::vector<int>& nums, int k) { //最小堆
        std::priority queue<int, std::vector<int>, std::greater<int> > Q;
        for (int i = 0; i < nums.size(); i++){ //遍历nums数组
            if (        1        ){
                Q.push(nums[i]);
            }
            else if (        2        ){
                Q.pop();
                            3
            }
        }
        return Q.top(); //返回堆顶
    }
};
```

3分钟时间填写代码，

有问题随时提出！

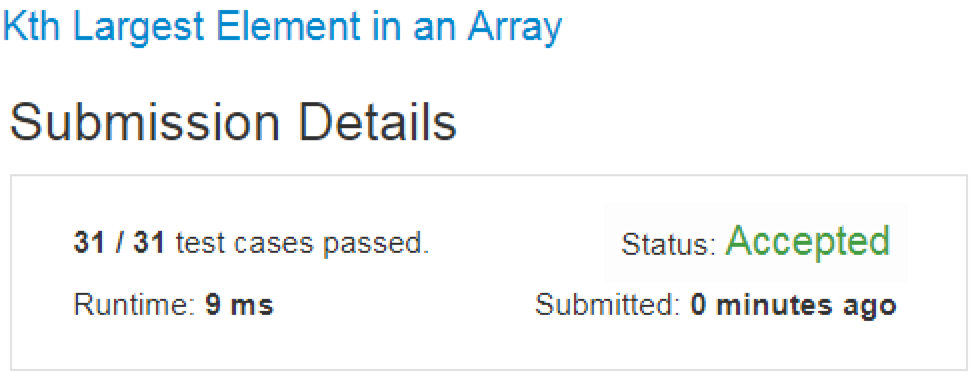
例6:实现



```
#include <vector>
#include <queue>
class Solution {
public:
    int findKthLargest(std::vector<int>& nums, int k) { //最小堆
        std::priority_queue<int, std::vector<int>, std::greater<int> > Q;
        for (int i = 0; i < nums.size(); i++){ //遍历nums数组
            if (Q.size() < k ){
                Q.push(nums[i]); //如果堆中元素个数小于k，直接push进入堆
            }
            else if (Q.top() < nums[i]) { //如果堆顶比新元素小，弹出堆顶
                Q.pop();                  //push进入新元素(即替换堆顶)
                Q.push(nums[i]);
            }
        }
        return Q.top(); //返回堆顶
    }
};
```

例6:测试与leetcode提交结果

```
int main(){
    std::vector<int> nums;
    nums.push_back(3);
    nums.push_back(2);
    nums.push_back(1);
    nums.push_back(5);
    nums.push_back(6);
    nums.push_back(4);
    Solution solve;
    printf("%d\n", solve.findKthLargest(nums, 2));
    return 0;
}
```



Kth Largest Element in an Array

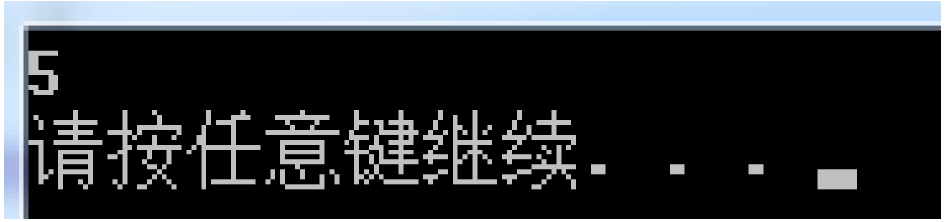
Submission Details

31 / 31 test cases passed.

Status: Accepted

Runtime: 9 ms

Submitted: 0 minutes ago



```
5
请按任意键继续. . .
```

例7:寻找中位数

设计一个数据结构，该数据结构**动态**维护一组数据，且**支持**如下操作:

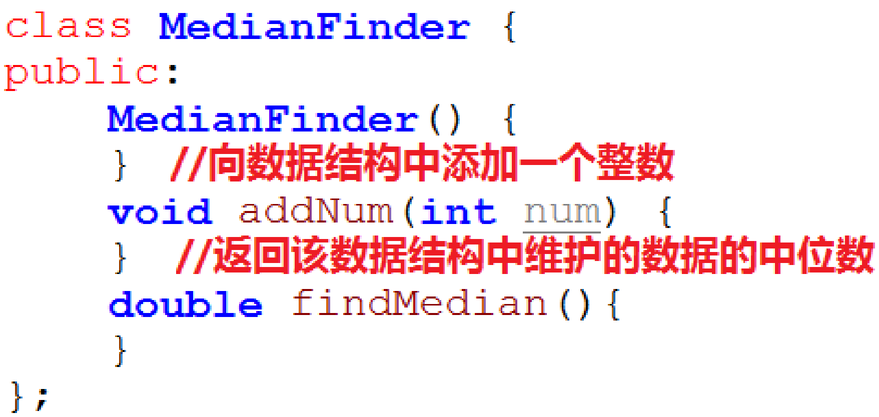
1.**添加**元素: void addNum(int num)，将整型num添加至数据结构中。

2.返回数据的**中位数**: double findMedian()，返回其维护的数据的**中位数**。

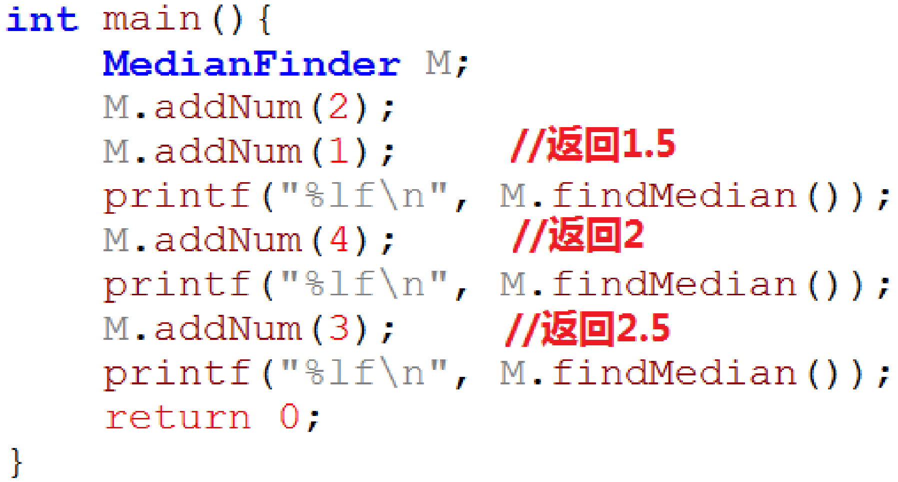
中位数定义:

1.若数据个数为奇数，中位数是该组数排序后中间的数。[1,2,3] -> 2

2.若数据个数为偶数，中位数是该组数排序后中间的两个数字的平均值。[1,2,3,4] -> 2.5



```
class MedianFinder {
public:
    MedianFinder() {
    }  //向数据结构中添加一个整数
    void addNum(int num) {
    }  //返回该数据结构中维护的数据的中位数
    double findMedian(){
    }
};
```



```
int main(){
    MedianFinder M;
    M.addNum(2);
    M.addNum(1);          //返回1.5
    printf("%lf\n", M.findMedian());
    M.addNum(4);          //返回2
    printf("%lf\n", M.findMedian());
    M.addNum(3);          //返回2.5
    printf("%lf\n", M.findMedian());
    return 0;
}
```

选自 **LeetCode 295. Find Median from Data Stream**

https://leetcode.com/problems/find-median-from-data-stream/description/

难度:**Hard**

例7:思考:如何获取中位数

最**直观**的方法:

存储结构使用**数组**，每次**添加元素**或**查找中位数**时对数组**排序**，再计算结果。

时间复杂度:

1.若**添加元素时排序**，addNum复杂度O(n)，findMedian复杂度O(1)

2.若**查询中位数时排序**，addNum复杂度O(1)，findMedian复杂度O(nlogn)

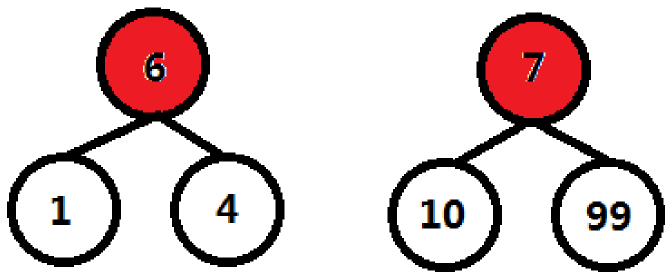
若添加元素或查询中位数是**随机**的操作，共n次操作，按上述思想，整体复杂度**最佳为O(n^2)**

是否还有**更好方法**？思考1分钟！

例7:思路:巧用堆的性质

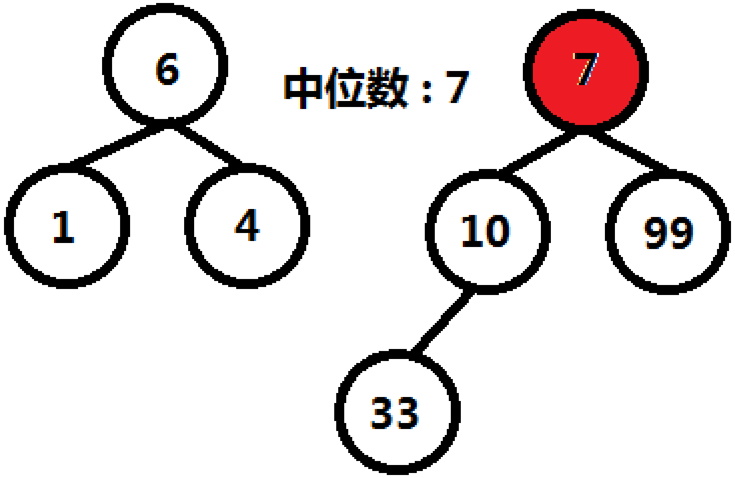
动态维护一个**最大堆**与一个**最小堆**，最大堆存储一半数据，最小堆存储一般数据，**维持**最大堆的堆顶比最小堆的堆顶小。

最大堆: 最小堆:



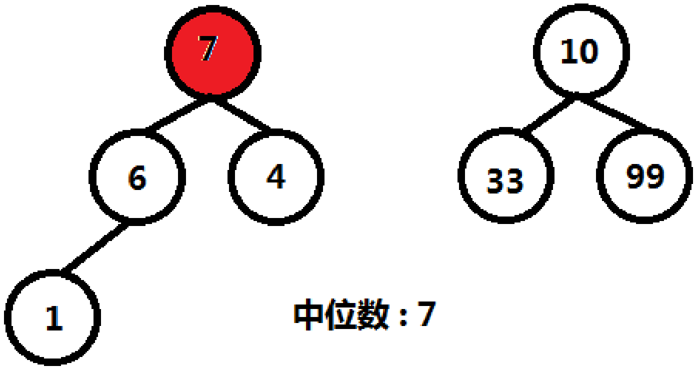
中位数：(6 + 7)/2 = 6.5

最大堆: 最小堆:



中位数：7

最大堆: 最小堆:



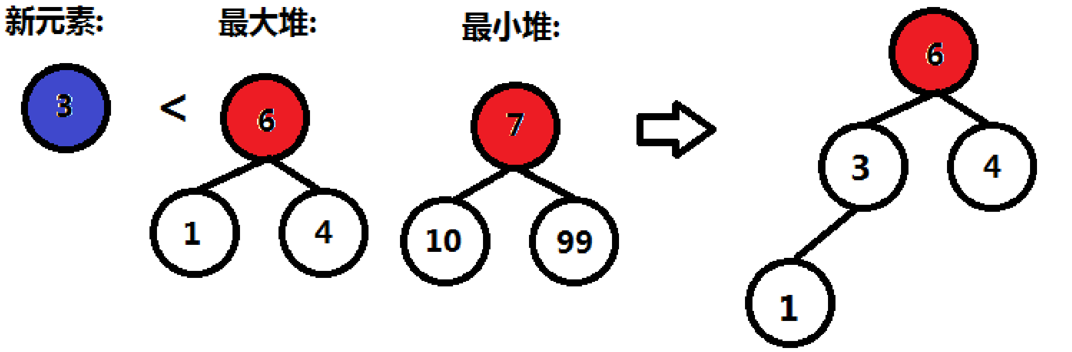
中位数：7

例7:思路:添加元素时堆调整1

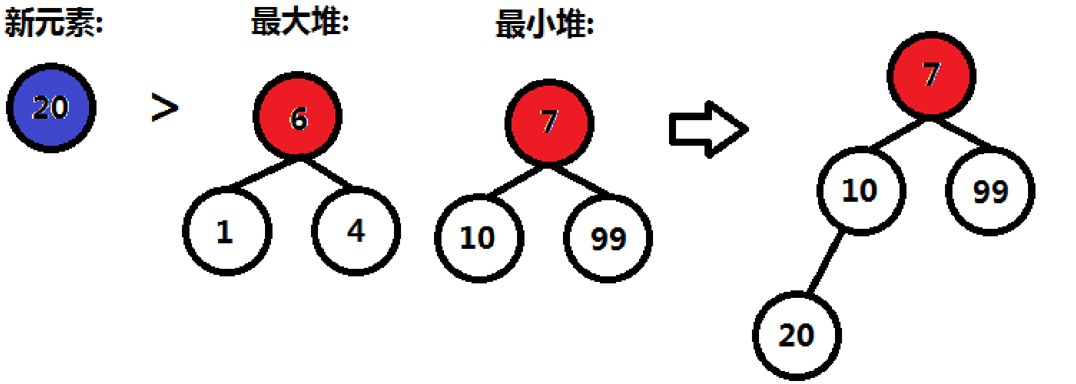
情况1:

最大堆与最小堆元素个数相同时:

将3push进入最大堆



将20 push进入最小堆

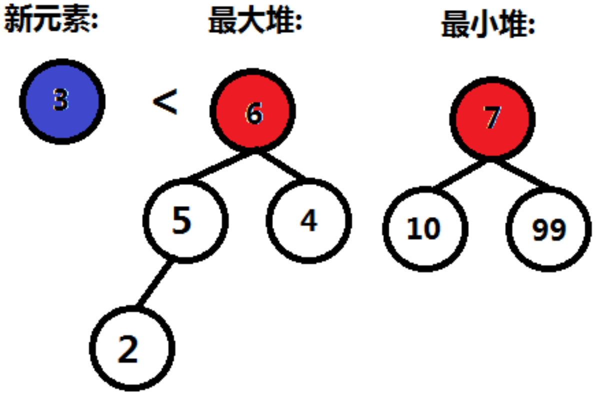


例7:思路:添加元素时堆调整2

情况2:

最大堆比最小堆多一个元素:

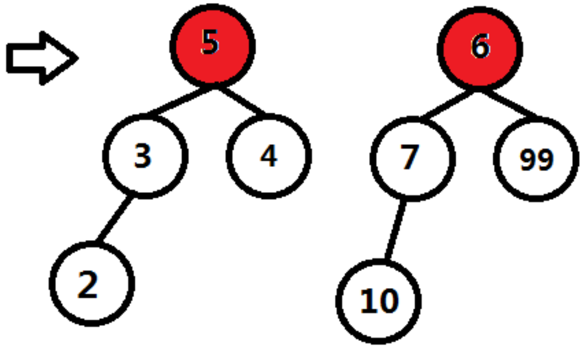
a. 如果新元素小于最大堆堆顶:



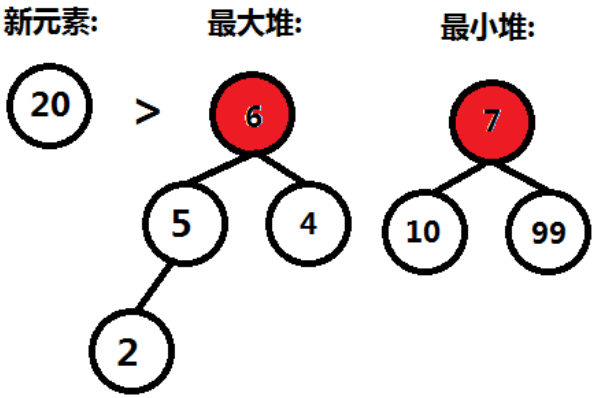
将最大堆的堆顶push进入最小堆

将最大堆的堆顶移除(pop)

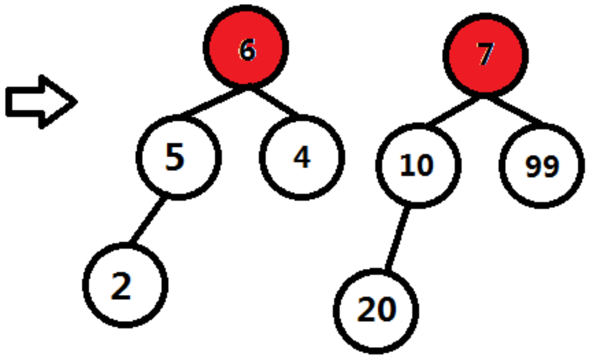
将新元素添加至最大堆



b. 如果新元素大于最大堆堆顶:



将新元素直接push进入最小堆



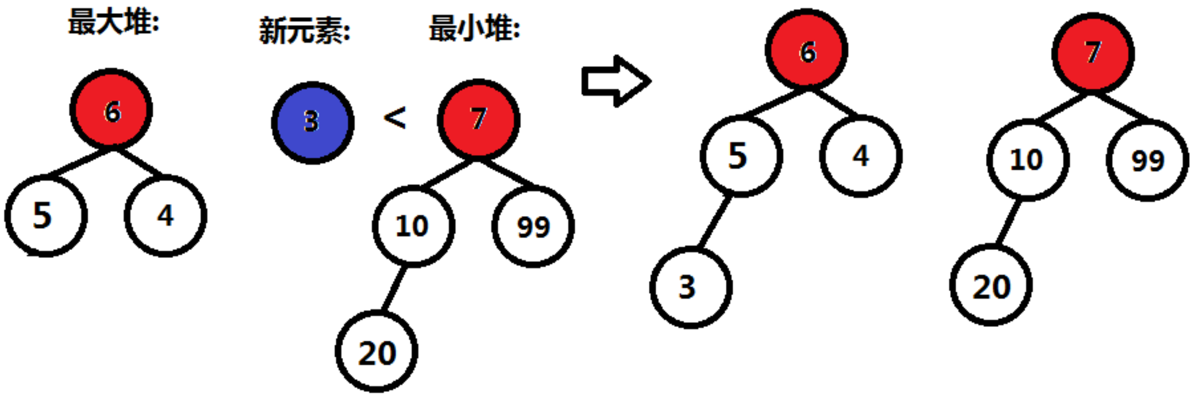
例7:思路:添加元素时堆调整3

情况3:

最大堆比最小堆少一个元素:

a. 如果新元素小于最小堆堆顶:

将新元素直接push进入最大堆

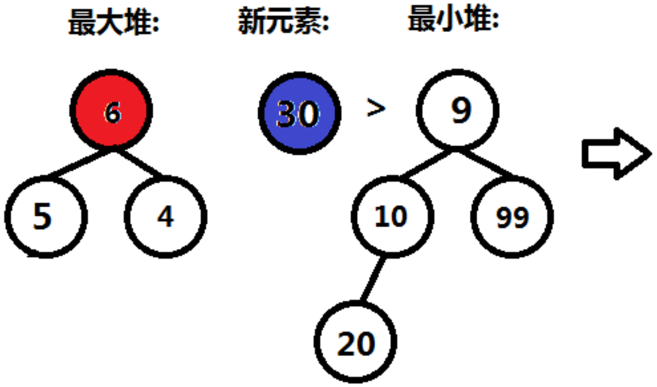


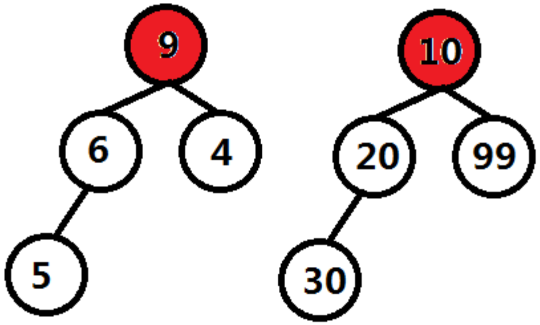
b. 如果新元素大于最小堆堆顶:

将最小堆的堆顶push进入最大堆

将最小堆的堆顶移除(pop)

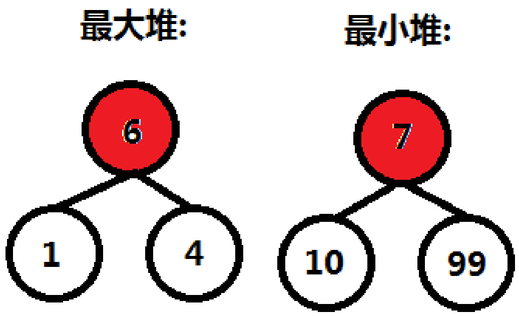
将新元素添加至最小堆





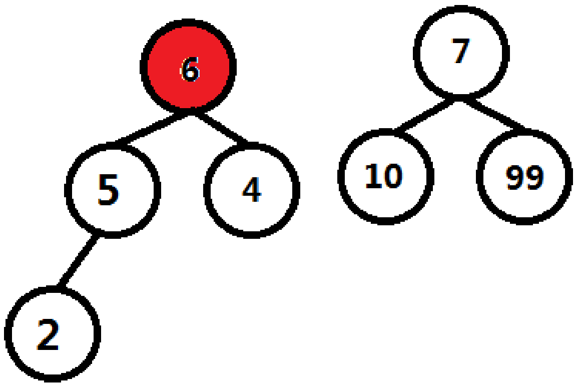
例7:思路:获取中位数

a.最大堆最小堆中的元素个数相同时



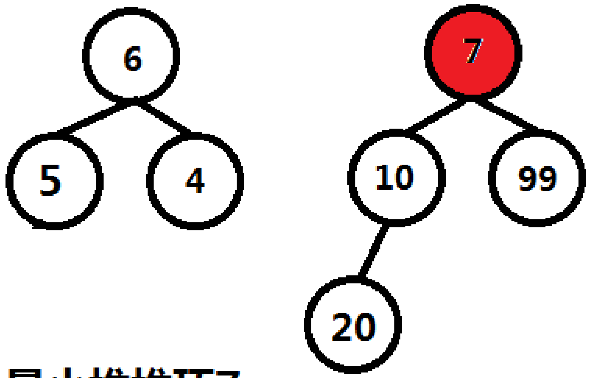
最大堆堆顶与最小堆堆顶的平均值: (6+7)/2 = 6.5

b.最大堆比最小堆多一个元素:



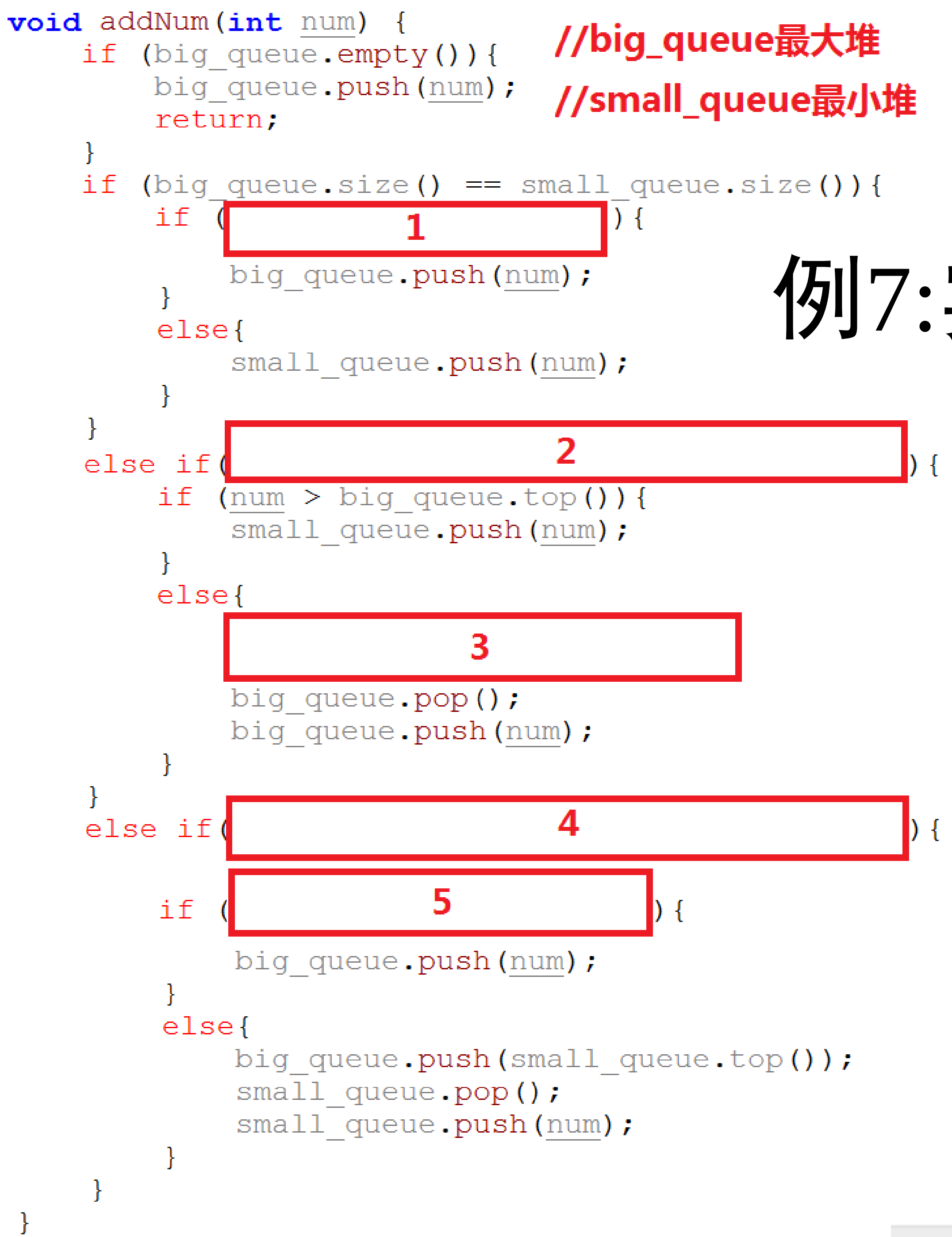
最大堆堆顶6

c.最大堆比最小堆少一个元素:



最小堆堆顶7

例7:实现，课堂练习



```
void addNum(int num) {
    if (big_queue.empty()){
        big_queue.push(num);
        return;
    }
    if (big_queue.size() == small_queue.size()){
        if (         1         ){
            big_queue.push(num);
        }
        else{
            small_queue.push(num);
        }
    }
    else if(              2              ){
        if (num > big_queue.top()){
            small_queue.push(num);
        }
        else{
                      3
            big_queue.pop();
            big_queue.push(num);
        }
    }
    else if(              4              ){

        if (         5         ){
            big_queue.push(num);
        }
        else{
            big_queue.push(small_queue.top());
            small_queue.pop();
            small_queue.push(num);
        }
    }
}
```

//big_queue最大堆

//small_queue最小堆

5分钟时间填写代码，

有问题随时提出！

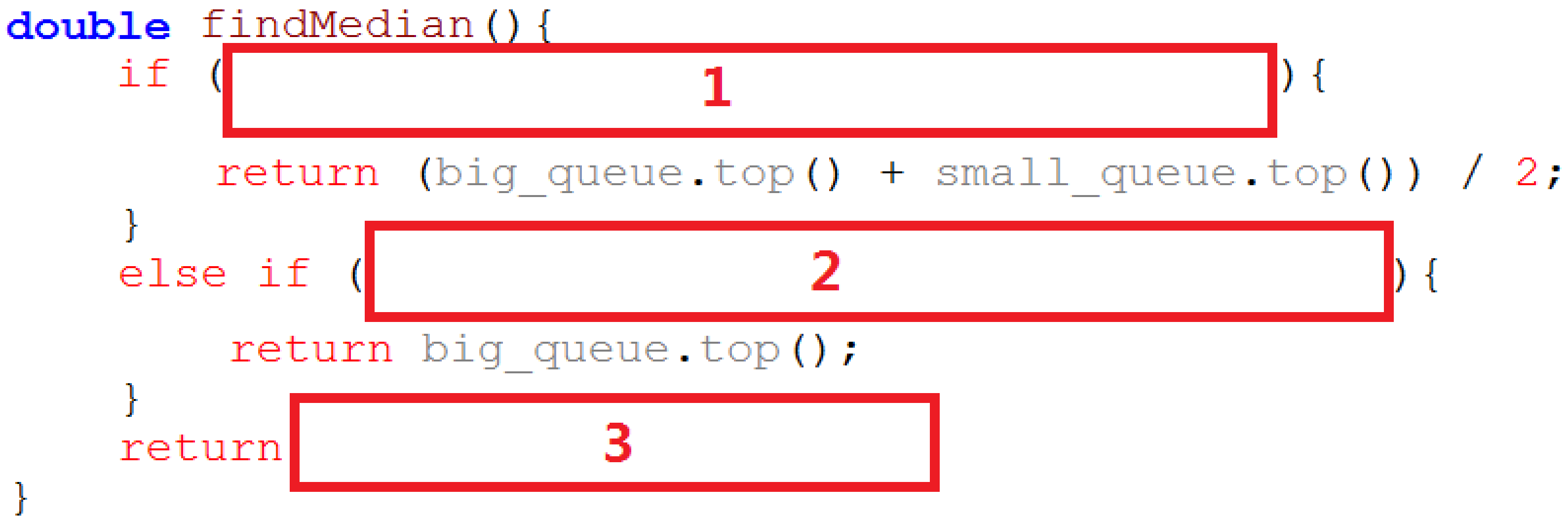
例7:实现

//big_queue最大堆

//small_queue最小堆

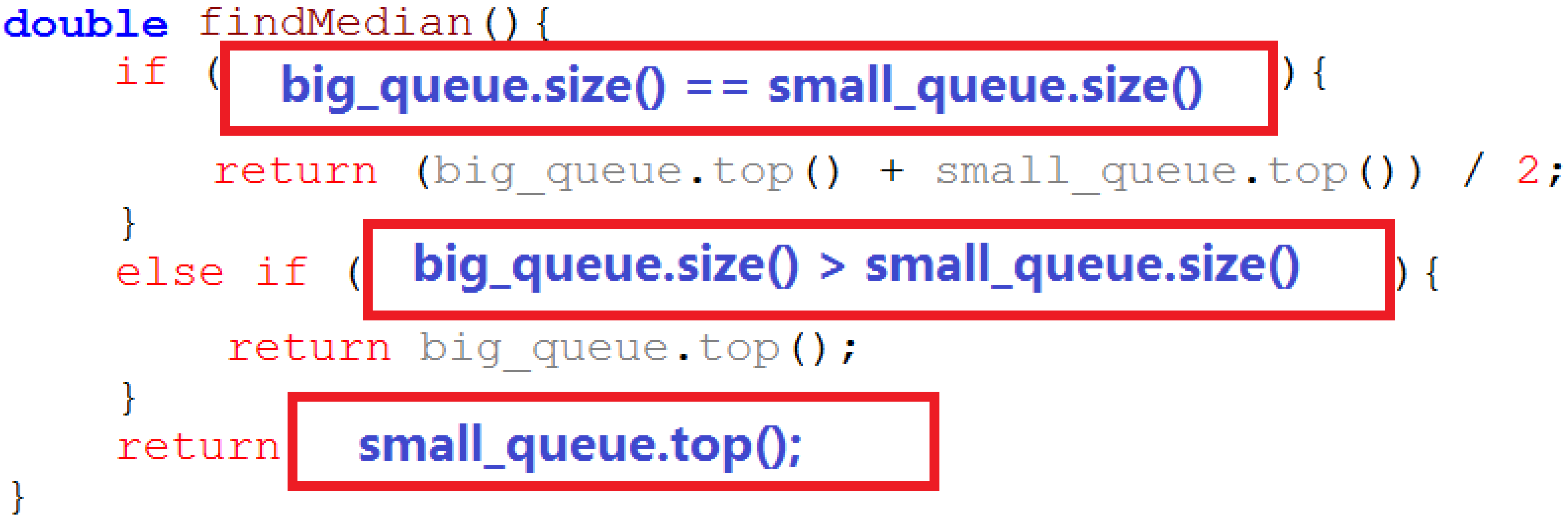
```
void addNum(int num) {
    if (big_queue.empty()){
        big_queue.push(num);
        return;
    }
    if (big_queue.size() == small_queue.size()){
        if ( num < big_queue.top() ){
            big_queue.push(num);
        }
        else{
            small_queue.push(num);
        }
    }
    else if( big_queue.size() > small_queue.size() ) {
        if (num > big_queue.top()){
            small_queue.push(num);
        }
        else{
            small_queue.push(big_queue.top());
            big_queue.pop();
            big_queue.push(num);
        }
    }
    else if( big_queue.size() < small_queue.size() ) {

        if ( num < small_queue.top() ) {
            big_queue.push(num);
        }
        else{
            big_queue.push(small_queue.top());
            small_queue.pop();
            small_queue.push(num);
        }
    }
}
```

例7:实现，课堂练习



```
double findMedian(){
    if (          1          ){
        return (big_queue.top() + small_queue.top()) / 2;
    }
    else if (          2          ){
        return big_queue.top();
    }
    return          3
}
```

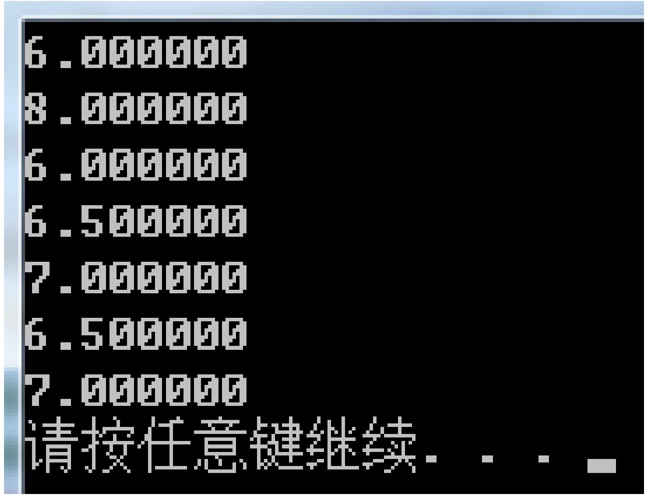
例7:实现



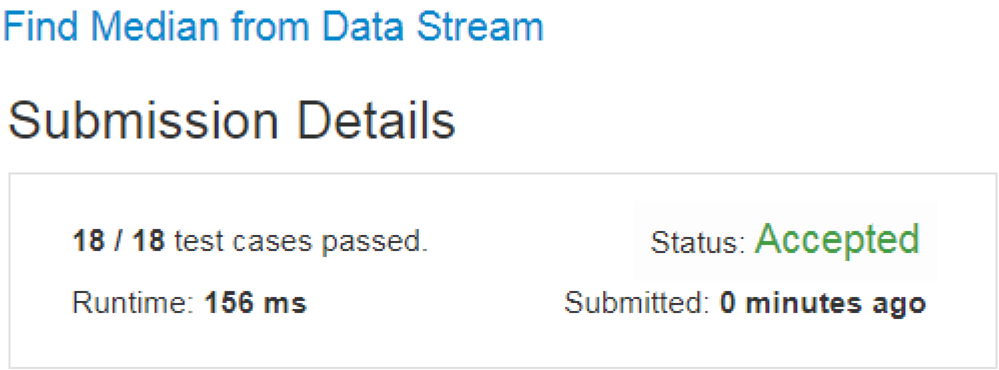
```
double findMedian(){
    if ( big_queue.size() == small_queue.size() ) {
        return (big_queue.top() + small_queue.top()) / 2;
    }
    else if ( big_queue.size() > small_queue.size() ) {
        return big_queue.top();
    }
    return small_queue.top();
}
```

例7:测试与leetcode提交结果

```
int main(){
    MedianFinder M;
    int test[] = {6, 10, 1, 7, 99, 4, 33};
    for (int i = 0; i < 7; i++){
        M.addNum(test[i]);
        printf("%lf\n", M.findMedian());
    }
    return 0;
}
```



```
6.000000
8.000000
6.000000
6.500000
7.000000
6.500000
7.000000
请按任意键继续. . .
```



Find Median from Data Stream

Submission Details

18 / 18 test cases passed.

Status: Accepted

Runtime: **156 ms**

Submitted: **0 minutes ago**

结束

非常感谢大家！

林沐