Stacks（1）

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Outline

- Stack ADT
- Array-Based Stack
- Linked Stack
- Comparison of Array-Based and Linked Stacks
- Applications

Stacks

- The stack is a list-like structure in which elements may be inserted or removed from only one end, called the top of the stack.
- All access is restricted to the most recently inserted elements
- Basic operations are push, pop

Stacks

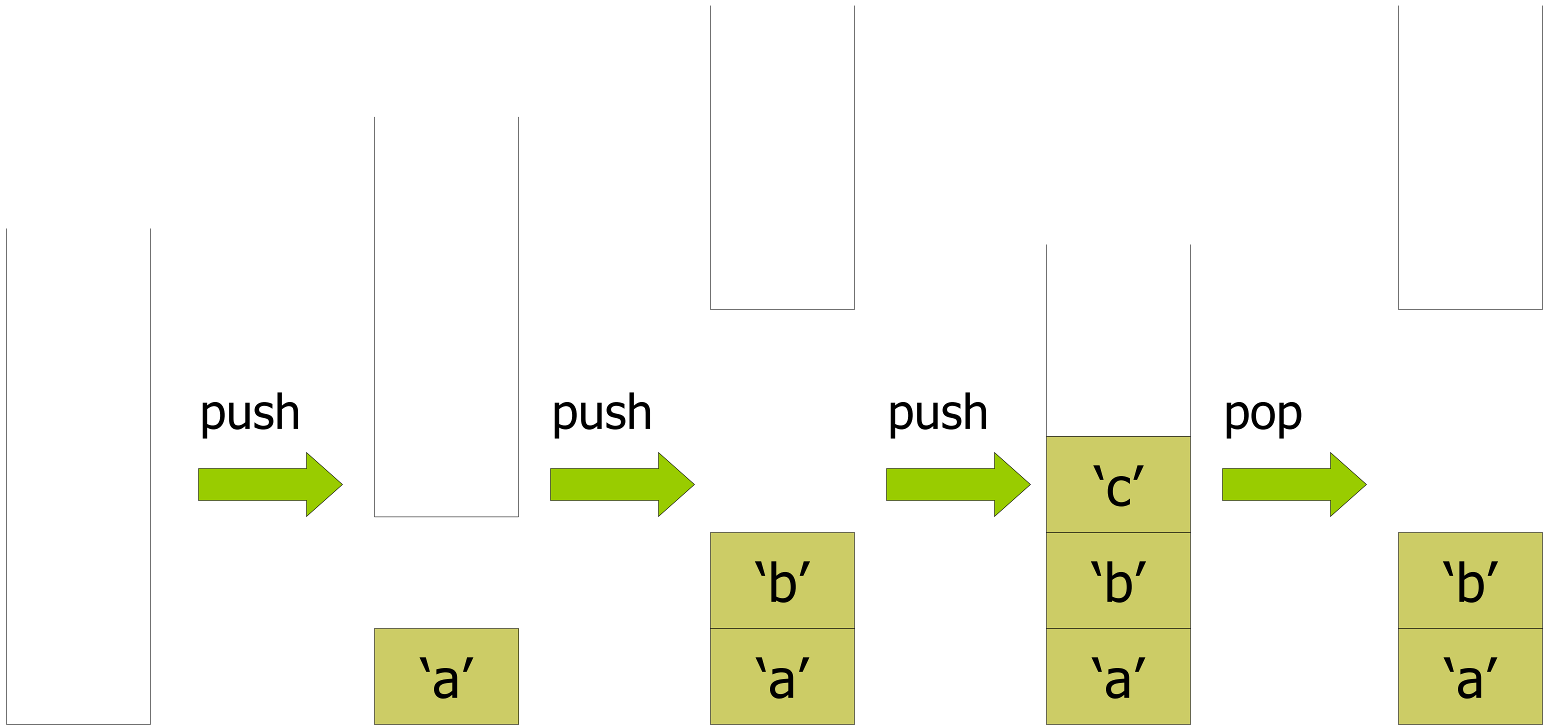
LIFO: Last In, First Out.

Restricted form of list: Insert and remove only at front of list.

Notation:

- Insert: PUSH
- Remove: POP
- The accessible element is called **top element**.

Example: Stack of Char



Stack ADT

```
// Stack abtract class
template <typename E> class Stack {
private:
  void operator =(const Stack&) {} // Protect assignment
  Stack(const Stack&) {} // Protect copy constructor
public:
  Stack() {} // Default constructor
  virtual ˜Stack() {} // Base destructor
  // Reinitialize the stack. The user is responsible for
  // reclaiming the storage used by the stack elements.
  virtual void clear() = 0;
```

Stack ADT

```
// Push an element onto the top of the stack.
// it: The element being pushed onto the stack.
virtual void push(const E& it) = 0;
// Remove the element at the top of the stack.
// Return: The element at the top of the stack.
virtual E pop() = 0;
// Return: A copy of the top element.
virtual const E& topValue() const = 0;
// Return: The number of elements in the stack.
virtual int length() const = 0;
}
```

Array-Based Stack

- The array-based stack implementation is essentially a simplified version of the array-based list.
- The only important design decision to be made is which end of the array should represent the top of the stack.
  - One choice is to make the top be at **position 0** in the array. This implementation is inefficient.（Why？）
  - The other choice is have the top element be at **position n-1** when there are n elements in the stack.
- For the implementation of Figure 4.18, **top** is defined to be the array index of the **first free position** in the stack. Thus, an empty stack has top set to 0, the first available free position in the array.

Array-Based Stack

```
// Array-based stack implementation
private:
  int size;     // Maximum size of stack
  int top;      // Index for top element
  Elem *listArray; // Array holding elements
public:
  AStack(int size =defaultSize) // Constructor
    { maxSize = size; top = 0; listArray = new E[size]; }
  ~AStack() { delete [] listArray; } // Destructor
  void clear() { top = 0; } // Reinitialize
  void push(const E& it) { // Put "it" on stack
    Assert(top != maxSize, "Stack is full");
    listArray[top++] = it;
 }
```

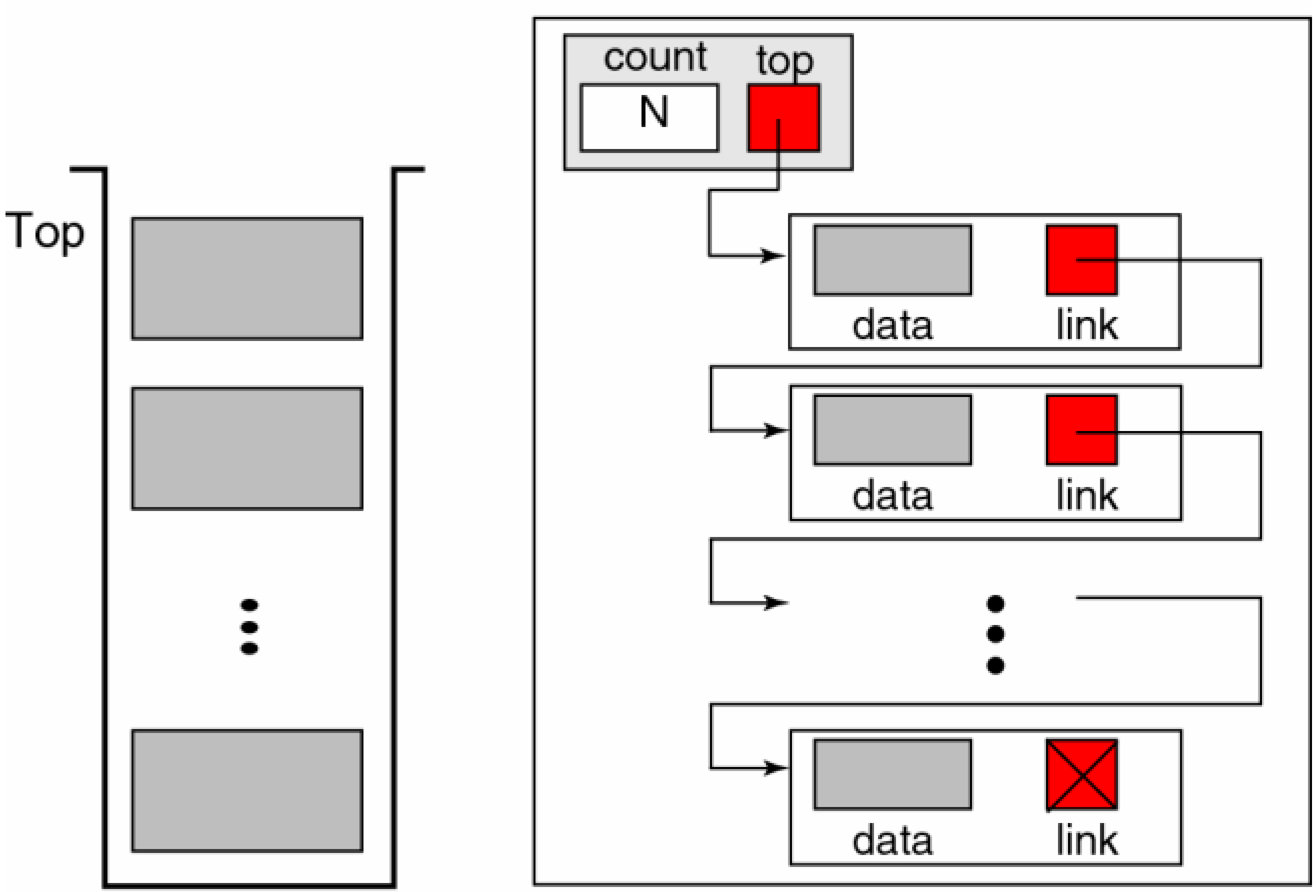
Array-Based Stack

```
  E pop() { // Pop top element
    Assert(top != 0, "Stack is empty");
    return listArray[--top];
  }
  const E& topValue() const { // Return top element
    Assert(top != 0, "Stack is empty");
    return listArray[top-1];
  }
  int length() const { return top; } // Return length
};
```

Issues:

- Which end is the top?
- What is the cost of the operations?

Linked Stack



Conceptual view

Linked list implementation

Linked Stack

- The linked stack implementation is quite simple. The freelist of Section 4.1.2 is an example of a linked stack.
- Elements are inserted and removed only from the head of the list. A header node is not used because no special-case code is required for lists of zero or one elements.
- The only data member is **top**, a pointer to the first (top) link node of the stack.

Linked Stack

```
// Linked stack implementation
private:
  Link<Elem>* top; // Pointer to first elem
  int size;        // Count number of elems
public:
  LStack(int sz =defaultSize) // Constructor
  { top = NULL; size = 0; }
  ˜LStack() { clear(); } // Destructor
```

Linked Stack

```
  void clear() { // Reinitialize
    while (top != NULL) { // Delete link nodes
    Link<E>* temp = top;
    top = top->next;
    delete temp;
  }
  size = 0;
  }
  void push(const E& it) { // Put "it" on stack
    top = new Link<E>(it, top);
    size++;
}
```

Linked Stack

```
E pop() { // Remove "it" from stack
  Assert(top != NULL, "Stack is empty");
  E it = top->element;
  Link<E>* ltemp = top->next;
  delete top;
  top = ltemp;
  size--;
  return it;
}
```

Linked Stack

```
  const E& topValue() const { // Return top value
    Assert(top != 0, "Stack is empty");
    return top->element;
  }
  int length() const { return size; } // Return length
};
```

What is the cost of the operations?

How do space requirements compare to the array-based stack implementation?

Comparison of Array-Based and Linked Stacks

- All operations for the array-based and linked stack implementations take constant time
- Total space required: the analysis is similar to that done for list implementations
- When multiple stacks are to be implemented, it is possible to take advantage of the one-way growth of the array-based stack. This can be done by using a single array to store two stacks, as illustrated by Figure 4.20

Implementing Recursion

- Perhaps the most common computer application that uses stacks is the implementation of subroutine calls in most programming language runtime environments.
- A subroutine call is normally implemented by placing necessary information about the subroutine (including the return address, parameters, and local variables) onto a stack.
- Further subroutine calls add to the stack
- Each return from a subroutine pops the top activation record off the stack

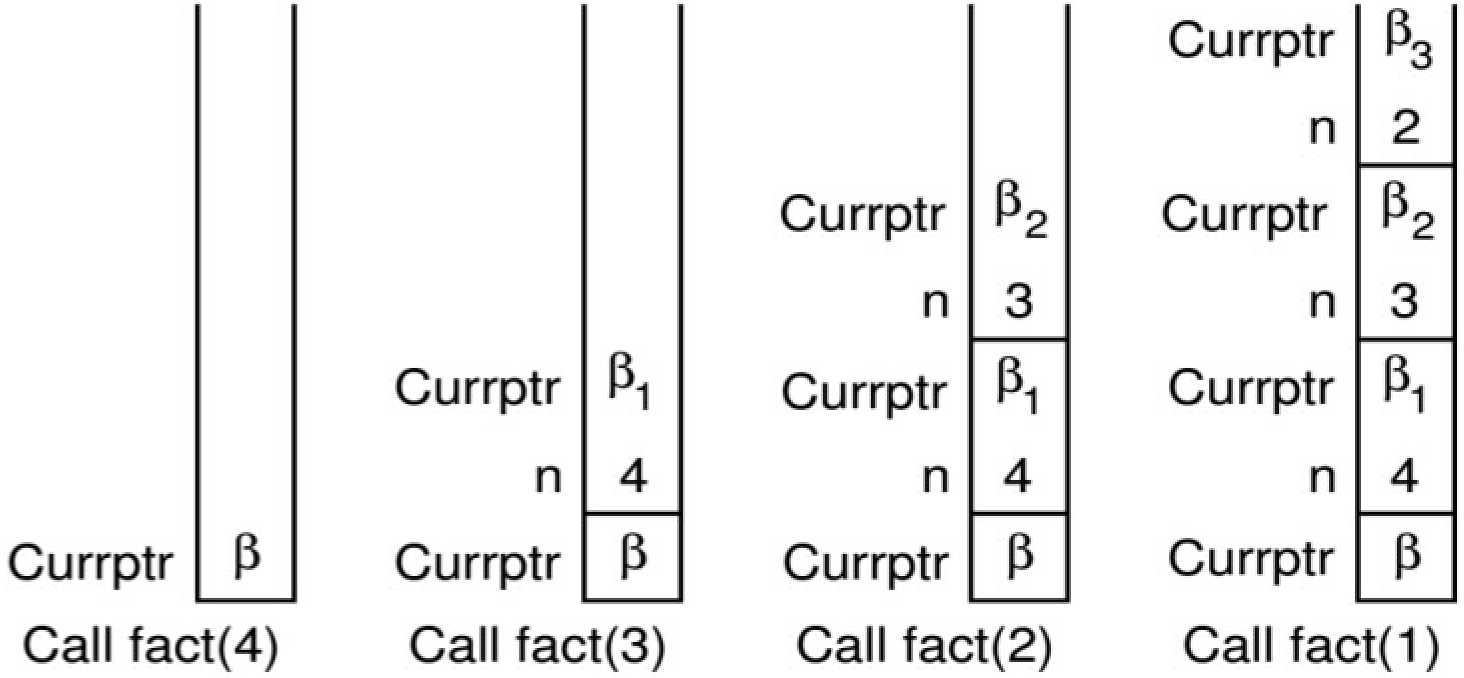
Implementing Recursion

- An algorithm is recursive if it calls itself to do part of its work.
- In general, a recursive algorithm must have two parts:
  - The base case, which handles a simple input that can be solved without resorting to a recursive call
  - The recursive part which contains one or more recursive calls to the algorithm where the parameters are in some sense “closer” to the base case than those of the original call.

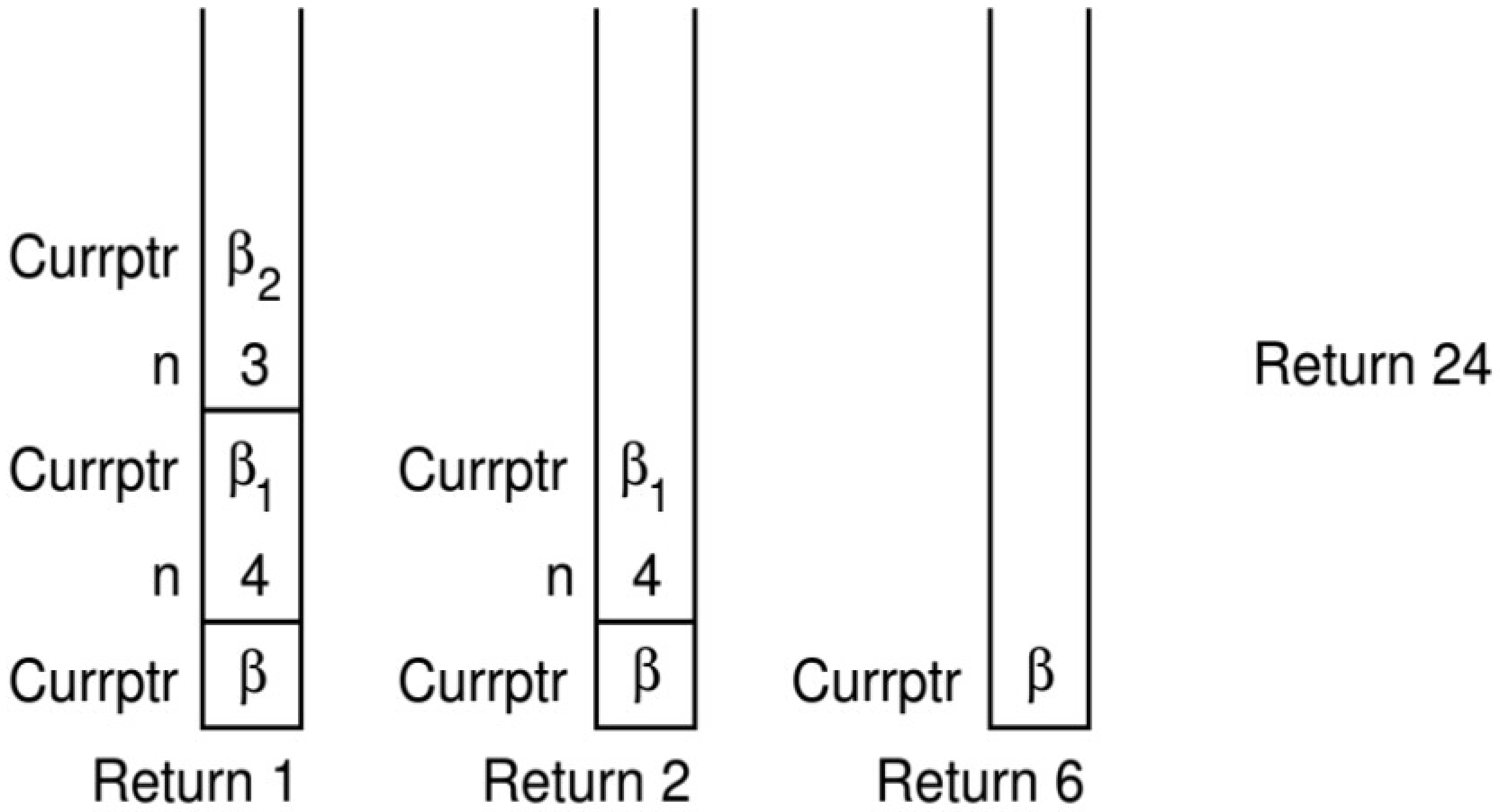
```
long fact(int n) {        // Compute n! recursively
  // To fit n! into a long variable, we require n <= 12
  Assert((n >= 0) && (n <= 12), "Input out of range");
  if (n <= 1)  return 1; // Base case: return base solution
  return n * fact(n-1);  // Recursive call for n > 1
}
```

Implementing Recursion

Consider what happens when we call fact with the value 4:



Implementing Recursion



Stack Applications

Application 1
Data conversion

- A simple algorithm uses the following law:

  N=(N/ d) × d+ N% d

  eg: Convert decimal to binary

  (100)10 = (1100100)2

  - divide decimal number by 2 continuously
  - record the remainders until the quotient becomes 0
  - print the remainders in backward order.

2	100	
2	50	0
2	25	0
2	12	1
2	6	0
2	3	0
2	1	1
	0	1

- Stack is an ideal structure to implement this process.
- How to implement it?

Applications 2
Balancing Symbols

- How do we know the following parentheses are nested correctly ?

  7-((X*((X+Y)/(J-3))+Y)/(4-2.5))

  1. There are an equal number of right and left parentheses.
  2. Every right parenthesis is preceded by a matching left parenthesis.

- ((A+B) or A+B(violate 1
-)A+B(-C or (A+B))-(C+D violate 2

Applications 2
Balancing Symbols

- Stack can be used to check a program for balanced symbols (such as {}, (), []).
- Example: {()} is legal, {(}) is not (so simply counting symbols does not work).
- When a closing symbol is seen, it matches the most recently seen unclosed opening symbol. Therefore, a stack will be appropriate.

Applications 2
Balancing Symbols

- Make an empty stack. Read characters until end of file.
- If the character is an opening symbol, push it onto stack.
- If it is a closing symbol, then if the stack is empty, report an error. Otherwise, pop the stack.
- If the symbol popped is not the corresponding opening symbol, then report an error.
- At the end of file, if the stack is not empty, report an error.

Reference

- **Data Structures and Algorithm Analysis in C++ .Third Edition.Clifford A. Shaffer**(P.120-127)
- 《数据结构（ C 语言版）》，严蔚敏，吴伟民编著，清华大学出版社，1997年第1版,P48-49

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