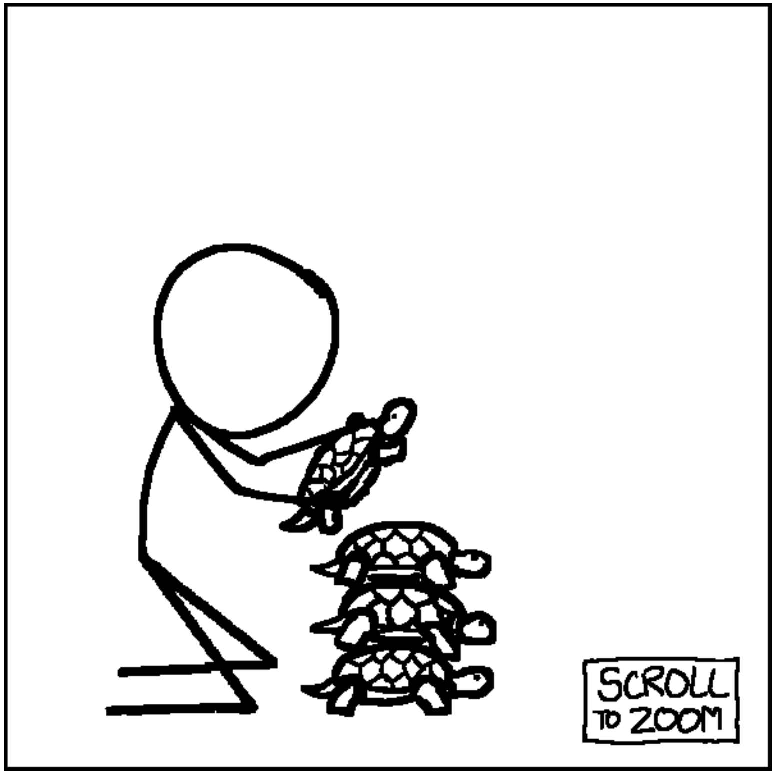
VE280 Programming and Elementary Data Structures

Paul Weng
UM-SJTU Joint Institute

Linear List; Stack



Learning Objectives

- Understand what is a linear list and what is a stack
- Know how they can be implemented
- Discover some applications of the stack data structure

Outline

- Linear List
- Stack
  - Implementation
  - Application

Linear List ADT

- Recall the IntSet ADT
  - A collection of zero or more integers, with **no duplicates**.
  - It supports insertion and removal, but by value.

- A related ADT: linear list
  - A collection of zero or more integers; **duplicates possible.**
    - $L = (e_0, e_1, \dots, e_{N-1})$
  - It supports insertion and removal **by position**.

Linear List ADT

Insertion

```
void insert(int i, int v) // if 0 <= i <= N
// (N is the size of the list), insert v at
// position i; otherwise, throws BoundsError
// exception.
```

```
                0    1    2    3
Example: L1 = (1, 2, 3)
L1.insert(0, 5) = (5, 1, 2, 3);
L1.insert(1, 4) = (1, 4, 2, 3);
L1.insert(3, 6) = (1, 2, 3, 6);
L1.insert(4, 0) throws BoundsError
```

Linear List ADT

Removal

```
void remove(int i) // if 0 <= i < N (N is
// the size of the list), remove the i-th
// element; otherwise, throws BoundsError
// exception.
```

Example: `L2 = (1, 2, 3)`

```
L2.remove(0) = (2, 3);
L2.remove(1) = (1, 3);
L2.remove(2) = (1, 2);
L2.remove(3) throws BoundsError
```

A linear list ADT can be implemented with:

Select all the correct answers.

- **A.** an array.
- **B.** a singly-linked list.
- **C.** a doubly-linked list.
- ~~**D.**~~ any container.

Outline

- Linear List
- Stack
  - Implementation
  - Application

Stack

- A "pile" of objects where new object is put on **top** of the pile and the top object is removed first.
  - LIFO access: last in, first out.
  - Restricted form of a **linear list**: insert and remove only at the end of the list.

Methods of Stack

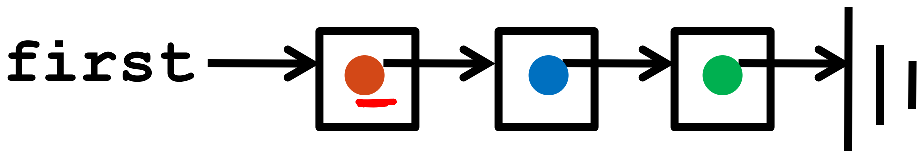
- `size()` : number of elements in the stack.
- `isEmpty()` : checks if stack has no elements.
- `push(Object o)` : add object `o` to the top of stack.
- `pop()` : remove the top object if stack is not empty; otherwise, throw `stackEmpty`.
- `Object &top()` : return a reference to the top element.

Stacks Using Arrays

	0	1		size-1	size
`Array[MAXSIZE]`:	2	3	1	4	0	

- Maintain an integer **`size`** to record the size of the stack.
- **`size()`**: **`return size;`**
- **`isEmpty()`**: **`return (size == 0);`**
- **`push(Object o)`**: add object **`o`** to the end of the array and increment **`size`**. Allocate more space if necessary.
- **`pop()`**: If **`isEmpty()`**, throw **`stackEmpty;`** otherwise, decrement **`size`.**
- **`Object &top()`**: return a reference to the top element **`Array[size-1]`**

Stacks Using Linked Lists

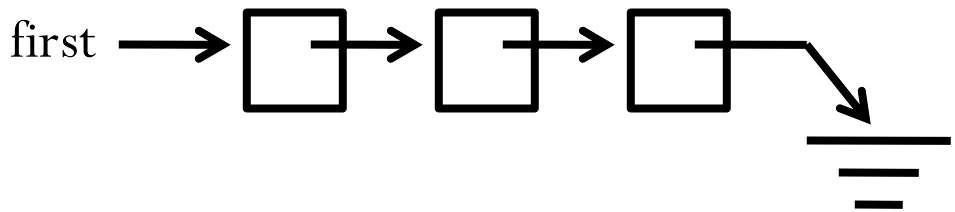


For single-ended linked list, which end is preferred to be the top? Why?

- **`size()`**: **`LinkedList::size();`**
- **`isEmpty()`**: **`LinkedList::isEmpty();`**
- **`push(Object o)`**: insert object at the beginning
  `LinkedList::insertFirst(Object o);`
- **`pop()`**: remove the first node
  `LinkedList::removeFirst();`
- **`Object &top()`**: return a reference to the object stored in the first node.

LinkedList::size()

- How to get the size of a linked list?




```
int LinkedList::size() {
  int count = 0;
  node *current = first;
  while(current){
    count++;
    current = current->next;
  }
  return count;
}
```

Array vs. Linked List: Which is Better?

- They both have advantages and disadvantages

- Linked list
  - memory-efficient: a new item just needs extra constant amount of memory
  - not time-efficient for size operation

- Array
  - time-efficient for size operation
  - not memory-efficient: need to allocate a big enough array

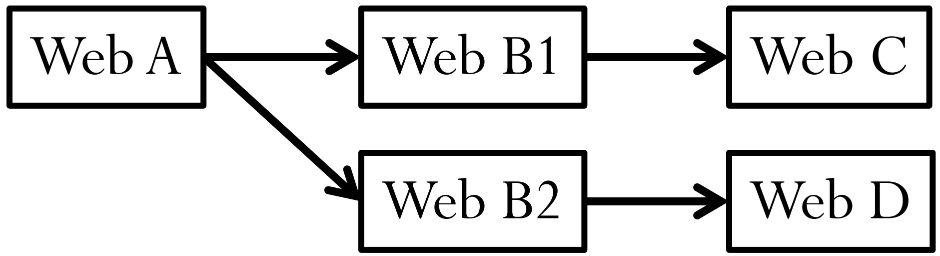
Outline

- Linear List
- Stack
  - Implementation
  - Application

Applications of Stacks

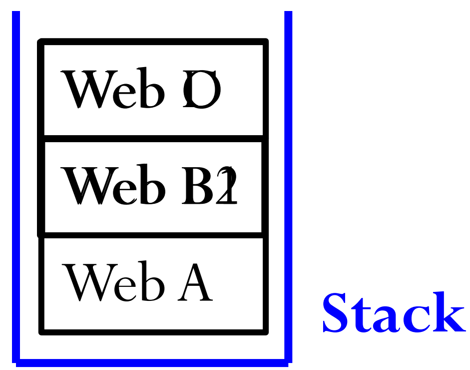
- Function calls in C++
- Web browser's "back" feature
- Parentheses Matching

Web Browser’s “back” Feature



Visiting order

- Web A
- Web B1
- Web C
- Back (to Web B1)
- Back (to Web A)
- Web B2
- Web D



Parentheses Matching

- Output pairs (u,v) such that the left parenthesis at position u is matched with the right parenthesis at v.

```
( ( a + b ) * c + d - e ) / ( f + g )
0 1 2 3 4 5 6 7 8 9 10  12  14  16  18
```

  - Output is: (1, 5); (0, 12); (14, 18);

```
( a + b ) ) * ( ( c + d )
0 1 2 3 4 5 6 7 8 9 10  12
```

  - Output is

    (0, 4);

    Right parenthesis at 5 has no matching left parenthesis;

    (8, 12);

    Left parenthesis at 7 has no matching right parenthesis

How to Realize Parentheses Matching?

```
( ( a + b ) * c + d - e ) / ( f + g )
0 1 2 3 4 5 6 7 8 9 10  12  14  16  18
```

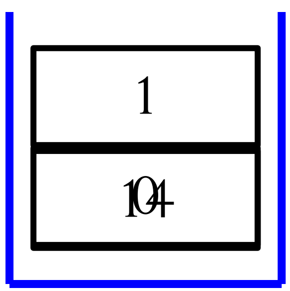
- Scan expression from left to right.
- When a **left** parenthesis is encountered, push its position to the stack.
- When a **right** parenthesis is encountered, pop the top position from the stack, which is the position of the **matching left** parenthesis.
  - If the stack is empty, the **right** parenthesis is not matched.
- If string is scanned over but the stack is not empty, there are not-matched **left** parentheses.

Parentheses Matching

```
( ( a + b ) * c + d - e ) / ( f + g )
```

0 1 2 3 4 5 6 7 8 9 10 12 14 16 18

Stack



(1, 5) (0, 12) (14, 18)

A stack can be used:

Select all the correct answers.

- **A.** to manage any arithmetic expression. evaluate
- **B.** to undo operations (such as in a text editor).
- **C.** to reverse a list.
- ~~**D.**~~ to provide an efficient implementation of a queue. FIFO

Reference

- **Problem Solving with C++ (8th Edition)**, by *Walter Savitch*, Addison Wesley Publishing (2011)
  - Chapter 13.2 Stack