

# Ve 280

## Programming and Elementary Data Structures

### **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  $0 \leq i \leq N$   
// (N is the size of the list), insert v at  
// position i; otherwise, throws BoundsError  
// exception.
```

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  $0 \leq i < N$  (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`



# Which Answers Are Correct?

Suppose we want to implement a linear list ADT so that it can grow as large as the user wants. It can be implemented by:

- **A.** a static array
- **B.** a dynamic array
- **C.** a singly-linked list
- **D.** a doubly-linked list



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# 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.

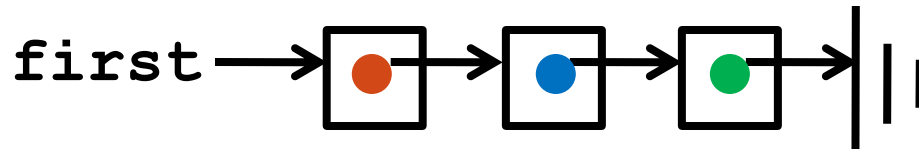
# Stacks Using Arrays

Array[**MAXSIZE**] : 

2	3	1	4		
---	---	---	---	--	--

- Maintain an integer **size** to record the size of the stack.
- **size():return size;**
- **isEmpty():return (size == 0);**
- **push(Object o):** add object **o** at index **size** 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

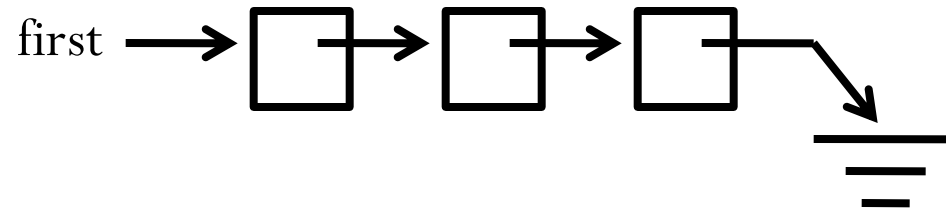


For single-ended linked list, which end is preferred to be the top? Why?

- **`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;  
}
```

A fast version: add a size data member

# Linked List with a size data member

```
class LinkedList {  
    node *first;  
    int size;  
public:  
    ...  
};
```

```
int LinkedList::size()  
{  
    return size;  
}
```

- Question: do we need to change any other parts of the code?
  - We need to increment/decrement **size** when nodes are inserted/removed.

# Array vs. Linked List: Which is Better?

- Linked list **with a size data member** is better
- Array
  - not memory-efficient: need to allocate a big enough array
- Linked list with a size data member
  - memory-efficient: a new item just needs extra constant amount of memory
  - All operations are of constant runtime, same as array

# Outline

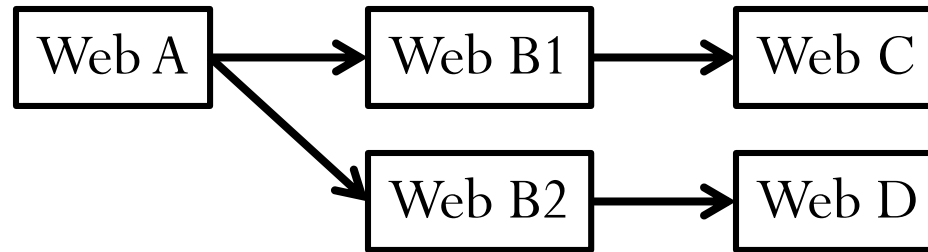
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# Application of Stacks

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

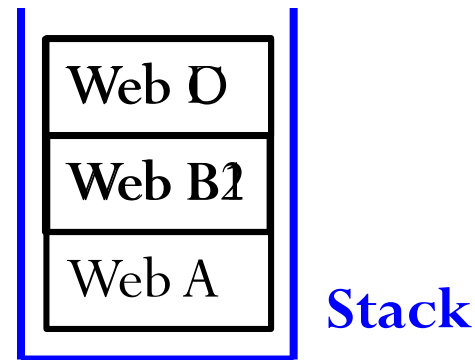


# Web Browser's "back" Feature



## 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

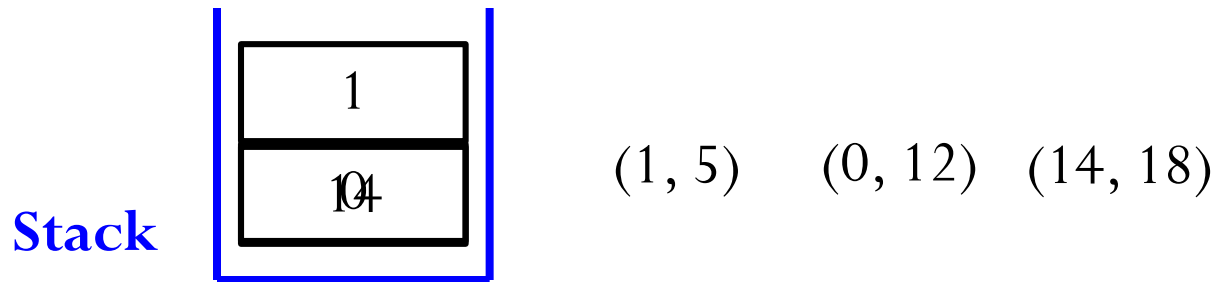
# How to Realize Parentheses Matching?

( ( 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





# A Stack Can Be Used:

Select all the correct answers.

- **A.** to manage any arithmetic expression
- **B.** to undo operations (such as a text editor)
- **C.** to reverse an array
- **D.** to implement an output buffer



# Reference

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