# ECE2800J

## 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.**
    - $L = (e_0, e_1, \ldots, e_{N-1})$
  - 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.
```

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
```

# 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.
  - Restricted form of a **linear list**: insert and remove only at the end of the list.
  - LIFO access: last in, first out.

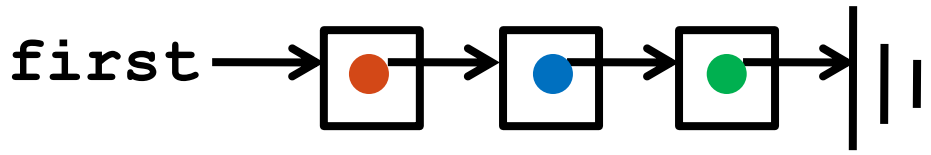
# Methods of Stack

- **`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


- 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

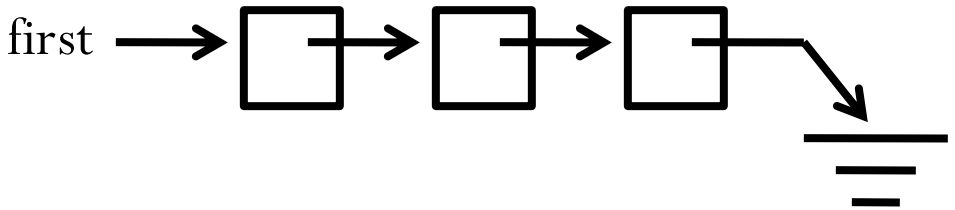



For single-ended linked list, which end is preferred to be the top? Why?

- **`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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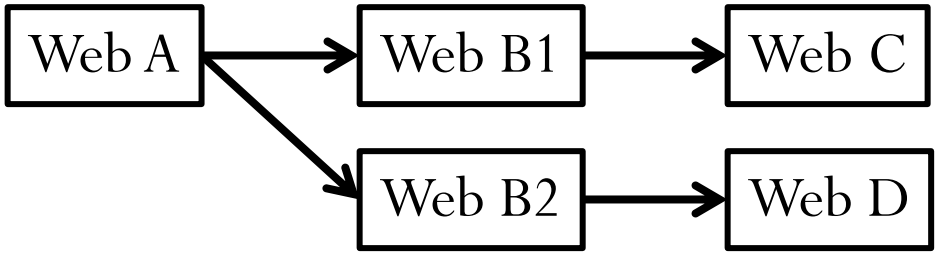
# Application of Stacks

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

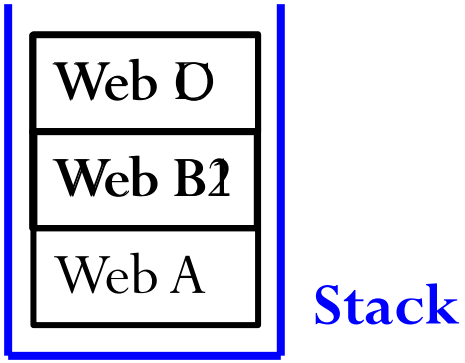
# Web Browser's "back" Feature

- Stack stores URL




**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?

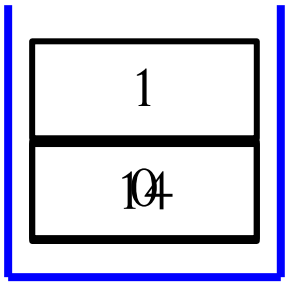
```
( ( a + b ) * c + d – e ) / ( f + g )
0 1 2 3 4 5 6 7 8 9 10  12  14  16  18
```

- 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)

# Reference

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