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IST 2060: Introduction to Data Structures

Stack Data Structure

Acknowledgement

Learning Outcomes

- By the end of this chapter, the learner should be able to:
  - Describe various stack operations
  - Implement a stack as an array
  - Implement a stack as a linked list
  - Describe stack applications.

Introduction

- A stack is a list of homogenous elements in which the addition and deletion of elements occurs only at one end, called the top of the stack.
  - E.g., in a cafeteria, the second tray in a stack of trays can be removed only if the first tray has been removed.

Stack

- A data structure in which the elements are added and removed from one end only.

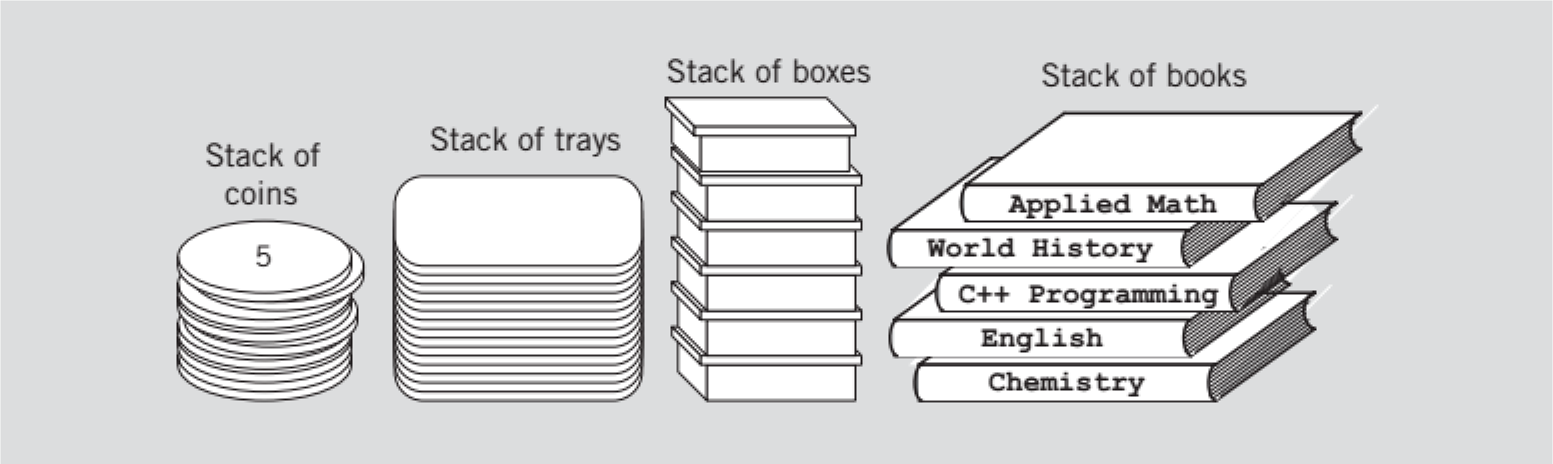
Stack

- **Stack** is an abstract data type with a bounded (predefined) capacity.
  - It is a simple data structure that allows adding and removing elements in a particular order.
  - Every time an element is added, it goes on the **top** of the stack and the only element that can be removed is the element that is at the top of the stack, just like a pile of objects

Stack

- It is named stack as it behaves like a real-world stack, for example:
  - A deck of cards or
  - A pile of plates, etc.

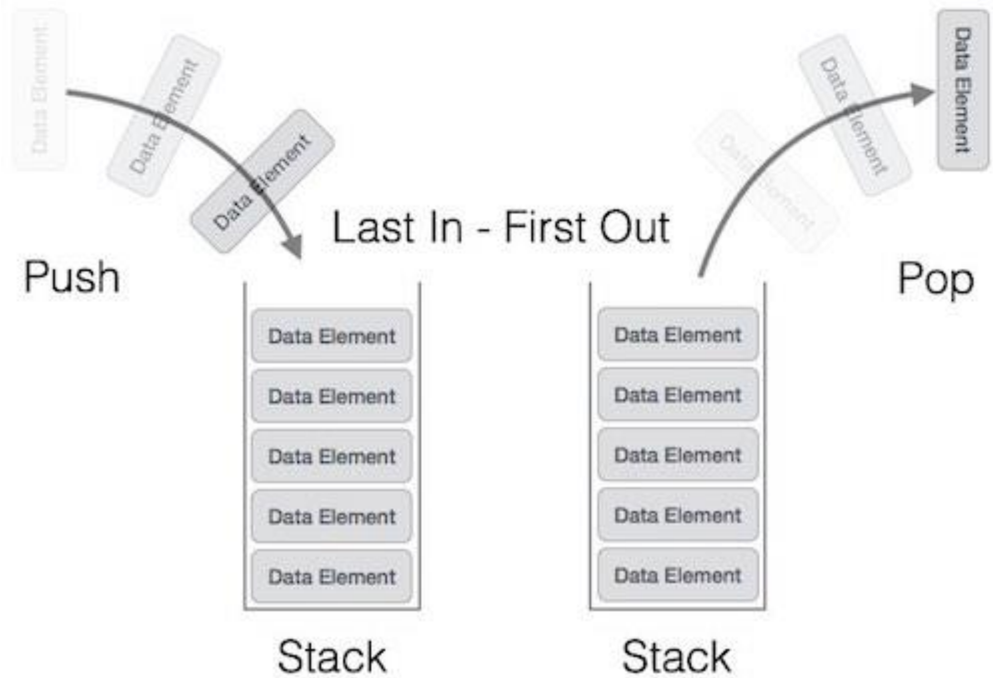
Various Examples of Stacks



Stack

- This feature makes it LIFO data structure. LIFO stands for Last-in-first-out.
  - Here, the element which is placed (inserted or added) last, is accessed first.
  - In stack terminology, insertion operation is called **PUSH** operation and removal operation is called **POP** operation.

Stack Representation



Stack Implementation

- A stack can be implemented by means of:
  - Array
  - Structure
  - Pointer, and
  - Linked List.

Stack Implementation

- Stack can either be a fixed size one or it may have a sense of dynamic resizing.
- In this unit, we are going to implement stack using arrays, which makes it a fixed size stack implementation.

Basic Stack Operations

- Stack operations may involve initializing the stack, using it and then de-initializing it.
- Apart from these basic operations, a stack is used for the following two primary operations:
  - **push()** – Pushing (storing) an element on the stack.
  - **pop()** – Removing (accessing) an element from the stack.

Basic Stack Operations

- To use a stack efficiently, we need to check the status of stack as well.
- For the same purpose, the following functionality is added to stacks –
  – **peek()** – get the top data element of the stack, without removing it.
  – **isFull()** – check if stack is full.
  – **isEmpty()** – check if stack is empty.

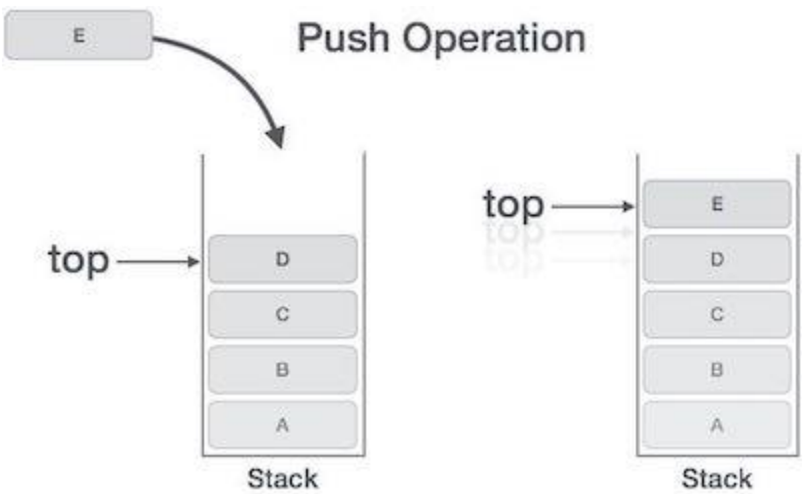
Basic Stack Operations

- At all times, we maintain a pointer to the last PUSHed data on the stack.
- As this pointer always represents the top of the stack, hence named **top**.
- The **top** pointer provides top value of the stack without actually removing it.

Push Operation

- The process of putting a new data element onto stack is known as a Push Operation.
- Push operation involves a series of steps –
  - **Step 1** – Checks if the stack is full.
  - **Step 2** – If the stack is full, produces an error and exit.
  - **Step 3** – If the stack is not full, increments **top** to point next empty space.
  - **Step 4** – Adds data element to the stack location, where top is pointing.
  - **Step 5** – Returns success.

Push Operation



Pop Operation

- Accessing the content while removing it from the stack, is known as a Pop Operation.
- In an array implementation of pop() operation, the data element is not actually removed, instead **top** is decremented to a lower position in the stack to point to the next value.

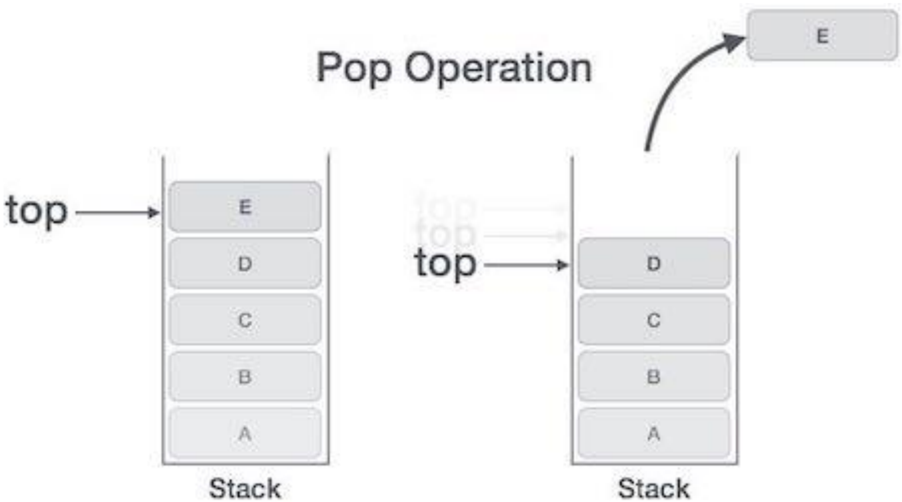
Pop Operation

- But in linked-list implementation, pop() actually removes data element and deallocates memory space.

Pop Operation

- A Pop operation may involve the following steps –
  - **Step 1** – Checks if the stack is empty.
  - **Step 2** – If the stack is empty, produces an error and exit.
  - **Step 3** – If the stack is not empty, accesses the data element at which **top** is pointing.
  - **Step 4** – Decreases the value of top by 1.
  - **Step 5** – Returns success.

Pop Operation



Applications of Stack

- The simplest application of a stack is to reverse a word.
  - You push a given word to stack - letter by letter - and then pop letters from the stack.
- There are other uses also like:
  - Parsing
  - Expression Conversion(Infix to Postfix, Postfix to Prefix etc)

Expression Parsing

- The way to write arithmetic expression is known as a notation.
- An arithmetic expression can be written in three different but equivalent notations, i.e., without changing the essence or output of an expression.

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Expression Parsing

- These notations are:
  - Infix Notation
  - Prefix (Polish) Notation
  - Postfix (Reverse-Polish) Notation
- These notations are named as how they use operator in expression

Expression Parsing : Infix Notation

- We write expression in **infix** notation, e.g. a - b + c, where operators are used **in**-between operands.
- It is easy for us humans to read, write, and speak in infix notation but the same does not go well with computing devices.

Expression Parsing : Infix Notation

- An algorithm to process infix notation could be difficult and costly in terms of time and space consumption.

Prefix Notation

- In this notation, operator is **prefix**ed to operands, i.e. operator is written ahead of operands.
  - E.g., **+ab**. This is equivalent to its infix notation **a + b**.
- Prefix notation is also known as Polish Notation.

Postfix Notation

- This notation style is known as Reversed Polish Notation.
- In this notation style, the operator is **postfix**ed to the operands i.e., the operator is written after the operands.
  - E.g., **ab+**. This is equivalent to its infix notation **a + b**.

Difference In all Three Notations

Sr.No.	Infix Notation	Prefix Notation	Postfix Notation
1	a + b	+ a b	a b +
2	(a + b) ∗ c	∗ + a b c	a b + c ∗
3	a ∗ (b + c)	∗ a + b c	a b c + ∗
4	a / b + c / d	+ / a b / c d	a b / c d / +
5	(a + b) ∗ (c + d)	∗ + a b + c d	a b + c d + ∗
6	((a + b) ∗ c) - d	- ∗ + a b c d	a b + c ∗ d -

Parsing Expressions

- It is not a very efficient way to design an algorithm or program to parse infix notations.
- Instead, these infix notations are first converted into either postfix or prefix notations and then computed.
- To parse any arithmetic expression, we need to take care of operator precedence and associativity also.

Parsing Expressions : Precedence

- When an operand is in between two different operators, which operator will take the operand first, is decided by the precedence of an operator over others.
  - For example a + b * c = a + (b* c)
- As multiplication operation has precedence over addition, b * c will be evaluated first.

Parsing Expressions: Associativity

- Associativity describes the rule where operators with the same precedence appear in an expression.
  - E.g., in expression a + b − c, both + and – have the same precedence, then which part of the expression will be evaluated first, is determined by associativity of those operators.
  - Here, both + and − are left associative, so the expression will be evaluated as **(a + b) − c**.

Parsing Expressions: Associativity

- Precedence and associativity determines the order of evaluation of an expression.

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Postfix Evaluation Algorithm

- Step 1 – scan the expression from left to right
- Step 2 – if it is an operand push it to stack
- Step 3 – if it is an operator pull operand from stack and perform operation
- Step 4 – store the output of step 3, back to stack
- Step 5 – scan the expression until all operands are consumed
- Step 6 – pop the stack and perform operation

Implementation of Stack Data Structure

- Stack can be easily implemented using an Array or a Linked List.
- Arrays are quick, but are limited in size and Linked List requires overhead to allocate, link, unlink, and deallocate, but is not limited in size.
- Here we will implement Stack using array

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End of lesson