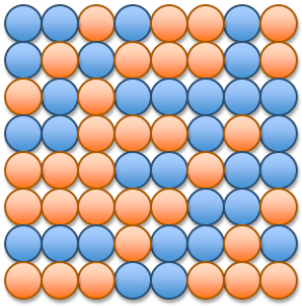


UNIT 6A
Organizing Data: Lists

Data Structure

- The organization of data is a very important issue for computation.
- A **data structure** is a way of storing data in a computer so that it can be used efficiently.
  - Choosing the right data structure will allow us to develop certain algorithms for that data that are more efficient.
  - An **array** or **list** is a very simple data structure for holding a sequence of data.

Arrays in Memory

- Typically, array elements are stored in adjacent memory cells. The subscript (or index) is used to calculate an offset to find the desired element.
- Example:
  Assume integers are stored using 4 bytes (32 bits).
- If we want data[3], the computer takes the address of the start of the array and adds the offset * the size of an array element to find the element we want.
- Do you see why the first index of an array is 0 now?

Address	Contents
100	50
104	42
108	85
112	71
116	99

Location of data[3] is 100 + 3*4 = 112

Arrays: Pros and Cons

- Pros:
  - Access to an array element is fast since we can compute its location quickly.
- Cons:
  - If we want to insert or delete an element, we have to shift subsequent elements which slows our computation down.
  - We need a large enough block of memory to hold our array.

Linked Lists

- Another data structure that stores a sequence of data values is the **linked list**.
- Data values in a linked list do not have to be stored in adjacent memory cells.
- To accommodate this feature, each data value has an additional "pointer" that indicates where the next data value is in computer memory.
- In order to use the linked list, we only need to know where the first data value is stored.

Linked List Example

- Linked list to store the sequence: 50, 42, 85, 71, 99

Assume each integer and pointer requires 4 bytes.

Starting Location of List (head)
124

address	data	next
100	42	148
108	99	0 (null)
116		
124	50	100
132	71	108
140		
148	85	132
156		

Linked List Example

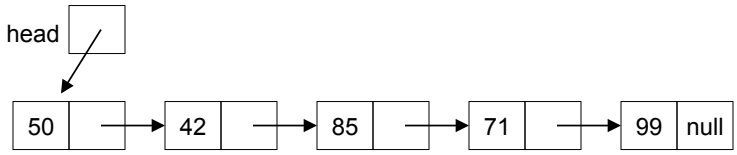
- To insert a new element, we only need to change a few pointers.
- Example: Insert 20 after 42.

Starting Location of List (head)
124

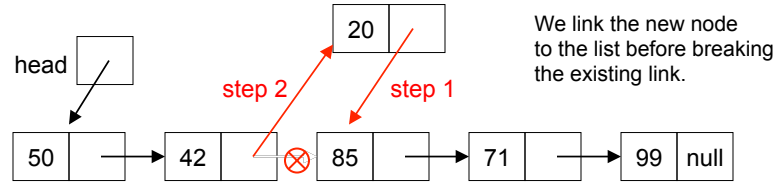
address	data	next
100	42	**156**
108	99	0 (null)
116		
124	50	100
132	71	108
140		
148	85	132
156	**20**	**148**

Drawing Linked Lists Abstractly

- L = [50, 42, 85, 71, 99]



- Inserting 20 after 42:

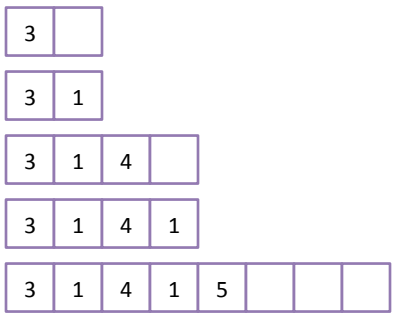


Linked Lists: Pros and Cons

- Pros:
  - Inserting and deleting data does not require us to move/shift subsequent data elements.
- Cons:
  - If we want to access a specific element, we need to traverse the list from the head of the list to find it which can take longer than an array access.
  - Linked lists require more memory. (Why?)

Lists in Python

- Lists in Python are really **dynamic arrays**.
  - The list has a fixed size (like an array) with elements stored in adjacent memory cells.
  - Once the list fills up, the list size is doubled to accommodate more elements.



Two-dimensional lists

- Some data can be organized efficiently in a **table** (also called a **matrix** or **2-dimensional list/array**)
- Each cell is denoted with two subscripts, a row and column indicator

B[2][3] = 50

B	0	1	2	3	4
0	3	18	43	49	65
1	14	30	32	53	75
2	9	28	38	50	73
3	10	24	37	58	62
4	7	19	40	46	66

2D Lists in Python

```
data = [ [ 1, 2, 3, 4],
         [5, 6, 7, 8],
         [9, 10, 11, 12]
       ]
```

	0	1	2	3
0	1	2	3	4
1	5	6	7	8
2	9	10	11	12

```
data[0]   =>   [1, 2, 3, 4]
data[1][2]  =>  7
data[2][5]  =>  error (out of range)
data[4][2]  =>  error (out of range)
```

2D List Example in Python

- Find the sum of all elements in a 2D list

number of rows in the table

number of columns in the given row of the table

```
def sumMatrix(table):
    sum = 0
    for row in range(0,len(table)):
        for col in range(0,len(table[row])):
            sum = sum + table[row][col]
    return sum
```


Tracing the Nested Loop

```
for row in range(0,len(table)):
    for col in range(0,len(table[row])):
        sum = sum + table[row][col]
```

	0	1	2	3
0	1	2	3	4
1	5	6	7	8
2	9	10	11	12

`len(table) = 3`
`len(table[row]) = 4 for every row`

row	col	sum
0	0	1
0	1	3
0	2	6
0	3	10
1	0	15
1	1	21
1	2	28
1	3	36
2	0	45
2	1	55
2	2	66
2	3	78

Stacks

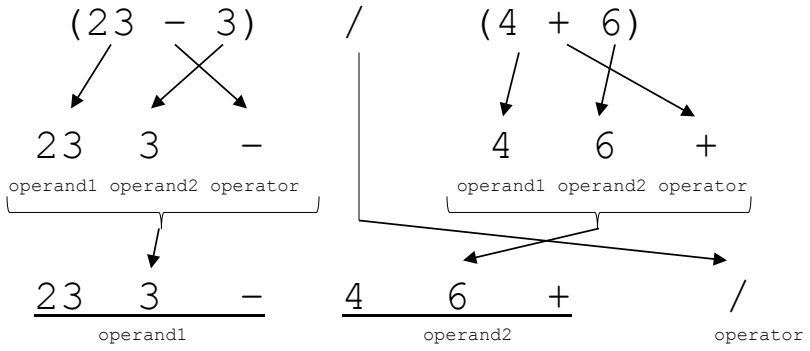
- A **stack** is a data structure that works on the principle of Last In First Out (LIFO).
  - LIFO: The last item put on the stack is the first item that can be taken off.
- Common stack operations:
  - Push – put a new element on to the top of the stack
  - Pop – remove the top element from the top of the stack
- Applications: calculators, compilers, programming

RPN

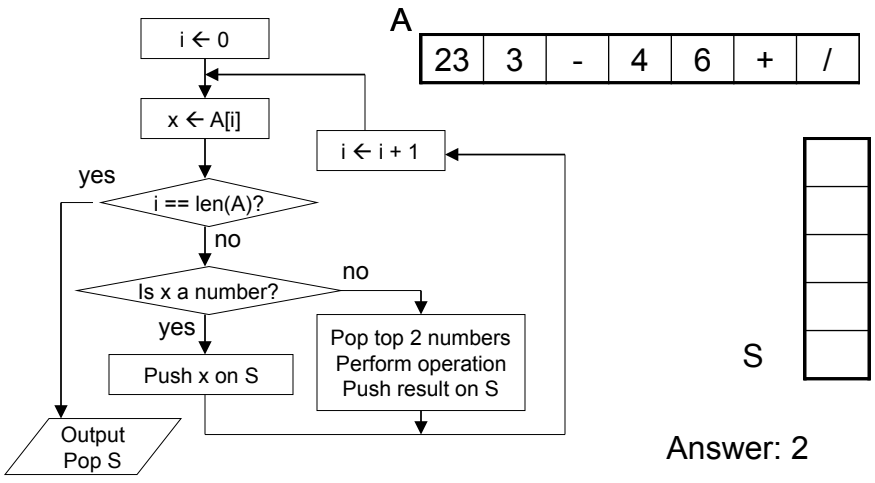
- Some modern calculators use Reverse Polish Notation (RPN)
  - Developed in 1920 by Jan Lukasiewicz
  - Computation of mathematical formulas can be done without using any parentheses
  - Example:
    (3 + 4) * 5 =
    becomes in RPN:
    3 4 + 5 *

RPN Example

Convert the following standard mathematical expression into RPN:

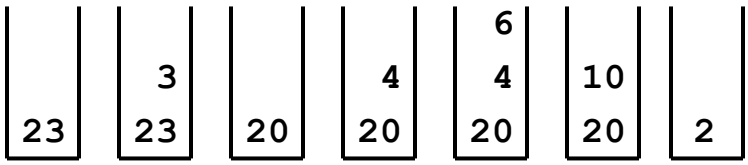


Evaluating RPN with a Stack



Example Step by Step

- RPN: `23 3 - 4 6 + /`
- Stack Trace:



Stacks in Python

- You can treat lists as stacks in Python.

	stack	x
`stack = []`	`[]`	
`stack.append(1)`	`[1]`	
`stack.append(2)`	`[1,2]`	
`stack.append(3)`	`[1,2,3]`	
`x = stack.pop()`	`[1,2]`	`3`
`x = stack.pop()`	`[1]`	`2`
`x = stack.pop()`	`[]`	`1`
`x = stack.pop()`	`[]`	`ERROR`

Queues

- A **queue** is a data structure that works on the principle of First In First Out (FIFO).
  - FIFO: The first item stored in the queue is the first item that can be taken out.

- Common queue operations:
  - Enqueue – put a new element in to the rear of the queue
  - Dequeue – remove the first element from the front of the queue
- Applications: printers, simulations, networks