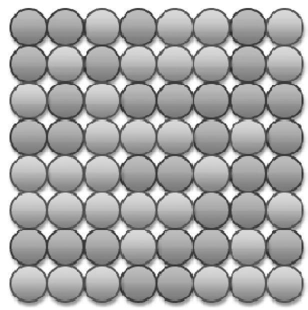


UNIT 6A
Organizing Data: Lists

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: data = [50, 42, 85, 71, 99] 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.

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

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

- Do you see why the first index of an array is 0 now?

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

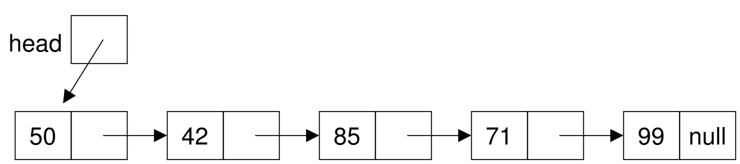
- To insert a new element, we only need to change a few pointers.
- Example: Insert 20 after 42.

Starting Location of List (head)
124

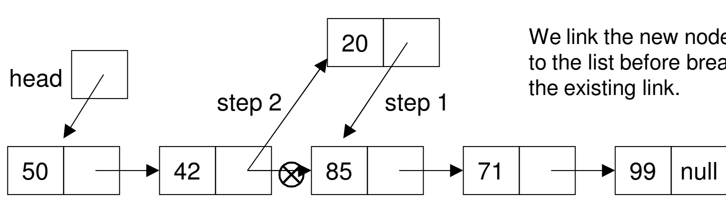
address	data	next
100	42	**156**
108	99	0 (null)
116		
124	50	100
132	71	108
140		
148	85	132
156	**20**	**148**

Drawing Linked Lists Abstractly

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



- Inserting 20 after 42:



We link the new node to the list before breaking the existing link.

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?)

Two-dimensional arrays

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

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

B[2][3] = 50

2D Arrays in Ruby

```
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]  =>  nil
data[4][2]  =>  undefined method '[]' for nil
```


2D Array Example in Ruby

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

```
def sumMatrix(table)
  sum = 0
  for row in 0..table.length-1 do
     for col in 0..table[row].length-1 do
          sum = sum + table[row][col]
     end
  end
  return sum
end
```

number of rows in the table

number of columns in the given row of the table

Tracing the Nested Loop

```
for row in 0..table.length-1 do
  for col in 0..table[row].length-1 do
    sum = sum + table[row][col]
  end
end
```

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

```
table.length = 3
table[row].length = 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

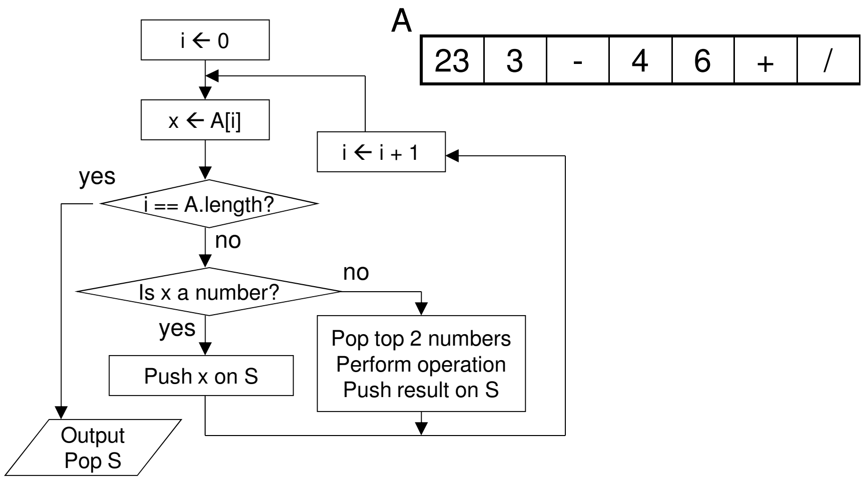
- Some modern calculators use Reverse Polish Notation (RPN)
  - Developed in 1920 by Jan Lukasiewicz
  - Computation of mathematical formulas can be done without using any parentheses
  - Example:
    (3 + 4) * 5 =
    becomes in RPN:
    3 4 + 5 *

RPN Example

Convert the following standard mathematical expression into RPN:

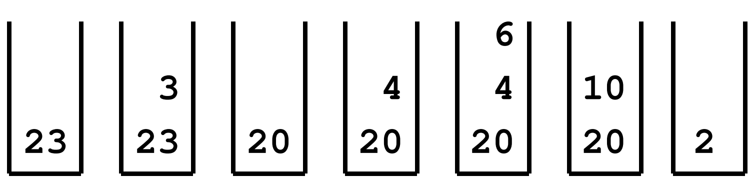
```
(23 – 3)    /    (4 + 6)

23 3 –                    4 6 +
operand1 operand2 operator    operand1 operand2 operator

23 3 –        4 6 +        /
operand1      operand2     operator
```

Evaluating RPN with a Stack



Example Step by Step

- RPN: **23 3 – 4 6 + /**
- Stack Trace:



Stacks in Ruby

- You can treat arrays (lists) as stacks in Ruby.

	stack	x
`stack = []`	[]	
`stack.push(1)`	[1]	
`stack.push(2)`	[1,2]	
`stack.push(3)`	[1,2,3]	
`x = stack.pop()`	[1,2]	3
`x = stack.pop()`	[1]	2
`x = stack.pop()`	[]	1
`x = stack.pop()`	nil	nil

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