B. Tech. I CSE (Sem-2)
Data Structures
CS102

# Queue: A Data Structure

*Some slides are kept with logical or syntax error. So, if you are absent in theory class, please also refer the slides provided at the end of the presentation.

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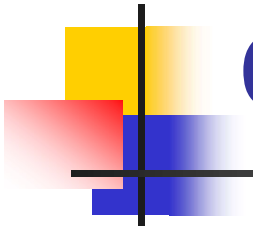


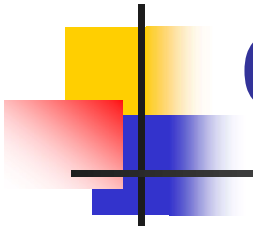
# Queue Data Structure

- Basic principles
- Operation of queue
- Queue using Array
- Applications of queue
- Queue using Linked List

# Queue Data Structure

- Data structure, somewhat similar to Stacks. Unlike stacks, a queue is open at both its ends. One end is always used to insert data (enqueue) and the other is used to remove data (dequeue).
- An ordered group of homogeneous items of elements.

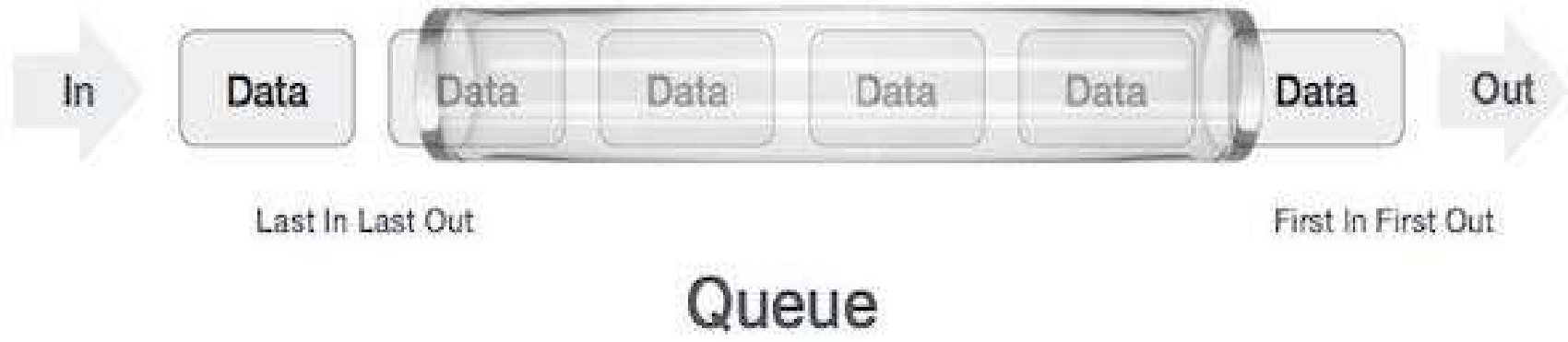

- Elements are added at one end.
- Elements are removed from the other end.
- The element added first is also removed first
- FIFO: First In, First Out



# Queue Data Structure

- Traffic Management Systems
  - In traffic control and toll booths, vehicles often form a queue as they wait for their turn
  - An example of queue real-time applications where vehicles are processed in the order they arrive
- Keyboards' keypress sequence
- Queue of network data packets to send
- Used as buffers on MP3 players and portable CD players, iPod playlist

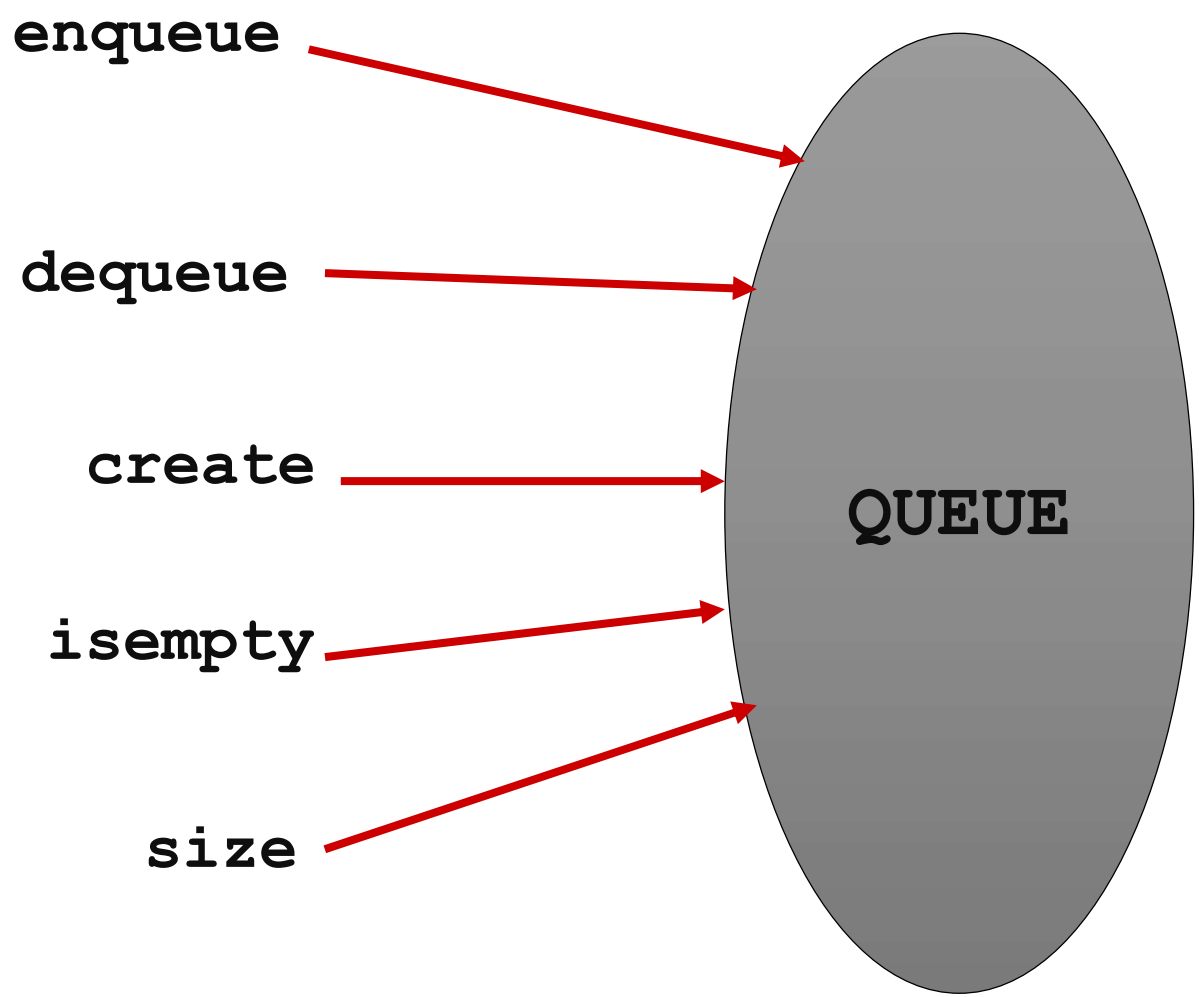
# Queue Data Structure

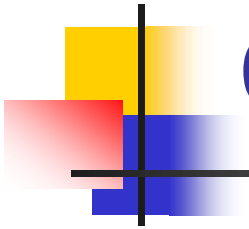



- As in stacks, a queue can also be implemented using Arrays, Linked-lists, Pointers and Structures.

# Queue Data Structure

Operations





# Queue Data Structure

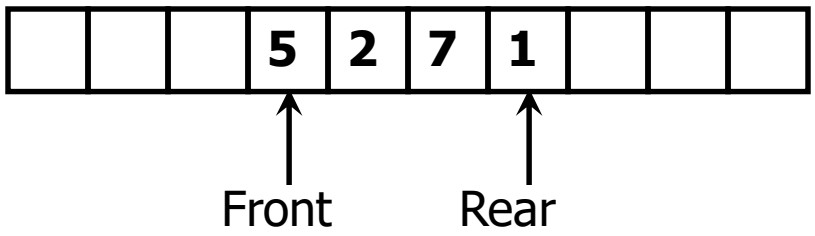
- Like stacks, *queues* are lists.
- With a queue, however, insertion is done at one end, whereas deletion is performed at the other end.
- The basic operations on a queue are *Enqueue*, which inserts an element at the end of the list (called the rear), and *Dequeue*, which deletes (and returns) the element at the start of the list (known as the front).

# Array Implementation of Queues

- For each queue data structure, we keep an array, *Queue*[], and the positions *Front* and *Rear*, which represent the ends of the queue.

- We also keep track of the number of elements that are actually in the queue, *Size*. All this information is part of one structure.

- The following figure shows a queue in some intermediate state. The cells that are blanks have undefined values in them:



# Algorithm Enqueue

```
Algorithm Enqueue (Q, F, R, Y)
    //Queue Q consisting of N elements
If( R>=N) /* check for the overflow condition */
        Printf ("Overflow"); return;
Else
{
        R = R + 1; /*Increment rear pointer */
        Q[R] = Y; /* insert element */
        If (F == 0) /* set the front pointer */
                F = 1;
        Return;
}
```

# Algorithm Dequeue

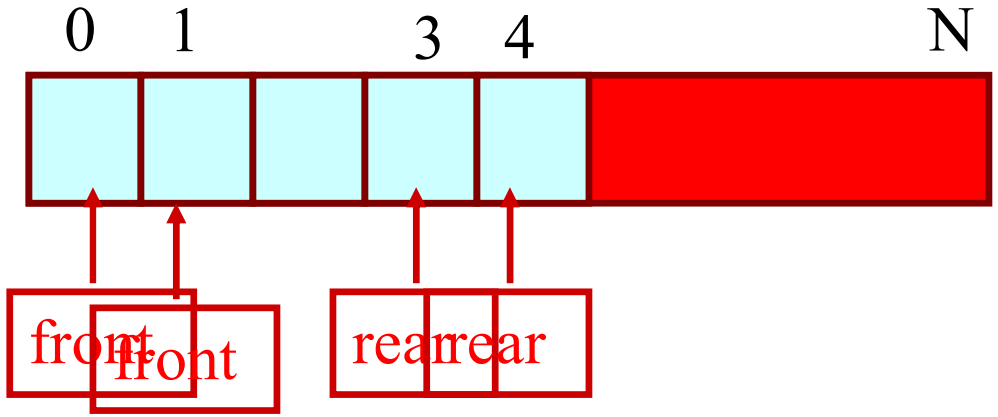
```
Algorithm DeQueue (Q, F, R)
If (F==0) /* check for the underflow condition */
        Printf (“underflow”);
        return 0; /* 0 denotes the empty queue */
Else
{
Y = Q [F]; /* delete element */
If (F == R)
F = R = 0;
Else
F = F + 1; /* increment front pointer */
Return Y;
}
```

# Array Implementation of Queues

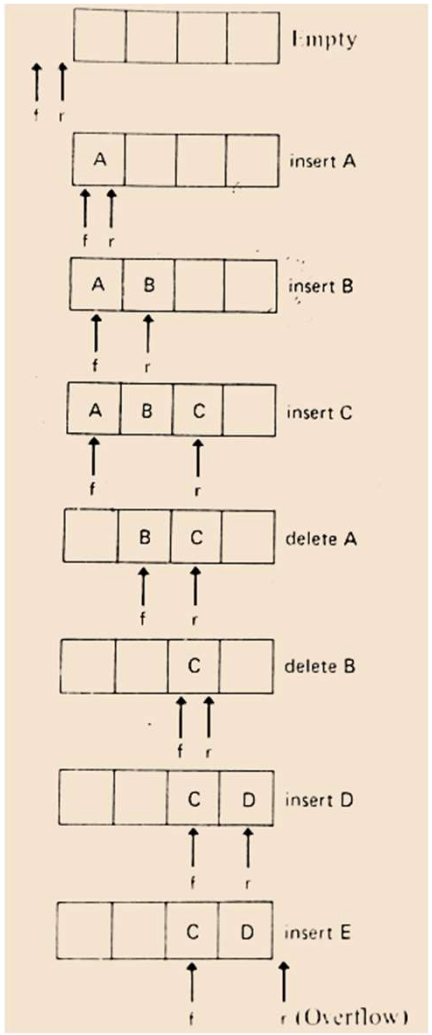
- The size of the queue depends on the number and order of enqueue and dequeue.
- It may be situation where memory is available but enqueue is not possible.

ENQUEUE DEQUEUE

Overlfow occurs on trying to insert , even though the first few locations are not being used
Effective queuing storage area of array gets reduced.



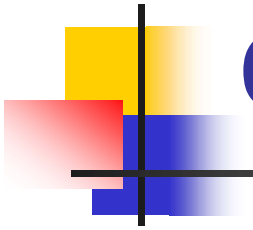
# Array Implementation of Queues




- How many elements are available?
- How many MORE elements CAN BE INSERTED?
- Show the different situation(s)
  - When only 1 element is available?
  - When 2 elements are available?
  - Etc.

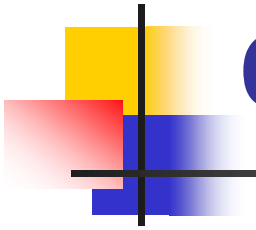
An introduction to data structures with applications
By Jean-Paul Tremblay, P. G. Sorenson · 1976

# Array Implementation of Queues



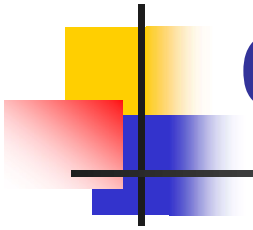
- Very wasteful of storage
- Arbitrary large amount of memory would be required to accommodate the elements
- ONLY BE USED
  - When the queue is emptied at certain intervals

# Array Implementation of Queues



- Performance
  - Let $n$ be the number of elements in the queue
  - The space used is $O(n)$
  - Each operation runs in time $O(1)$
- Limitations
  - The maximum size of the queue must be defined *a priori*, and cannot be changed
  - Trying to enqueue a new element into a full queue causes an implementation-specific exception

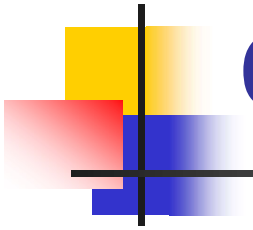
# Array Implementation of Queues



## Forwarding Elements Array-based Queue

- On element removal from array front location, remaining elements are shifted forward one position in the array
- Similar to what we did for an array-based stack
- The enqueue operation has running time
  - $O(n+k)$ with the k shifting

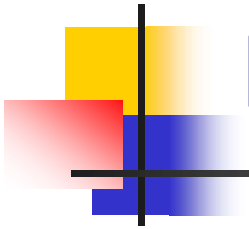
# Array Implementation of Queues



## Growable Array-based Queue

- In an enqueue operation, when the array is full, instead of throwing an exception, we can replace the array with a larger one
- Similar to what we did for an array-based stack
- The enqueue operation has running time
  - $O(n)$ with the incremental strategy
  - $O(1)$ with the doubling strategy

# Applications of Queue

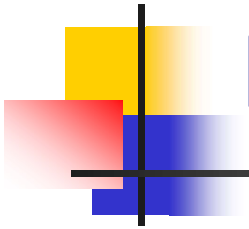


# Reading a String of Characters

- A queue can retain characters in the order in which they are typed

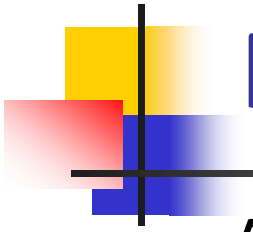
```
Queue.createQueue()
while (not end of line) {
    Read a new character ch
    Queue.enqueue(ch)
} //end while
```

- Once the characters are in a queue, the system can process them as necessary



# Recognizing Palindromes

- A palindrome
  - A string of characters that reads the same from left to right as its does from right to left
- To recognize a palindrome, a queue can be used in conjunction with a stack
  - A stack reverses the order of occurrences
  - A queue preserves the order of occurrences

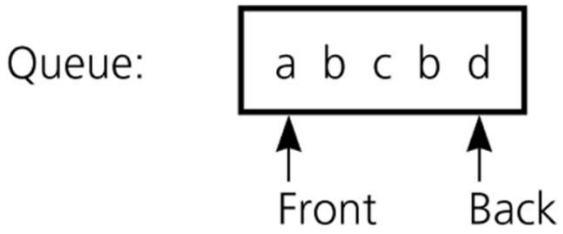


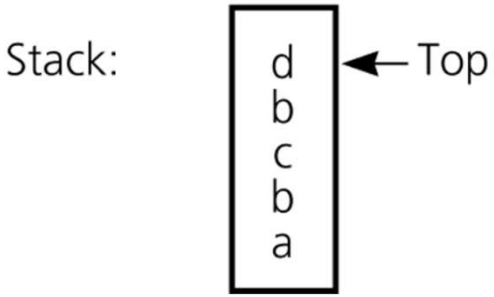
# Recognizing Palindromes

- A nonrecursive recognition algorithm for palindromes
  - As traverse the character string from left to right, insert each character into both a queue and a stack
  - Compare the characters at the front of the queue and the top of the stack

# Recognizing Palindromes

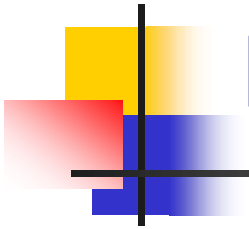
String: abcbd



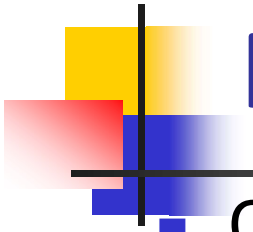

Inserting a string into both

a queue and a stack



# Radix Sort

- Radix is a synonym for base. base 10, base 2
- Multi pass sorting algorithm that only looks at individual digits during each pass
- Use queues as buckets to store elements
- Create an array of 10 queues
- Starting with the least significant digit place value in queue that matches digit
- Empty queues back into array
- Repeat, moving to next least significant digit



# Radix Sort

- Original values in array

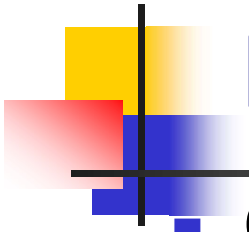
  9, 113, 70, 86, 12, 93, 37, 40, 252, 7, 79, 12

- Look at ones place

  **9**, 11**3**, 7**0**, 8**6**, 1**2**, 9**3**, 3**7**, 4**0**, 25**2**, **7**, 7**9**, 1**2**

- Array of Queues (all empty initially):

| | |
|---|---|
| 0 | 5 |
| 1 | 6 |
| 2 | 7 |
| 3 | 8 |
| 4 | 9 |



# Radix Sort

- Original values in array

  9, 113, 70, 86, 12, 93, 37, 40, 252, 7, 79, 12

- Look at ones place

  9, 113, 70, 86, 12, 93, 37, 40, 252, 7, 79, 12

- Queues:

| | | | |
|---|---|---|---|
| 0 | 70, 40 | 5 | |
| 1 | | 6 | 86 |
| 2 | 12, 252, 12 | 7 | 37, 7 |
| 3 | 113, 93 | 8 | |
| 4 | | 9 | 9, 79 |

# Radix Sort

- **Empty queues in order from 0 to 9 back into array**

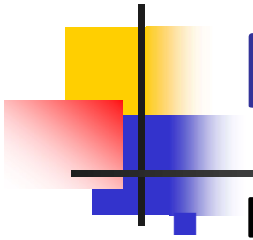
  70, 40, 12, 252, 12, 113, 93, 86, 37, 7, 9, 79

- **Now look at 10's place**

  70, 40, 12, 252, 12, 113, 93, 86, 37, _7, _9, 79

- Queues:

| | |
|---|---|
| 0 _7, _9 | 5 252 |
| 1 12, 12, 113 | 6 |
| 2 | 7 70, 79 |
| 3 37 | 8 86 |
| 4 40 | 9 93 |



# Radix Sort

- Empty queues in order from 0 to 9 back into array

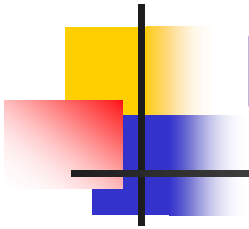
  7, 9, 12, 12, 113, 37, 40, 252, 70, 79, 86, 93

- Now look at 100's place

  __7, __9, _12, _12, 113, _37, _40, 252, _70, _79, _86, _93

- Queues:

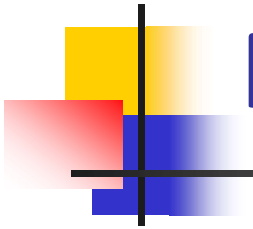
| | | |
|---|---|---|
| 0 | _7, _9, _12, _12, _37, _40, _70, _79, _86, _93 | 5 |
| 1 | 113 | 6 |
| 2 | 252 | 7 |
| 3 | | 8 |
| 4 | | 9 |



# Radix Sort

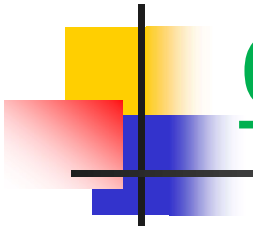
- Empty queues in order from 0 to 9 back into array

  7, 9, 12, 12, 40, 70, 79, 86, 93, 113, 252



# Point of Sale (POS)

- Maintains a list of customers waiting for service
  - Can add a new customer at the end
  - Can display name of next customer to serve
  - Can display the length of the line
  - Can determine how many people are ahead of a particular waiting customer



# Queue Variants

- Circular Queue
- Doubly Ended Queue
- Priority Queue