04-630
Data Structures and Algorithms for Engineers

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Lecture 11

Queue ADT

Implementation using List ADT (array and linked-list)

Comparison of order of complexity

Dedicated ADT

Circular queues

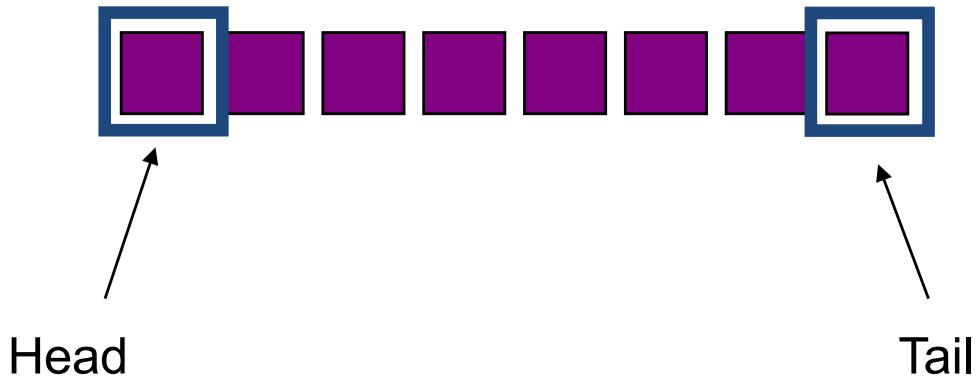
Queue applications

Queues

A queue is another special type of list

- insertions are made at one end, called the tail of the queue
- deletions take place at the other end, called the head
- thus, the last one added is always the last one available for deletion
- also referred to as
  - FiFO list (First In First Out)

Queues



Queue Operations

Declare: $\rightarrow$ $\mathbf{Q}$:

The function value of *Declare(Q)* is an empty queue

Queue Operations

Empty: $\rightarrow \mathbf{Q}$:

The function *Empty* causes the queue to be emptied and it returns position *End(Q)*

Queue Operations

IsEmpty: $\mathbf{Q} \rightarrow \mathbf{B}$:

The function value *IsEmpty*(*Q*) is *true* if *Q* is empty; otherwise it is *false*

Queue Operations

Head: $\mathbf{Q} \rightarrow \mathbf{E}$:

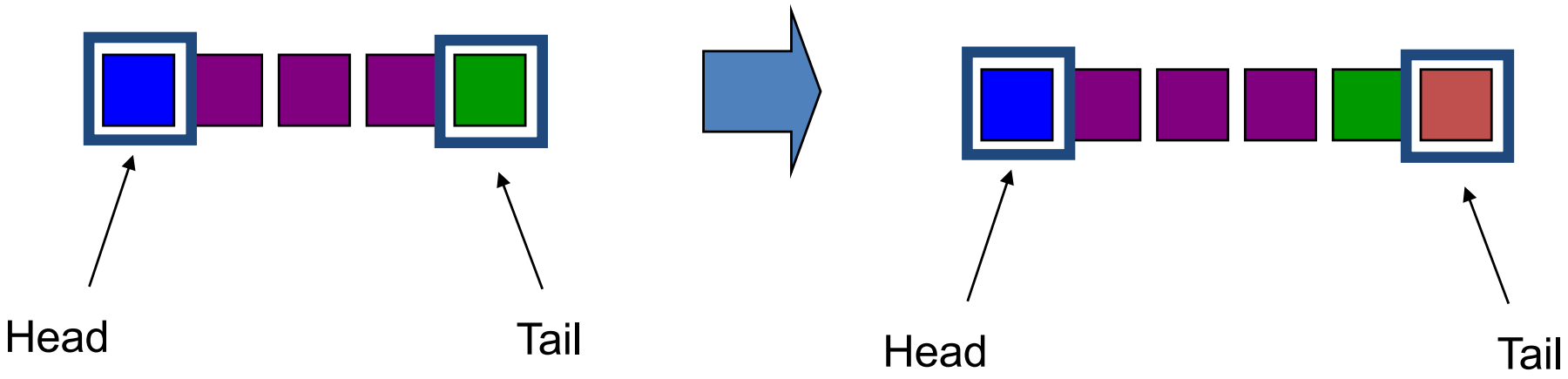
The function value *Head*(*Q*) is the first element in the list;

if the queue is empty, the value is undefined

Queue Operations

Enqueue: $\mathbf{E} \times \mathbf{Q} \rightarrow \mathbf{Q}$:

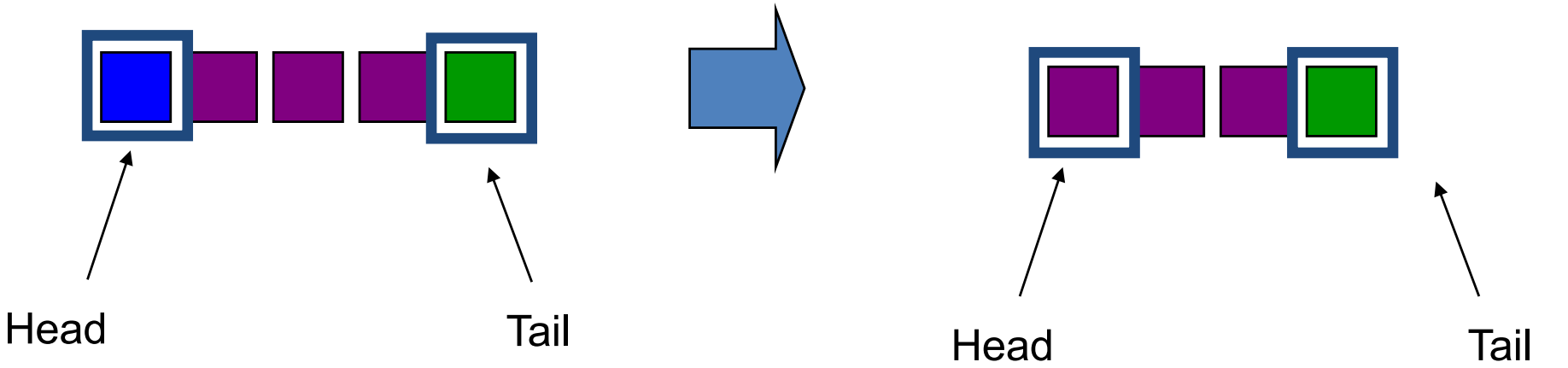
Enqueue(e, Q)
Add an element *e* the the tail of the queue



Queue Operations

Dequeue: $\mathbf{Q} \rightarrow \mathbf{E}$:

Dequeue(Q)
Remove the element from the head of the queue: i.e. return the first element and delete it from the queue



Queue Operations

- All these operations can be directly implemented using the LIST ADT operations on a queue Q
- Again, it may be more efficient to use a dedicated implementation
- And, again, it depends what you want: code efficiency or software re-use (i.e. utilization efficiency)

Queue Operations

Declare(Q)

Empty(Q)

Head(Q)

    Retrieve(First(Q), Q)

Enqueue(e, Q)

    Insert(e, End(Q), Q)

Dequeque(Q)

    Retrieve(First(Q), Q)

    Delete(First(Q), Q)

Queue Errors

- Queue overflow errors occur when you attempt to enqueue() an element in a queue that is full
- Queue underflow errors occur when you attempt to dequeue() an element from an empty queue
- Your ADT implementation should provide guards that catch these errors

Queue Implementation

- The List ADT can be implemented
  - As an array
  - As a linked-list
- So, therefore, so can the Queue ADT
- What are the advantages and disadvantages of the these two options?
- When would you pick one implementation over the other?

Queue Operations

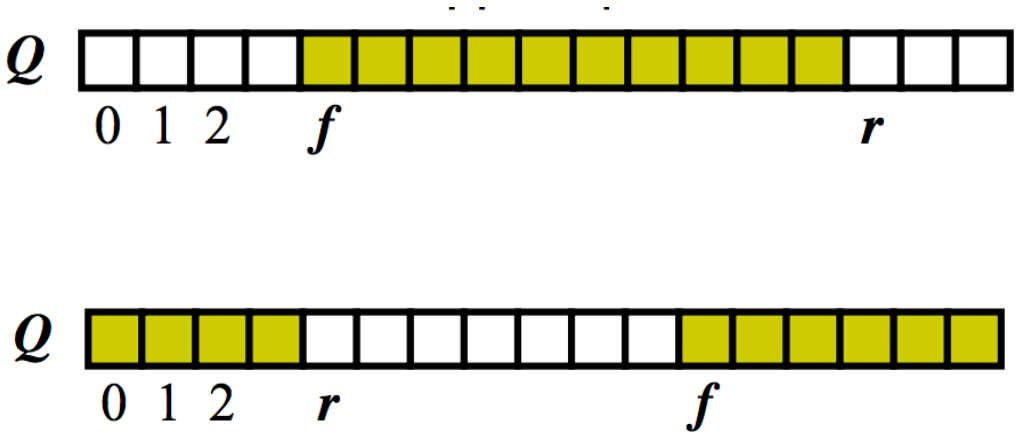
	Array	Linked-List
Declare(Q)	$O(1)$	$O(1)$
Empty(Q)	$O(1)$	$O(n)$
Head(Q) Retrieve(First(Q), Q)	$O(1)$	$O(1)$
Enqueue(e, Q) Insert(e, End(Q), Q)	$O(1)$	$O(n)$ ... why?
Dequeque(Q) Retrieve(First(Q), Q) Delete(First(Q), Q)	$O(n)$ ... why?	$O(1)$

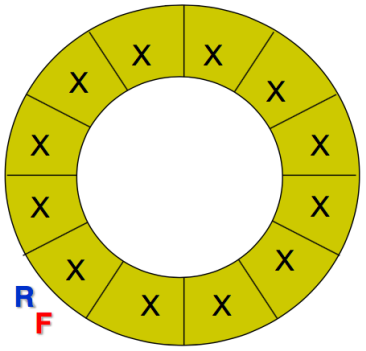
Queue Implementation

- Reusing the List ADT involves some compromises
- Alternative is to create a new Queue ADT
  - With an implementation that avoids these compromises

Queue Implementation

```
typedef struct {
            int front;
            int rear;
            ITEM_TYPE items[MAX_ITEMS];
        } QUEUE_TYPE;
```





Queue Implementation

```
void empty(QUEUE_TYPE *queue) {
   queue->front = 0;
   queue->rear  = 0;
   return(end(queue));
}
```

Queue Implementation

```
bool is_empty(QUEUE_TYPE *queue) {
   if (queue->front == queue->rear)
      return(true);
   else
      return(false)
}
```

Queue Implementation

```
void enqueue(ELEMENT_TYPE e, QUEUE_TYPE *queue) {
   items[rear] = e;
   rear = (rear +1) % MAX_ITEMS;
}
```

Queue Implementation

```
int is_full(QUEUE_TYPE *queue) {
   if (( rear + 1 ) % MAX_ITEMS == front )
      return(TRUE);
   else
      return(FALSE);
}
```

Queue Implementation

```
void enqueue(ITEM_TYPE e, QUEUE_TYPE *queue) {
   if (!is_full(queue)) {
      items[rear] = e;
     rear = (rear +1) % MAX_ITEMS;
   }
   else {
      error("Queue overflow: queue is already full");
   }
}
```

Queue Implementation

```
void dequeue(ITEM_TYPE *e, QUEUE_TYPE *queue) {
   if (!is_empty(queue)) {
      *e = items[front];
      front = (front+1) % MAX_ITEMS;
   }
   else {
      error("Queue underflow: queue is empty");
   }
}
```

Queue Implementation

- Can you see a particular problem with the linked-list implementation?

- How would you fix it?

Queue Operations

	Array	Linked-List
Declare(Q)	$O(1)$	$O(1)$
Empty(Q)	$O(1)$	$O(n)$
Head(Q) Retrieve(First(Q), Q)	$O(1)$	$O(1)$
Enqueue(e, Q) Insert(e, End(Q), Q)	$O(1)$	$O(n)$ ... why?
Dequeque(Q) Retrieve(First(Q), Q) Delete(First(Q), Q)	$O(n)$ ... why?	$O(1)$

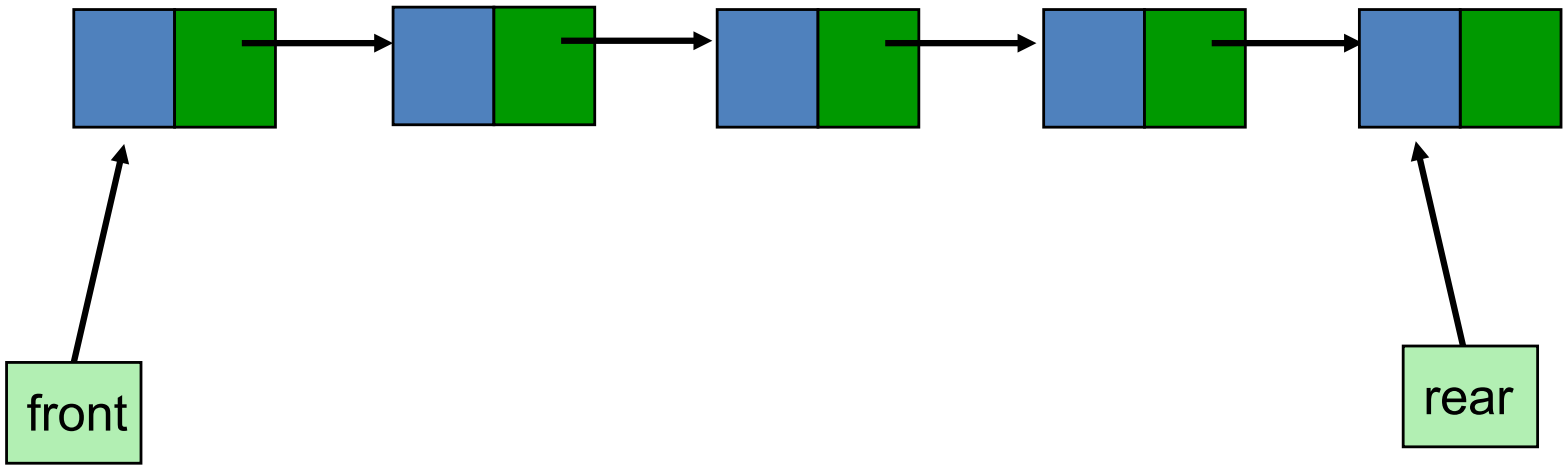
Queue Implementation

- Can you see a particular problem with the linked-list implementation?

- How would you fix it?

Queue Implementation

- Can you see a particular problem with the linked-list implementation?
- How would you fix it?



Queue Applications

- Scheduling/waiting for system service queues
- Resource queues – provide coordinated access to shared resources
- Message queues (Buffer)
- Multi-queues and priority queues