Data Structures and Algorithms for Engineers

Module 5: Lists

Lecture 4: Queues. Implementation using List ADT. Comparison of order of complexity. Dedicated ADT. Circular queues. Queue applications.

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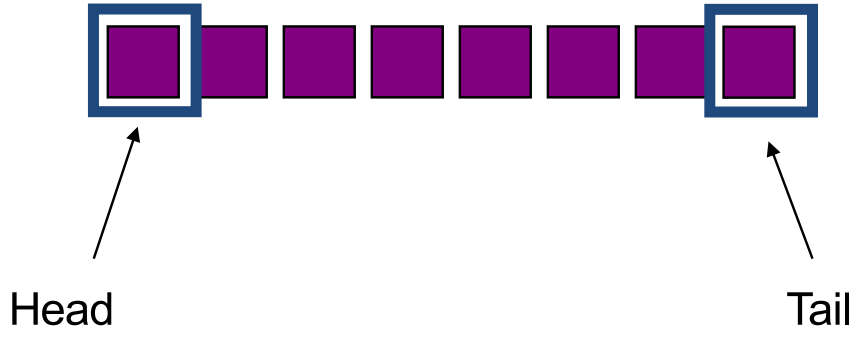
Queues

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 a FiFO list (First In First Out)

Queues



Queue Operations

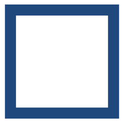
Declare: $\rightarrow$ Q :

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

Queue Operations

Empty: $\rightarrow$ Q :

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



Queue Operations

IsEmpty: Q $\rightarrow$ B :

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

Queue Operations

Head: $Q \rightarrow E$:

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

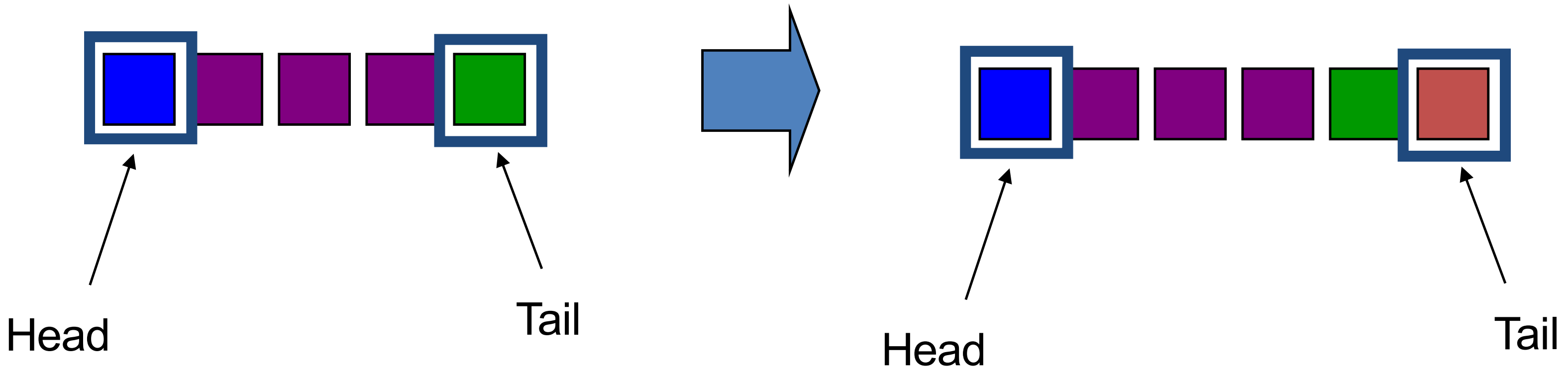
if the queue is empty, the value is undefined

Queue Operations

Enqueue: E x Q $\rightarrow$ Q :

Enqueue(e, Q)

Add an element e the the tail of the queue

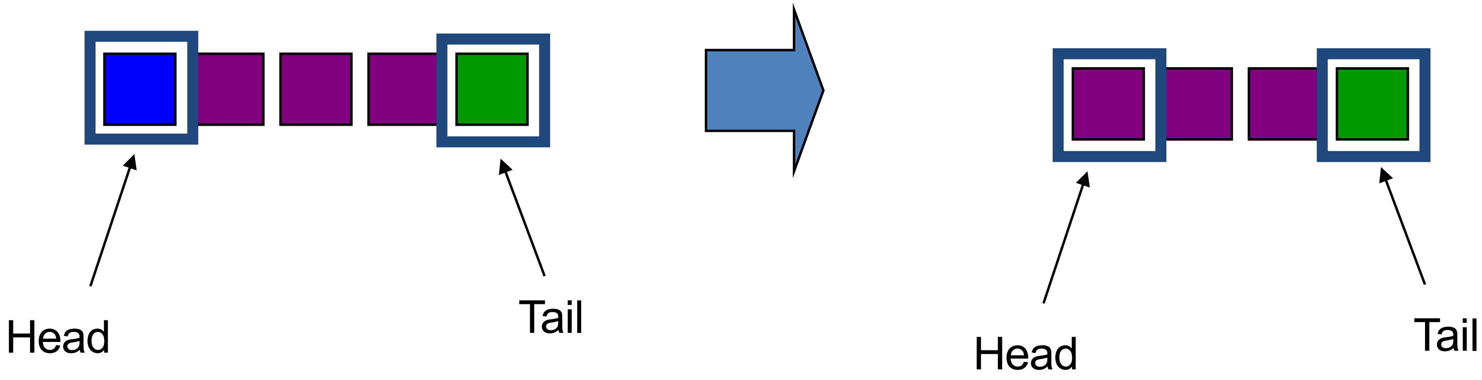


Queue Operations

Dequeue: $Q \rightarrow E$:

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)

Dequeue(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 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)	O(1)	O(1)
Retrieve(First(Q), Q)		
Enqueue(e, Q)	O(1)	O(n) … why?
Insert(e, End(Q), Q)		
Dequeque(Q)	O(n) … why?	O(1)
Retrieve(First(Q), Q)		
Delete(First(Q), Q)		

Queue Implementation

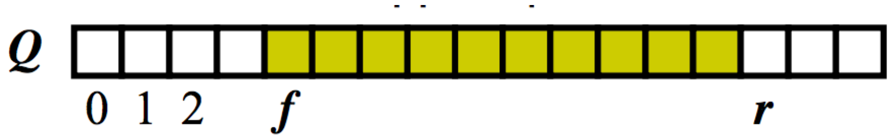
- Reusing the List ADT involves some compromises

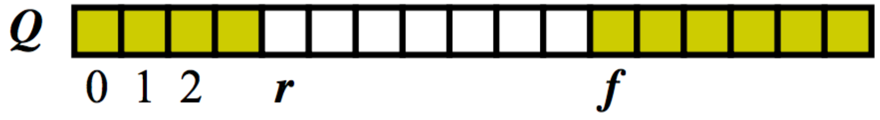
- Alternative is to create a new Queue ADT

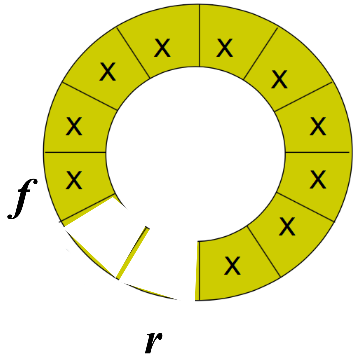
  – With an implementation that avoids these compromises

Queue Implementation

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

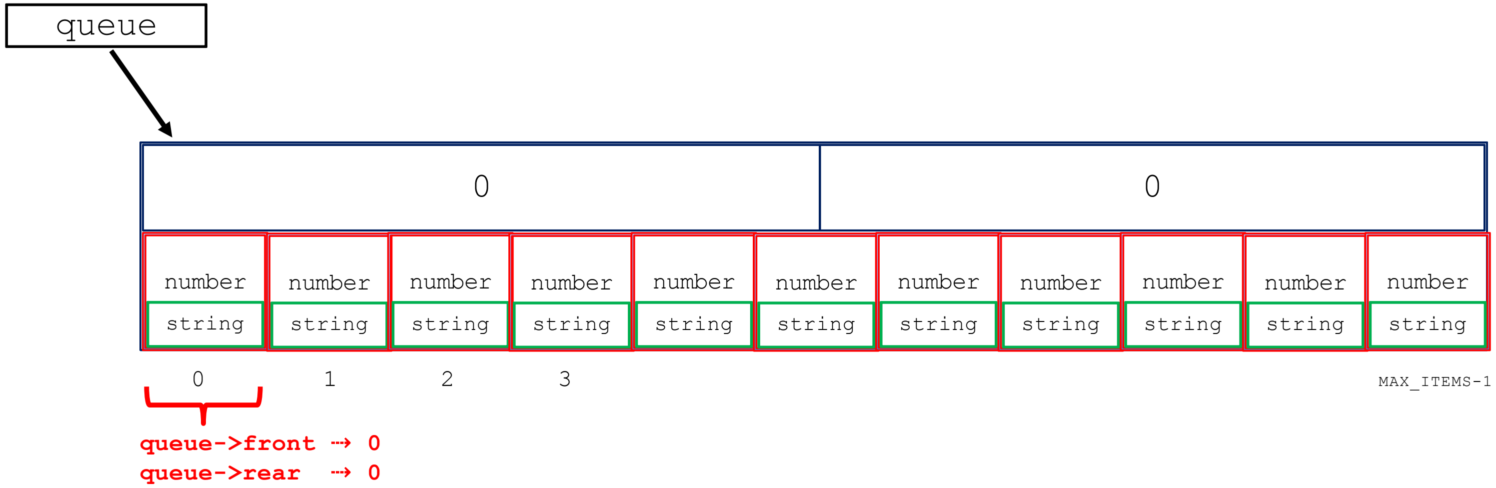






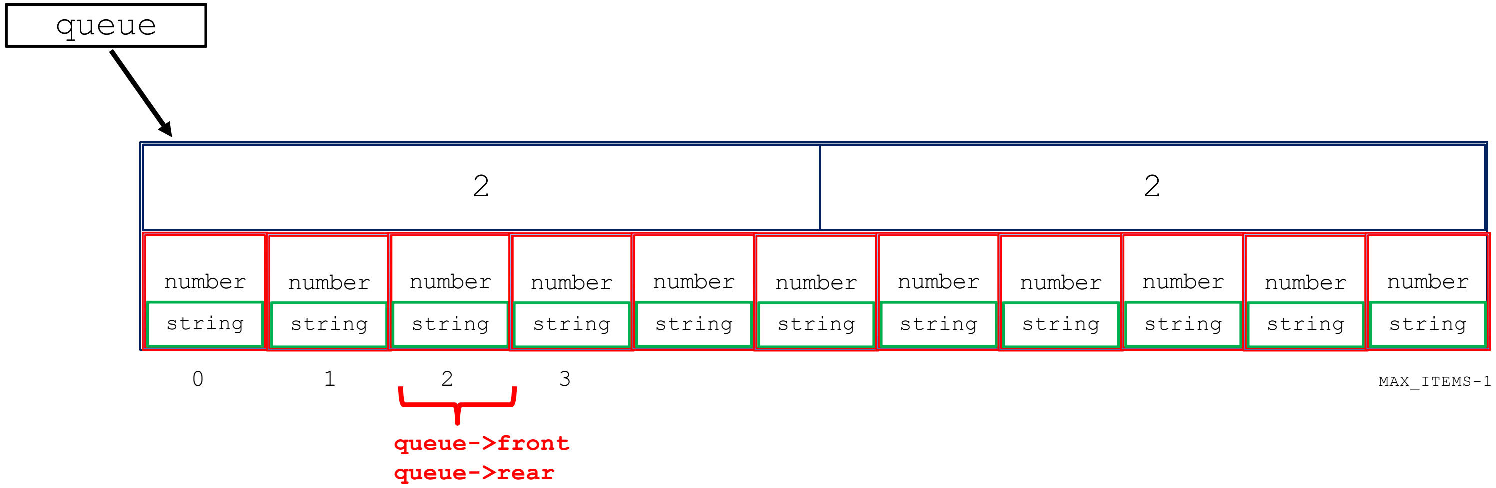
Queue Implementation

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



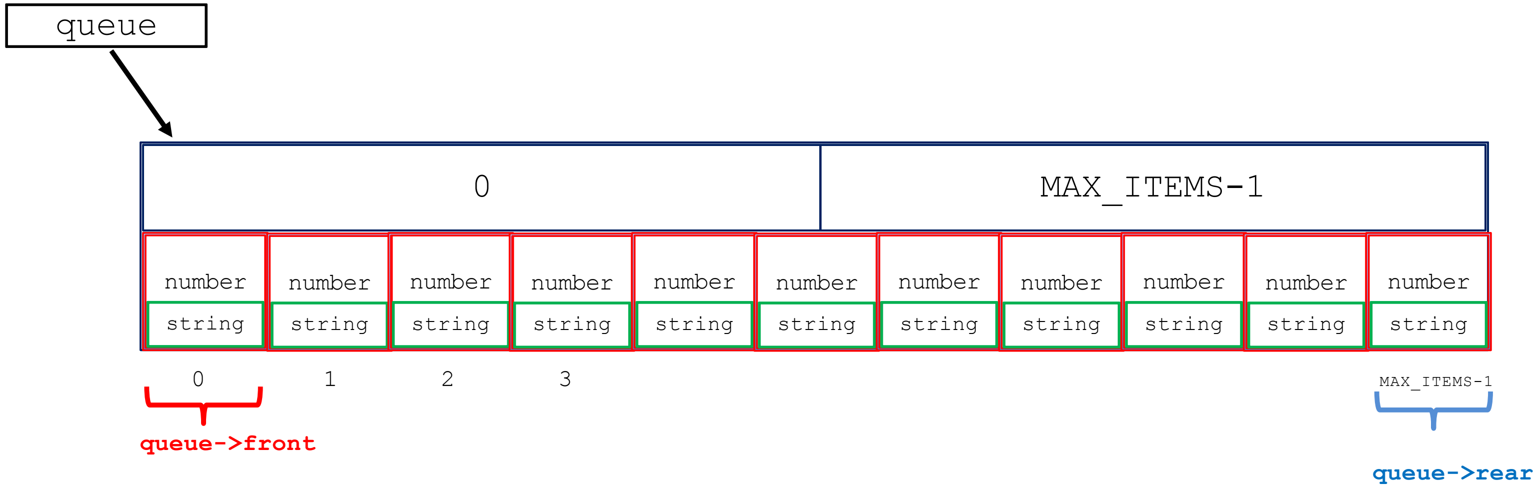
Queue Implementation

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



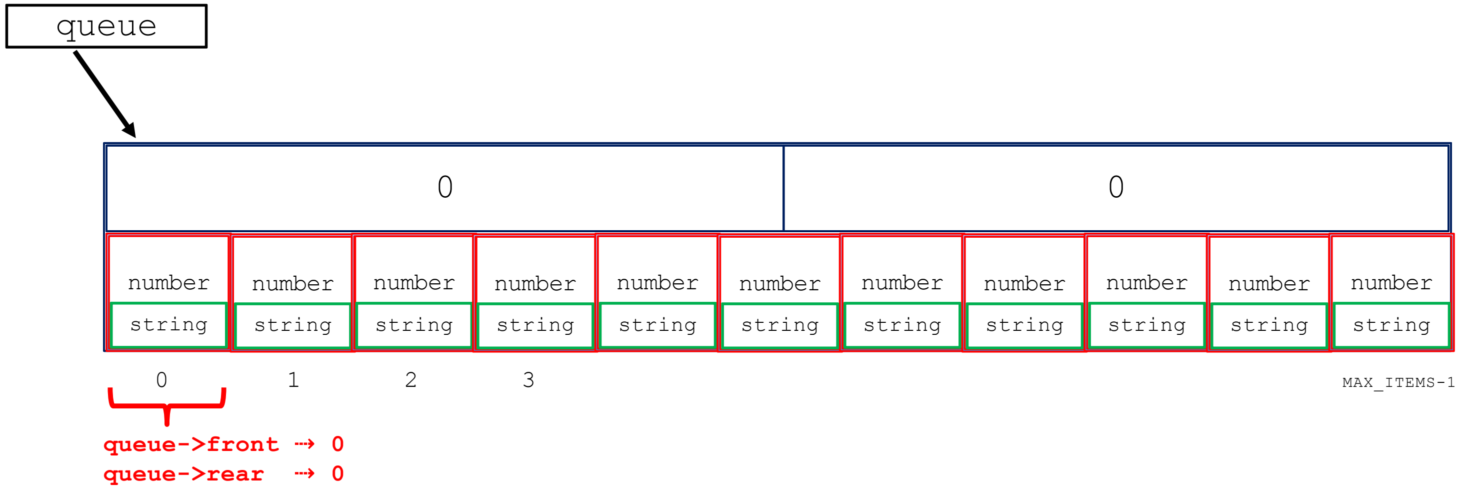
Queue Implementation

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



Queue Implementation

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



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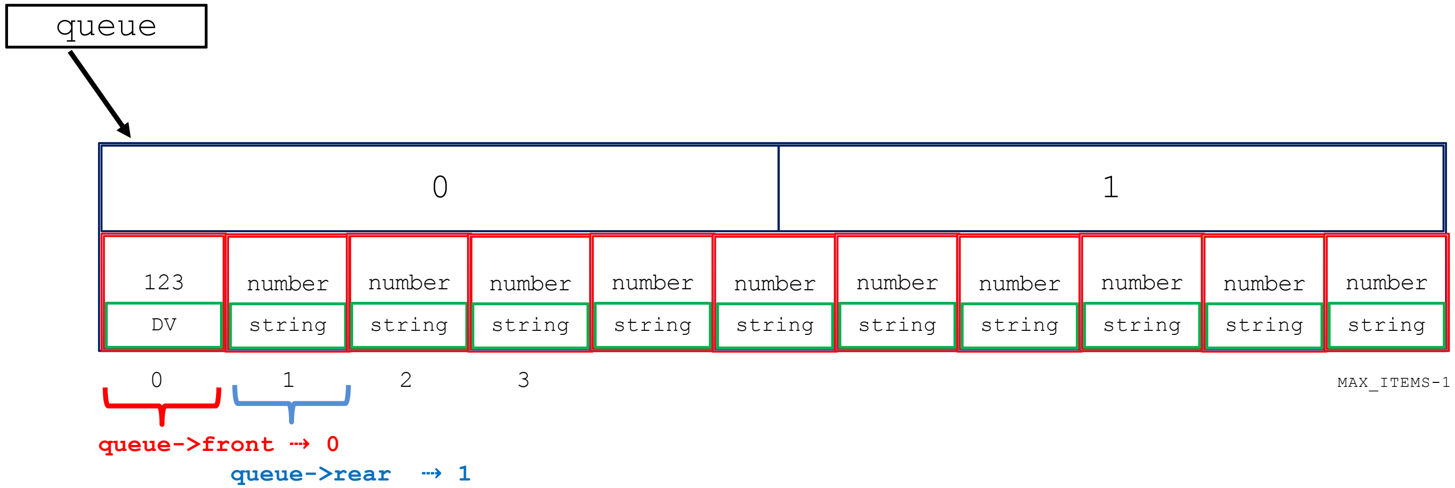

Queue Implementation

```
void dequeue(ITEM_TYPE *e, QUEUE_TYPE *queue) {
   if (!is_empty(queue)) {
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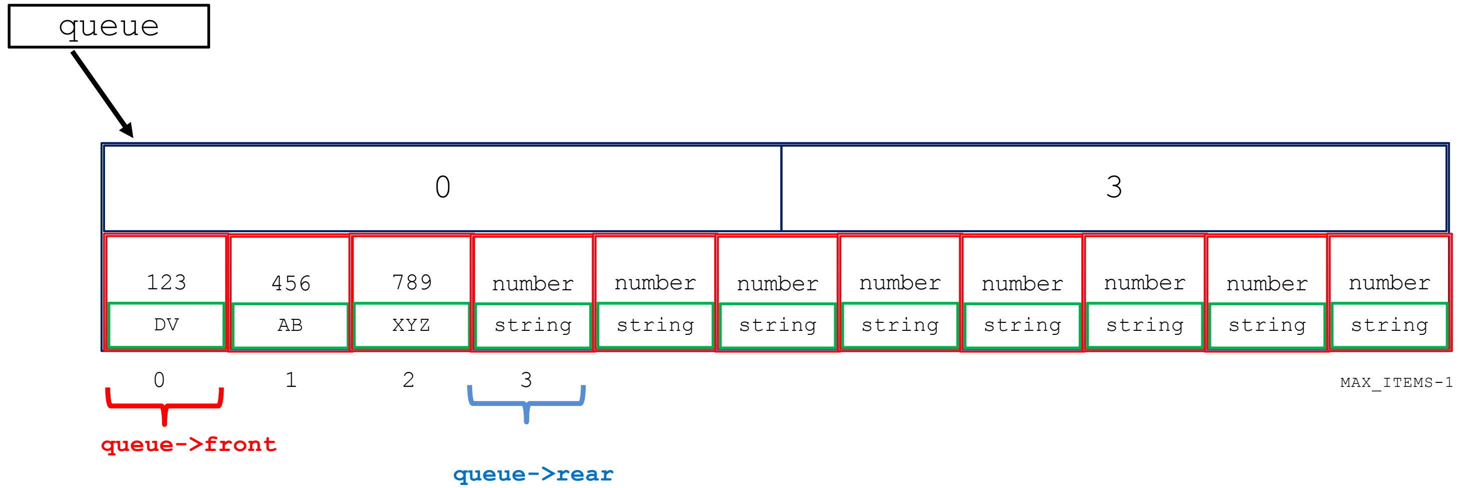

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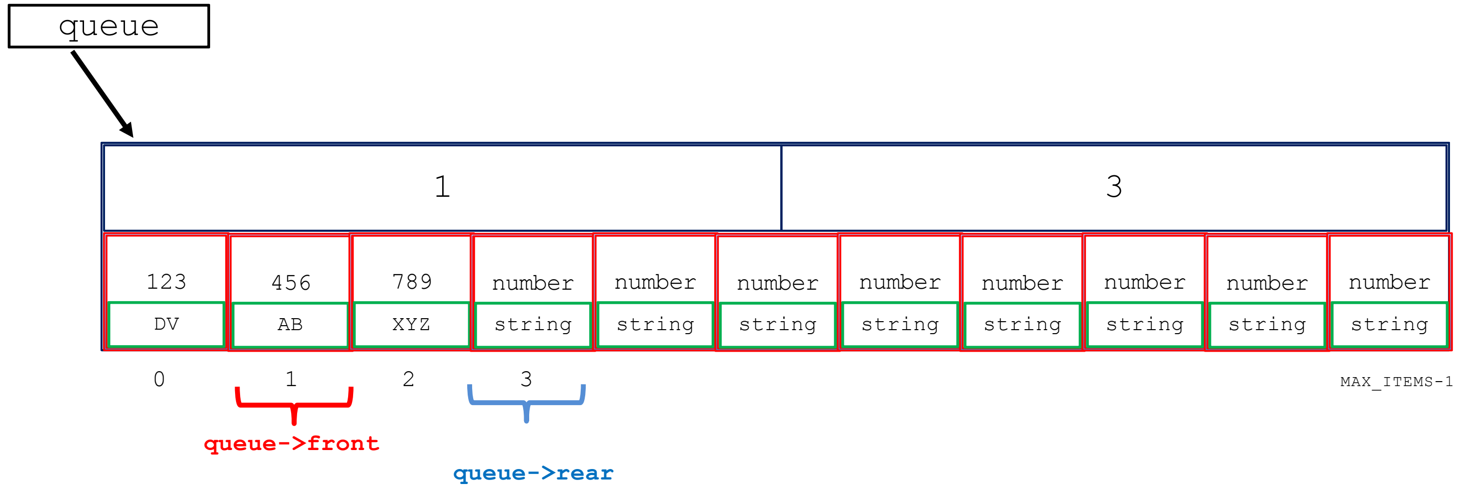

Queue Implementation

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

- How would you fix it?

Queue Operations

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Declare(Q)	O(1)	O(1)
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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

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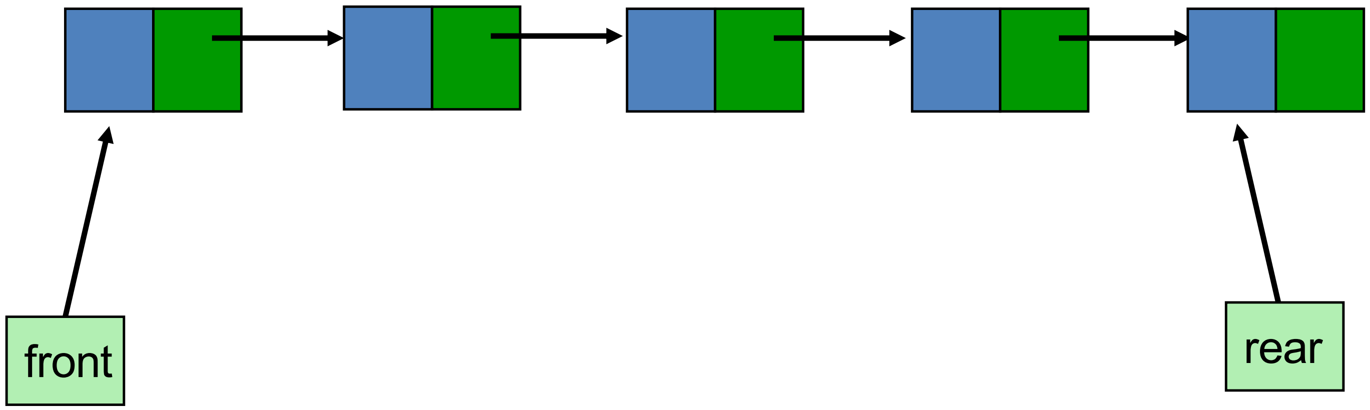
- How would you fix it?

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