Data Structure and Algorithms [CO2003]

Chapter 5 - Stack and Queue

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Contents

Outcomes

- **L.O.2.1** - Depict the following concepts: (a) array list and linked list, including single link and double links, and multiple links; (b) stack; and (c) queue and circular queue.
- **L.O.2.2** - Describe storage structures by using pseudocode for: (a) array list and linked list, including single link and double links, and multiple links; (b) stack; and (c) queue and circular queue.
- **L.O.2.3** - List necessary methods supplied for list, stack, and queue, and describe them using pseudocode.
- **L.O.2.4** - Implement list, stack, and queue using C/C++.

Outcomes

- **L.O.2.5** - Use list, stack, and queue for problems in real-life, and choose an appropriate implementation type (array vs. link).
- **L.O.2.6** - Analyze the complexity and develop experiment (program) to evaluate the efficiency of methods supplied for list, stack, and queue.
- **L.O.8.4** - Develop recursive implementations for methods supplied for the following structures: list, tree, heap, searching, and graphs.
- **L.O.1.2** - Analyze algorithms and use Big-O notation to characterize the computational complexity of algorithms composed by using the following control structures: sequence, branching, and iteration (not recursion).

Basic operations of Stacks

Linear List Concepts

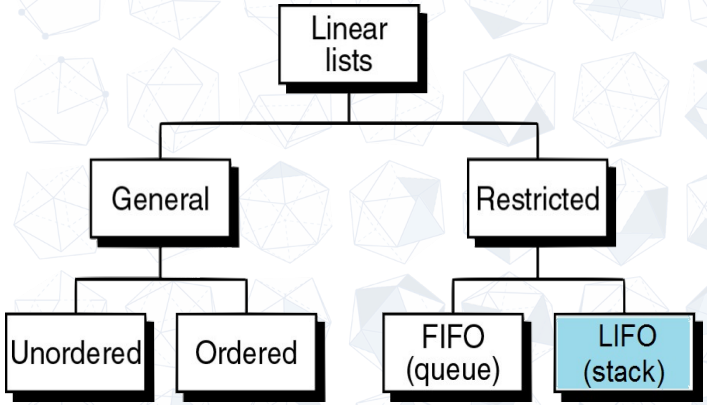
General list:

- No restrictions on which operation can be used on the list.
- No restrictions on where data can be inserted/deleted.

Restricted list:

- Only some operations can be used on the list.
- Data can be inserted/deleted only at the ends of the list.

Linear list concepts



Definition
A stack of elements of type T is a finite sequence of elements of T, in which all insertions and deletions are restricted to one end, called the top.

Stack is a Last In - First Out (LIFO) data structure.
LIFO: The last item put on the stack is the first item that can be taken off.

Basic operations of Stacks

Basic operations:

- `Construct` a stack, leaving it empty.
- `Push` an element: put a new element on to the top of the stack.
- `Pop` an element: remove the top element from the top of the stack.
- `Top` an element: retrieve the top element.

Basic operations of Stacks

Extended operations:

- Determine whether the stack is `empty` or not.
- Determine whether the stack is `full` or not.
- Find the `size` of the stack.
- `Clear` the stack to make it empty.

Basic operations of Stacks: Push

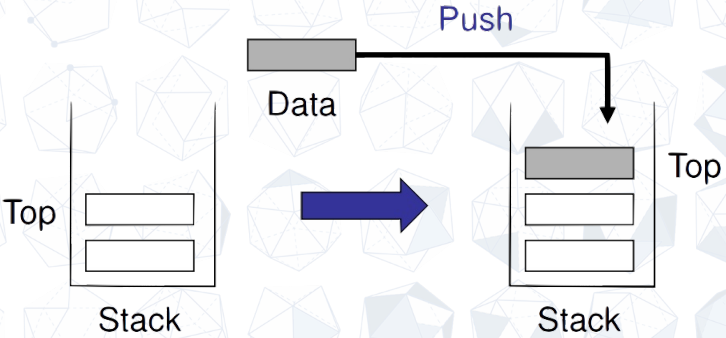


Figure 1: Successful Push operation

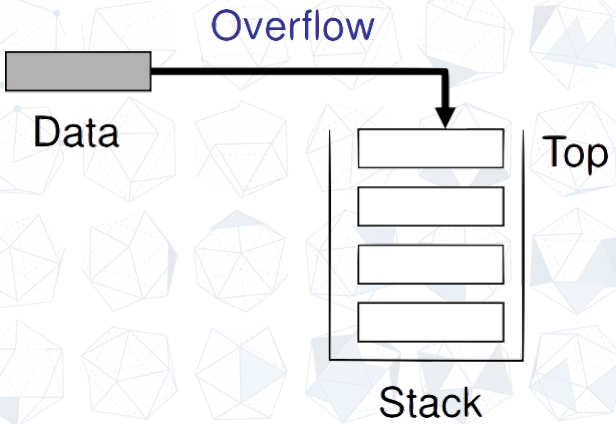


Figure 2: Unsuccessful Push operation. Stack remains unchanged.

Basic operations of Stacks: Pop

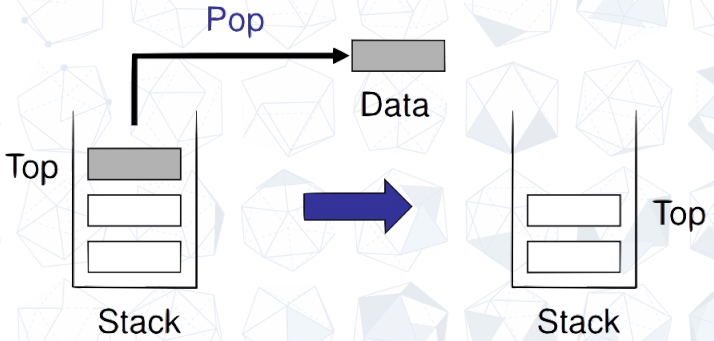


Figure 3: Successful Pop operation

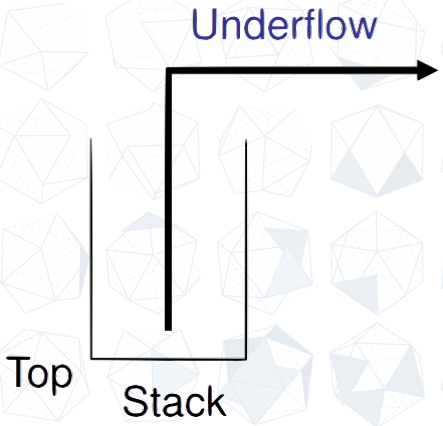


Figure 4: Unsuccessful Pop operation. Stack remains unchanged.

Basic operations of Stacks: Top

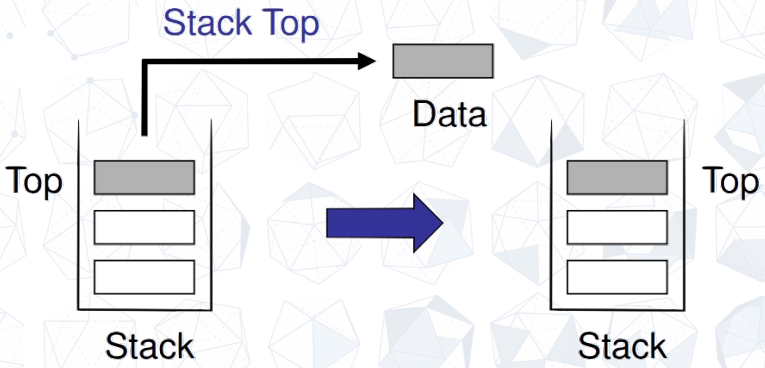


Figure 5: Successful Top operation. Stack remains unchanged.

Basic operations of Stacks: Top

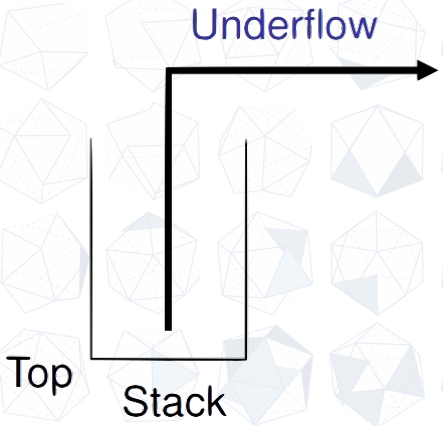
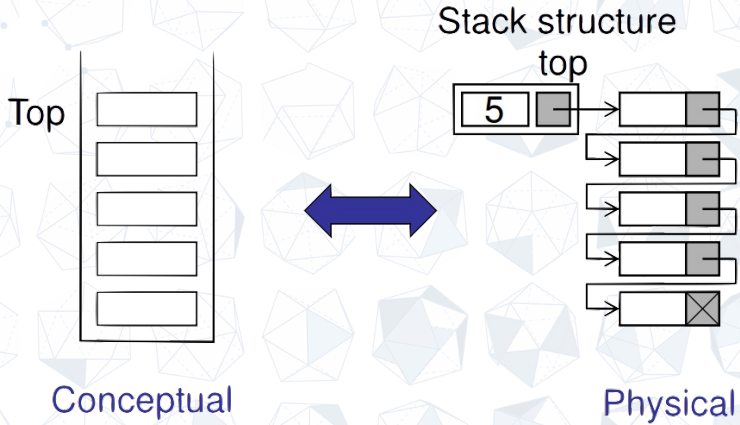


Figure 6: Unsuccessful Top operation. Stack remains unchanged.

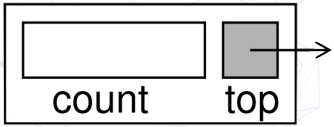
Implementation of Stacks

Linked-list implementation



Linked-list implementation

Stack structure

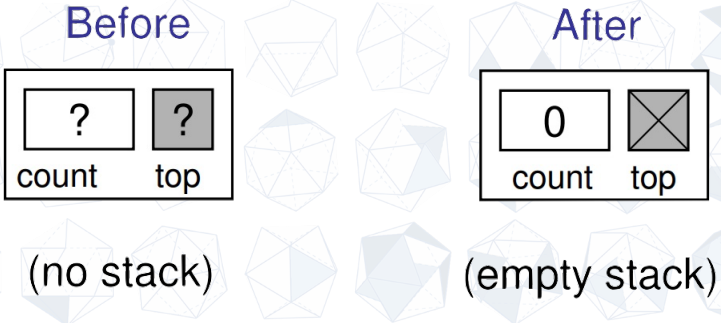



```
stack
  count <integer>
  top <node pointer>
end stack
```

Stack node structure


```
node
  data <dataType>
  next <node pointer>
end node
```

Create an empty Linked Stack

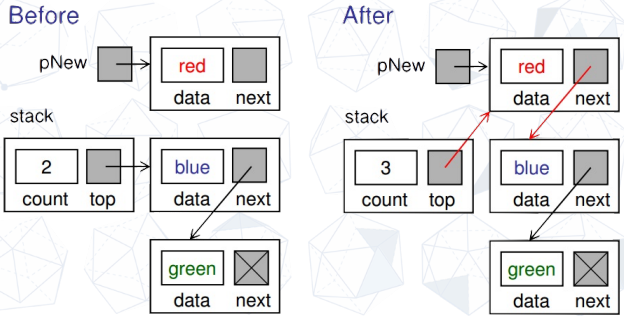


Create an empty Linked Stack

Algorithm createStack(ref stack <metadata>)
Initializes the metadata of a stack
Pre: stack is a metadata structure of a stack
Post: metadata initialized

stack.count = 0
stack.top = null
return
End createStack

Push data into a Linked Stack



1. Allocate memory for the new node and set up data.
2. Update pointers:
   - Point the new node to the top node (before adding the new node).
   - Point top to the new node.
3. Update count

Push data into a Linked Stack

Algorithm pushStack(ref stack <metadata>, val data <dataType>)
Inserts (pushes) one item into the stack
Pre: `stack` is a metadata structure to a valid stack
`data` contains value to be pushed into the stack
Post: data have been pushed in stack
Return `true` if successful; `false` if memory overflow

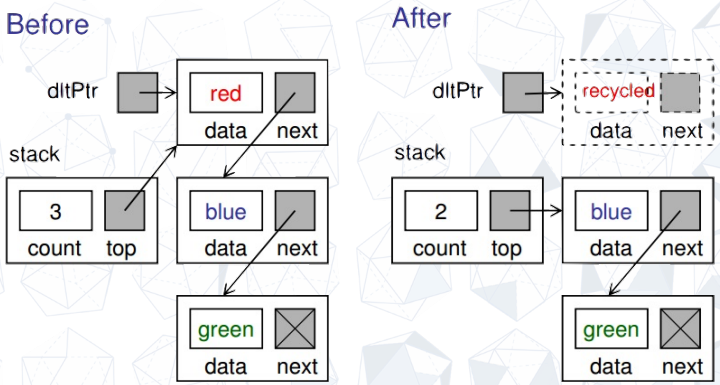
Push data into a Linked Stack

```
if stack full then
    success = false
else
    allocate (pNew)
    pNew -> data = data
    pNew -> next = stack.top
    stack.top = pNew
    stack.count = stack.count + 1
    success = true
end
return success
End pushStack
```

Push data into a Linked Stack

- Push is successful when allocation memory for the new node is successful.
- There is no difference between push data into a stack having elements and push data into an empty stack (top having NULL value is assigned to `pNew->next`: that's corresponding to a list having only one element).

Pop Linked Stack



1. `dltPtr` holds the element on the top of the stack.
2. `top` points to the next element.
3. Recycle `dltPtr`. Decrease `count` by 1.

Pop Linked Stack

Algorithm popStack(ref stack <metadata>, ref dataOut <dataType>)
Pops the item on the top of the stack and returns it to caller
Pre: `stack` is a metadata structure to a valid stack
`dataOut` is to receive the popped data
Post: data have been returned to caller
Return `true` if successful; `false` if stack is empty

Pop Linked Stack

```
if stack empty then
    success = false
else
    dltPtr = stack.top
    dataOut = stack.top -> data
    stack.top = stack.top -> next
    stack.count = stack.count - 1
    recycle(dltPtr)
    success = true
end
return success
End popStack
```

Pop Linked Stack

- Pop is successful when the stack is not empty.
- There is no difference between pop an element from a stack having elements and pop the only-one element in the stack (`dltPtr->next` having NULL value is assigned to top: that's corresponding to an empty stack).

Stack Top

Algorithm stackTop(ref stack <metadata>, ref dataOut <dataType>)
Retrieves the data from the top of the stack without changing the stack
Pre: `stack` is a metadata structure to a valid stack
`dataOut` is to receive top stack data
Post: data have been returned to caller
Return `true` if successful; `false` if stack is empty

Stack Top

```
if stack empty then
    success = false
else
    dataOut = stack.top -> data
    success = true
end
return success
End stackTop
```

Destroy Stack

Algorithm destroyStack(ref stack <metadata>)
Releases all nodes back to memory

Pre: stack is a metadata structure to a valid stack
Post: stack empty and all nodes recycled

Destroy Stack

```
if stack not empty then
    while stack.top not null do
        temp = stack.top
        stack.top = stack.top -> next
        recycle(temp)
    end
end
stack.count = 0
return
End destroyStack
```

isEmpty Linked Stack

Algorithm isEmpty(ref stack <metadata>)
Determines if the stack is empty
Pre: `stack` is a metadata structure to a valid stack
Post: return stack status
Return `true` if the stack is empty, `false` otherwise
if *count = 0* **then**
  Return `true`
else
  Return `false`
end
End isEmpty

Applications of Stack

Applications of Stack

- Reversing data items
  - Reverse a list
  - Convert Decimal to Binary
- Parsing
  - Brackets Parse
- Postponement of processing data items
  - Infix to Postfix Transformation
  - Evaluate a Postfix Expression
- Backtracking
  - Goal Seeking Problem
  - Knight's Tour
  - Exiting a Maze
  - Eight Queens Problem

Basic operations of Queues

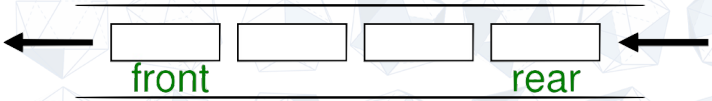
Definition
A queue of elements of type T is a finite sequence of elements of T, in which data can only be inserted at one end called the rear, and deleted from the other end called the front.

Queue is a First In - First Out (FIFO) data structure.
FIFO: The first item stored in the queue is the first item that can be taken out.

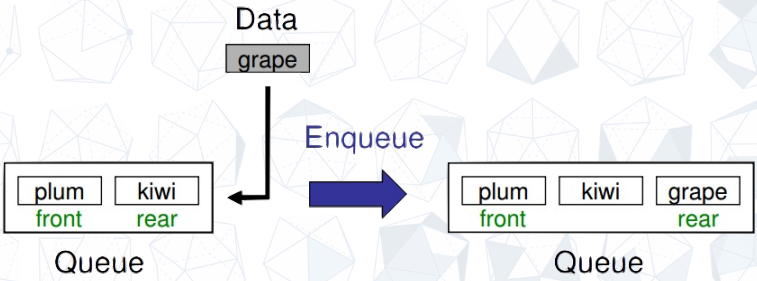
Basic operations of Queues

Basic operations:

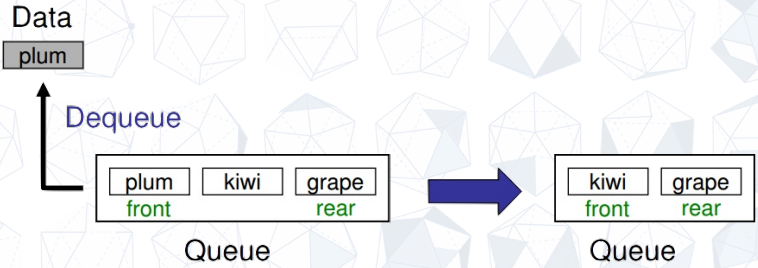
- `Construct` a queue, leaving it empty.
- `Enqueue`: put a new element in to the rear of the queue.
- `Dequeue`: remove the first element from the front of the queue.
- `Queue Front`: retrieve the front element.
- `Queue Rear`: retrieve the rear element.



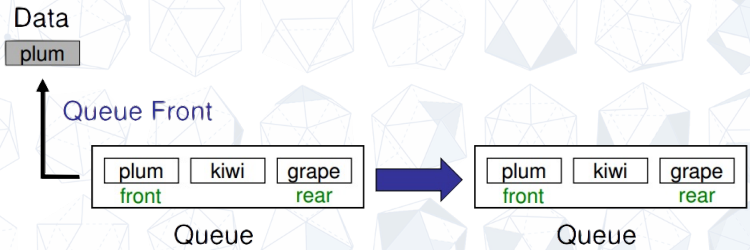
Basic operations of Queues: Enqueue



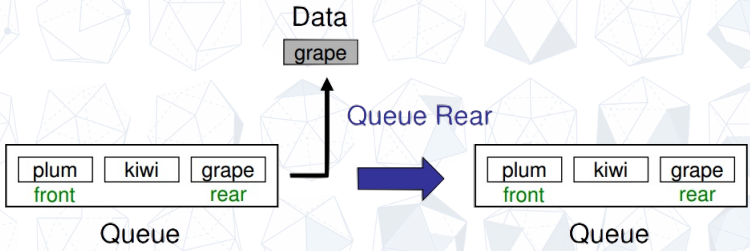
Basic operations of Queues: Dequeue



Basic operations of Queues: Queue Front

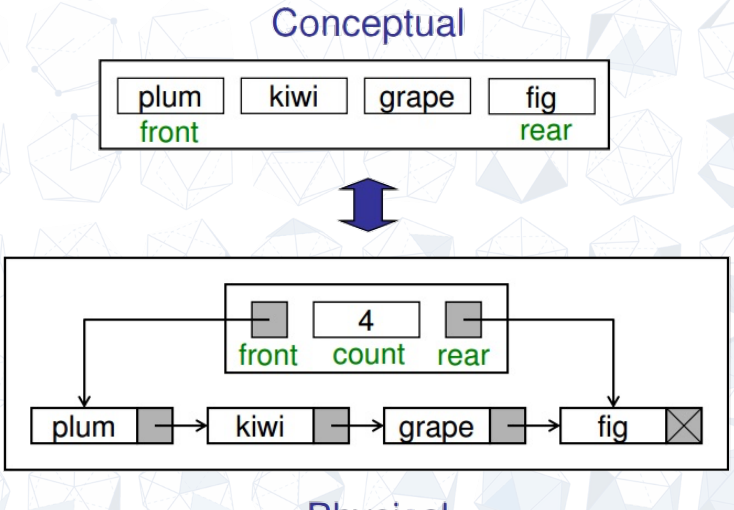


Basic operations of Queues: Queue Rear



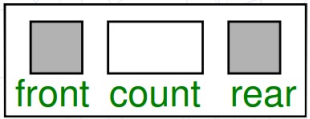
Implementation of Queue

Linked-list implementation



Linked-list implementation

Queue structure

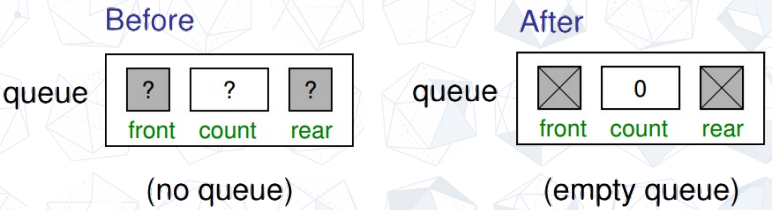



```
queue
    count <integer>
    front <node pointer>
    rear <node pointer>
endqueue
```

Queue node structure


```
node
    data <dataType>
    next <node pointer>
end node
```

Create Queue



Create Queue

Algorithm createQueue(ref queue <metadata>)
Initializes the metadata of a queue
Pre: queue is a metadata structure of a queue
Post: metadata initialized

queue.count= 0
queue.front = null
queue.rear = null
return
End createQueue

Enqueue: Insert into an empty queue

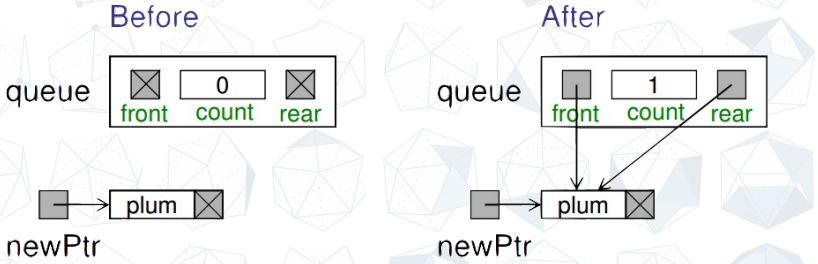


Figure 7: Insert into an empty queue

Enqueue: Insert into a queue with data

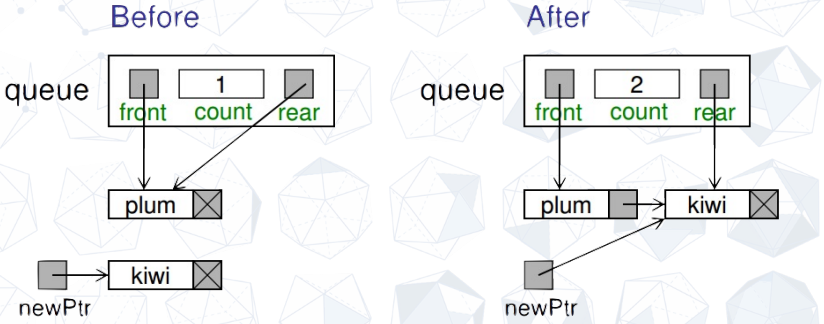


Figure 8: Insert into a queue with data

Enqueue

Algorithm enqueue(ref queue <metadata>, val data <dataType>)
Inserts one item at the rear of the queue

Pre: queue is a metadata structure of a valid queue
data contains data to be inserted into queue

Post: data have been inserted in queue
Return true if successful, false if memory overflow

Enqueue

```
if queue full then
    return false
end
allocate (newPtr)
newPtr -> data = data
newPtr -> next = null
if queue.count = 0 then
    queue.front = newPtr // Insert into an empty queue
else
    queue.rear -> next = newPtr // Insert into a queue with data
end
queue.rear = newPtr
queue.count = queue.count + 1
return true
```

Dequeue: Delete data in a queue with only one item

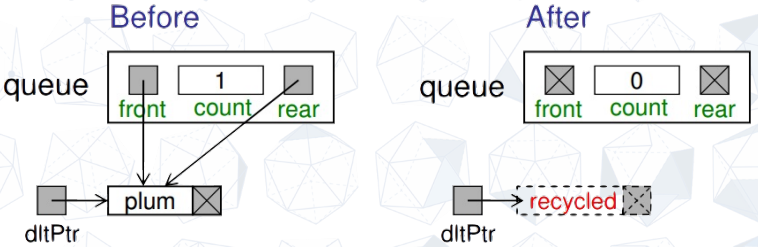


Figure 9: Delete data in a queue with only one item

Dequeue: Delete data in a queue with more than one item

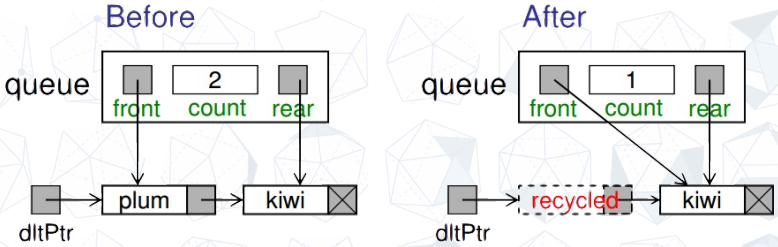


Figure 10: Delete data in a queue with more than one item

Dequeue

Algorithm dequeue(ref queue <metadata>, ref dataOut <dataType>)
Deletes one item at the front of the queue and returns its data to caller

Pre: queue is a metadata structure of a valid queue
`dataOut` is to receive dequeued data

Post: front data have been returned to caller
Return `true` if successful, `false` if memory overflow

Dequeue

```
if queue empty then
    return false
end
dataOut = queue.front -> data
dltPtr = queue.front
if queue.count = 1 then
    // Delete data in a queue with only one item
    queue.rear = NULL
end
queue.front = queue.front -> next
queue.count = queue.count - 1
recycle (dltPtr)
return true
End dequeue
```

Applications of Queue

Applications of Queue

- Polynomial Arithmetic
- Categorizing Data
- Evaluate a Prefix Expression
- Radix Sort
- Queue Simulation