Stacks and Queues

CSE 373

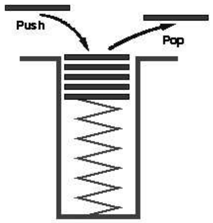
Data Structures

Unit 4

Reading: Sections 3.3 and 3.4

Stack ADT

- A list for which Insert and Delete are allowed only at one end of the list (the *top*)
  - › the implementation defines which end is the "top"
  - › LIFO – Last in, First out
- Push: Insert element at top
- Pop: Remove and return top element (aka TopAndPop)
- IsEmpty: test for emptyness



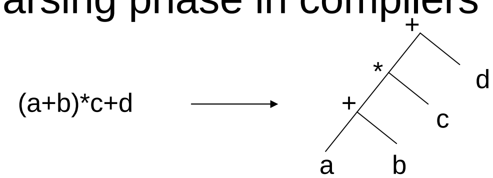
a tray stack

An Important Application of Stacks

- Call stack in run time systems
  - › When a function (method, procedure) is called, the work area (local variables, copies of parameters, return location in code) for the new function is pushed on to the stack. When the function returns the stack is popped.
  - › The order we need the data back is 'LIFO'
  - › This explains why calling a recursive procedure with a depth of N requires O(N) space.

Another Application of Stacks

- Parsing phase in compilers

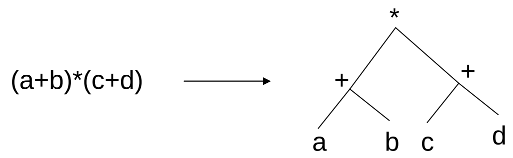


parse tree

yields the reverse Polish (postfix) notation:

ab+c*d+ (traversal of a binary tree in postorder; to be learnt…)

Another Application of Stacks



- The reverse Polish (postfix) notation:

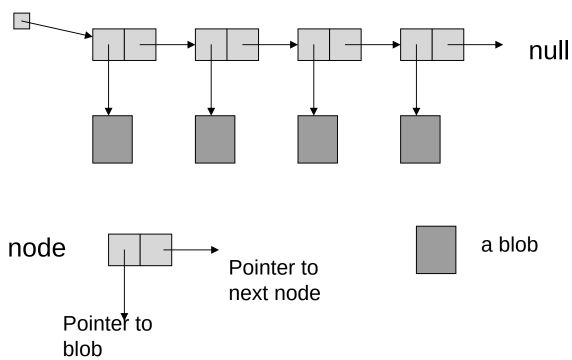
  ab+cd+*

Two Basic Implementations of Stacks

- Linked List
  - › Push is InsertFront
  - › Pop is DeleteFront (Top is “access” the element at the top of the stack)
  - › IsEmpty is test for null (or null after the header if there’s one)
- Array
  - › The k items in the stack are the first k items in the array.

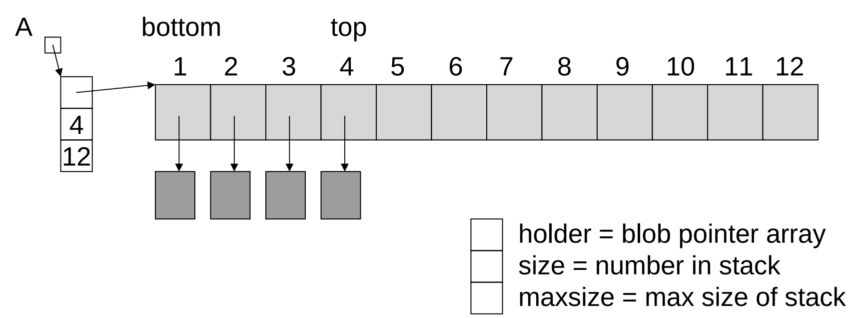
Linked List Implementation

- Stack of blobs



Array Implementation

- Stack of blobs



Push and Pop (array impl.)

```
IsEmpty(A : blobstack pointer) : boolean {
  return A.size = 0
}
IsFull(A : blobstack pointer) : boolean {
  return A.size = A.maxsize;
}
Pop(A : blobstack pointer) : blob pointer {
// Precondition: A is not empty //
  A.size := A.size – 1;
  return A.holder[A.size + 1];
}
Push(A : blobstack pointer, p : blob pointer): {
// precondition: A is not full//
  A.size := A.size + 1;
  A.holder[A.size] := p;
}
```


Linked Lists vs Array

- Linked list implementation
  - + flexible – size of stack can be anything
  - + constant time per operation
  - - Call to memory allocator can be costly
- Array Implementation
  - + Memory preallocated
  - + constant time per operation.
  - - Not all allocated memory is used
  - - Overflow possible - Resizing can be used but some ops will be more than constant time.

Exercise : Find Min

Propose a data structure that supports the stack ‘push’ and ‘pop’ operations and a third operation ‘find_min’, which returns the smallest element in the data structure.

All three operations in O(1) worst case.

Exercise : Find Min

Queue

- Insert at one end of List, remove at the other end
- Queues are “FIFO” – first in, first out
- Primary operations are Enqueue and Dequeue
- A queue ensures “fairness”

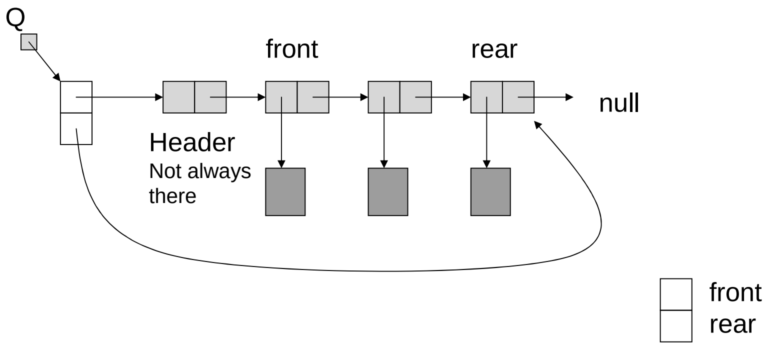
Queue ADT

- Operations:
  - › Enqueue - add an entry at the end of the queue (also called “rear” or “tail”)
  - › Dequeue - remove the entry from the front of the queue
  - › IsEmpty
  - › IsFull may be needed

A Sample of Applications of Queues

- Printer Queue: Jobs submitted to a printer are printed in order of arrival
- Phone calls made to customer service hotlines are usually placed in a queue
- File servers: Users needing access to their files on a shared file server machine are given access on a FIFO basis

Pointer Implementation

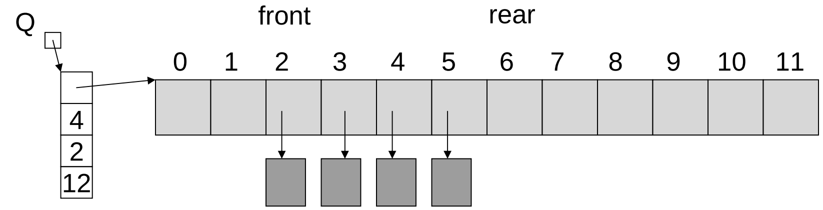


List Implementation

```
IsEmpty(Q : blobqueue pointer) : boolean {
  return Q.front = Q.rear
}
Dequeue(Q : blobqueue pointer) : blob pointer {
// Precondition: Q is not empty //
  B : blob pointer;
  B := Q.front.next;
  Q.front.next := Q.front.next.next;
  return B;
}
Enqueue(Q : blobqueue pointer, p : blob pointer): {
  Q.rear.next := new node;
  Q.rear := Q.rear.next;
  Q.rear.value := p;
}
```


Array Implementation

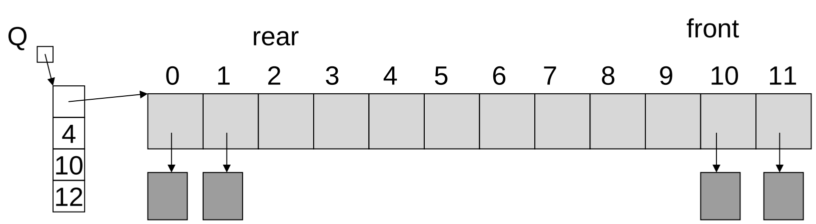
- Circular array



rear = (front + size) mod maxsize
(the index of the entry after the last occupied one)

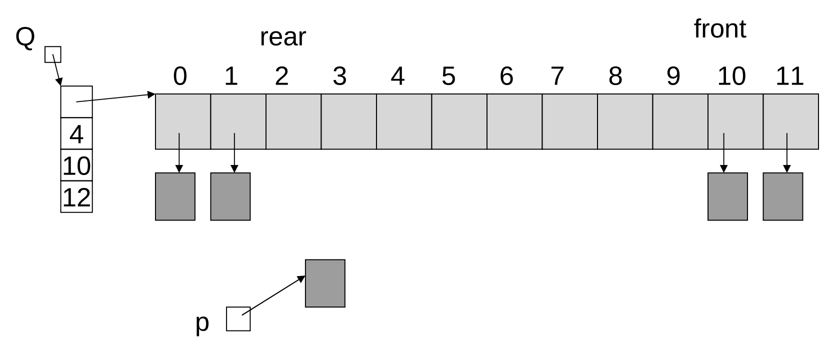
holder = blob pointer array
size = number in queue
front = index of front of queue
maxsize = max size of queue

Wrap Around

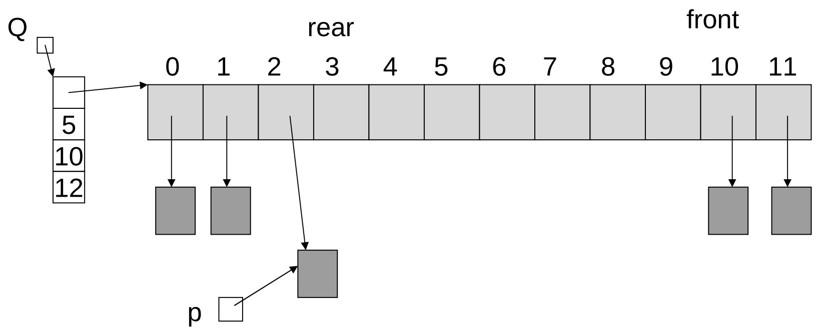


rear = (front + size) mod maxsize
= (10 + 4) mod 12 = 14 mod 12 = 2

Enqueue



Enqueue

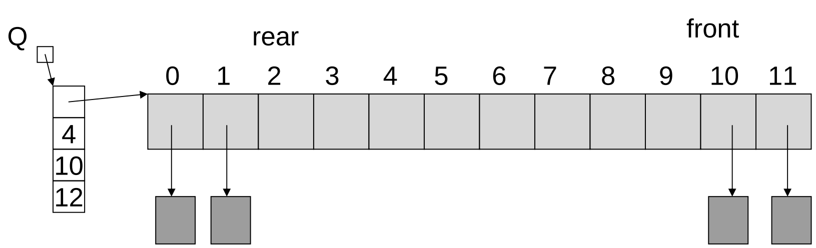


Enqueue

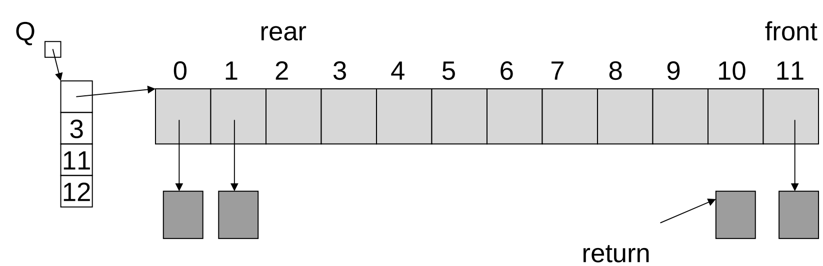
```
Enqueue(Q : blobqueue pointer, p : blob pointer) : {
// precondition : queue is not full //
Q.holder[(Q.front + Q.size) mod Q.maxsize] := p;
Q.size := Q.size + 1;
}
```

Constant time!

Dequeue



Dequeue



Try Dequeue

- Define the circular array implementation of Dequeue

Solution to Dequeue