Linked Lists, Stacks, and Queues

Dr. Baldassano
chrisb@princeton.edu
Yu's Elite Education

Last week recap

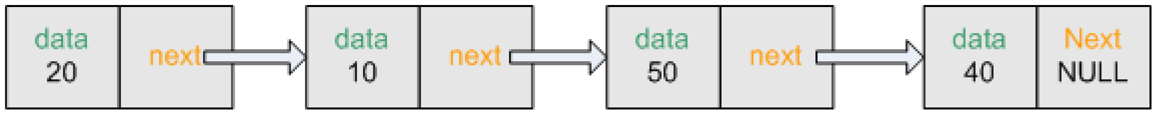
- Heaps
  - Heap structure and ordering
  - Adding elements
  - Removing elements
  - Using as priority queue
  - Heapsort

Problems with arrays

- Traditional arrays/lists store data in consecutive slots in memory
- Good: can easily calculate where element i can be found, as `(begin + i*datasize)`
- Bad: Inserting or deleting elements requires moving O(N) elements (unless at end)
- Python example

Linked lists

- Linked lists do not store elements consecutively in memory
- Each element contains some data, and the memory address of the next element



Linked list

- http://visualgo.net/list.html

Big-O for linked lists

- Inserting or deleting a node (assuming we know memory address of insertion/deletion point) is O(1) (vs. O(n) for array)
- Indexing (finding nth piece of data) is O(n) (vs. O(1) for array)

Implementing linked list

- Node structure
  - Data field
  - Pointer to next node (NULL if end of list)
- Head pointer to first node

- Example in python

Reversing linked list

- Can we reverse all links in a linked list in a single pass?

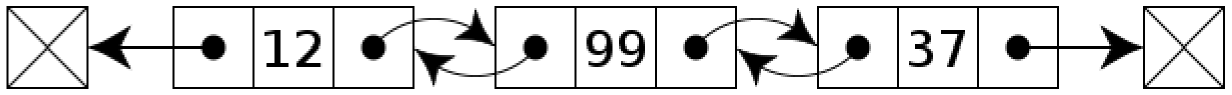
Detecting loops in a linked list

- How can we check that our list doesn't have any loops?
- Traverse until end?
- Mark each node?
- Check node against entire list so far?
  - Works, but $O(N^2)$
- Floyd's tortoise and hare
  - http://visualgo.net/cyclefinding.html

Problems with one-directional links

- We can only iterate through the list in one direction
- Even if given the memory address of a node to delete, we'd have to iterate through the list to find the previous node
- Solution: Doubly-linked lists

Doubly-linked lists

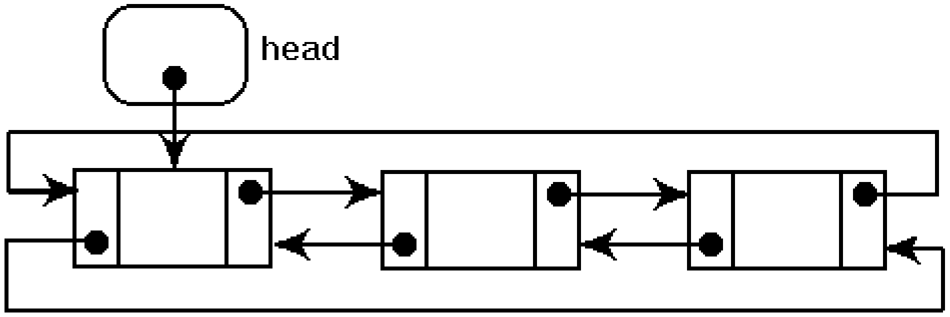


- Every node contains data, and pointers to both previous and next nodes
- Have head and tail pointers to the front and back of the list

- Example in python (for show and insert)

Circular doubly-linked lists

- We can get rid of some of the special cases at the ends of the list by connecting the head and tail nodes to each other



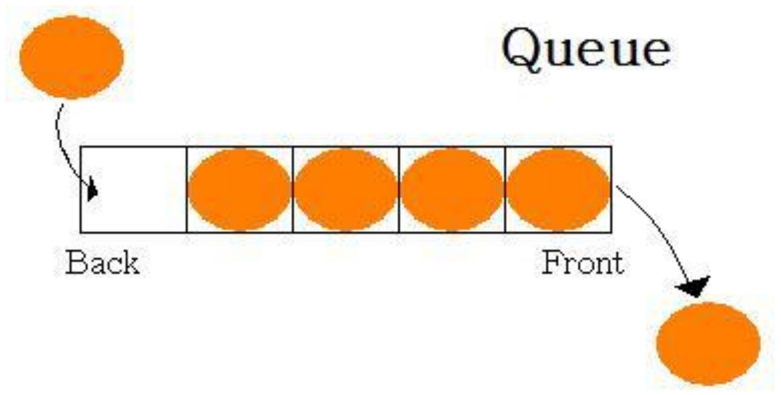
Doubly Linked Circular list

- Example in python (for show and insert)

Stacks and Queues

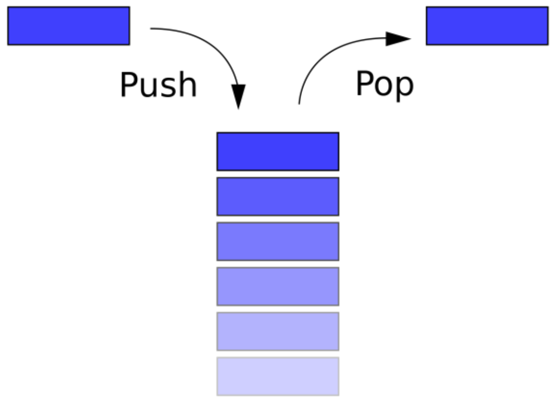
- Linked lists are often used to implement two other data structures: stacks and queues
- Both allow us to add or remove one element at a time
- Queues: First-in-first-out (FIFO)
- Stacks: First-in-last-out (FILO)

Queues



- Uses of queues?
  - Website requests
  - Simulations or game engines
  - Expanding algorithms like Dijkstra's

Stacks



- Uses of stacks?
  - Recursive algorithms like mergesort
  - Backtracking algorithms like constraint satisfaction (e.g. Sudoku)
  - Compiling and running programs

Implementing Queue with linked list

- Why implement with linked list?
- Enqueue operation:
  - Add node at head
- Dequeue operation
  - Remove and return node at tail
- http://visualgo.net/list.html

Implementing Stack with linked list

- Why implement with linked list?
- Push operation:
  - Add node at head
- Pop operation:
  - Remove and return node at head
- http://visualgo.net/list.html

Stack example: Reverse Polish Notation

- Traditional math notation: requires knowing order of operations, using parentheses

  7+(1+2)*5 = 22

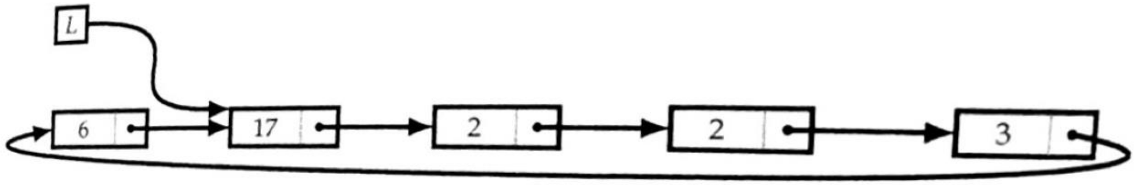
- Reverse Polish notation avoids these issues by using a stack

  7 1 2 + 5 * +

- Implement in python

Assignment: Median of sorted circularly linked list

- Sorted singly-linked circular list:



- Given a reference to some node, find median of the list
  - Note: need to handle all-equal special case