CS410 Lecture 4

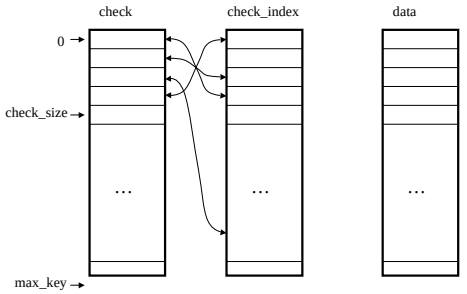
Neal Glew

HW1, Basic Structures

HW1 Q10 Solution

- Key maps directly into data array, but may not be intialised
- Need to know if entry intialised
- Keep stack of indices of intialised entries
- Need to search stack
- Keep another array to index into stack

HW Q10 Solution (cont.)



HW1 Q10 Solution (cont.)

```
class InvalidKey extends Exception {}
class DictionaryAbsent extends Exception {}

class Dictionary {
    private int check_size;
    private int check[];
    private int check_index[];
    private Object data[];

    public Dictionary(int max_key) {
        check_size = 0;
        check = new int[max_key];
        check_index = new int[max_key];
        data = new Object[max_key];
    }
```

```
    public boolean valid(int key) throws InvalidKey {
        // Check key is in range
        if (!(0<=key && key<check.length)) throw new InvalidKey();
        // Check if present
        int chk_ind = check_index[key];
        return 0<=chk_ind && chk_ind<check_size &&
               check[chk_ind]==key;
    }
    public void insert(int key, Object value) throws InvalidKey {
        if (!valid(key)) {
            // Not present; initialise
            int chk_ind = check_size++;
            check[chk_ind] = key;
            check_index[key] = chk_ind;
        }
        // Set data
        data[key] = value;
    }
```

HW1 Q10 Solution (cont.)

```
    public void delete(int key) throws InvalidKey {
        if (valid(key)) {
            // Present; delete it
            check_size--;
            int chk_ind = check_index[key];
            if (chk_ind!=check_size) {
                // Swap check entry for key with the top of stack
                check[chk_ind] = check[check_size];
                check_index[check[check_size]] = chk_ind;
            }
        } // Otherwise do nothing
    }
    public Object lookup(int key) throws InvalidKey, DictionaryAbsent {
        if (valid(key))    return data[key];                    // Present; return data
        else               throw new DictionaryAbsent();  // Absent; throw exception
    }
}
```

Basic Datastructures (CLR 11)

- Stacks
- Queues
- Linked Lists
- Sentinels
- Pointers as arrays
- Trees

Stacks

- Operations
  - Create empty stack
  - Is stack empty?
  - Push element
  - Pop element
- Stacks are LIFO, last element is called top of stack, first element is called bottom of stack

Stacks using Arrays

```
class Stack {
    private int top;
    private Object items[];
    public Stack(int cap) {
        top=0;
        items=new Object[cap];
    }
    public boolean empty() {
        return top<=0;
    }
    public void push(Object item)
    {
      if (top>=items.length)
          throw new Full();
      items[top++]=item;
    }
    public Object pop() {
      if (empty())
          throw new Empty();
      return items[--top];
    }
}
```

Queues

- Operations
  - Create empty queue
  - Is queue empty?
  - Enqueue item
  - Dequeue item
- Queues are FIFO, first element is called front of queue, last element is called back of queue

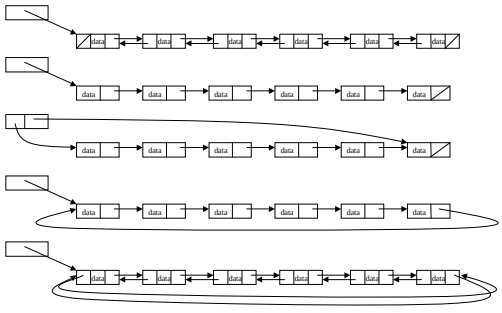
Queues using Arrays

```
class Queue {
    private int head, tail;
    private Object items[];
    public Stack(int cap) {
      head=tail=0;
      items=new Object[cap];
    }
    public void enqueue(Object item) {
      int nt = (tail+1)%items.length;
      if (nt==head)
          throw new Full();
      items[tail]=item; tail=nt;
    }
    public boolean empty() {
      return head==tail;
    }
    public Object dequeue() {
      if (empty())
          throw new Empty();
      Object item = items[head];
      head = (head+1)%items.size;
      return item;
    }
}
```

Linked Lists

- Sequence of nodes that are linked
- Singly linked and doubly linked - next and prev
- Head pointer, head and tail pointer, circular list
- List can be ordered or unordered

Linked Lists Pictorially



Linked List Code

```
class SinglyLN {
    Object data;
    SinglyLinkedNode next;
}

class DoublyLN {
    Object data;
    DoublyLN prev;
    DoublyLN next;
}
```

```
class SLinkedList {
    private SinglyLN head;
    public Object find(Object item) {
        SinglyLN current = head;
        while (current!=null &&
                item!=current.data)
            current=current.next;
        if (current!=null)
            return current.data;
        else
            throw new Absent();
    }
```

Linked List Code

```
public void insert(Object item) {
    SinglyLN nn =
        new SinglyLN();
    nn.data=item;
    nn.next=head;
    head=nn;
}
public void delete(Object item) {
    SinglyLN prev = null;
    SinglyLN current = head;
    while (current!=null &&
            item!=current.data) {
        prev=current;
        current=current.next;
    }
    if (current==null) return;
    if (prev==null)
        head=current.next;
    else
        prev.next=current.next;
    }
}
```

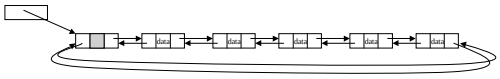
Linked List Code

```
class DLinkedList {
    private DoublyLN head;
    // Find same as SLinkedList
    public void insert(Object item) {
        DoublyLN nn =
            new DoublyLN();
        nn.data=item;
        nn.next=head;
        if (head!=null) head.prev=nn;
        nn.prev=null;
        head=nn;
    }
```

```
    public void delete(Object item) {
        DoublyLN current = head;
        while (current!=null &&
                item!=current.data)
            current=current.next;
        if (current==null) return;
        if (current.prev==null)
            head=current.next;
        else
            current.prev.next=current.next;
        if (current.next!=null)
            current.next.prev=current.prev;
    }
}
```

Sentinels

- Avoid the special cases
- Use a sentinel - a dummy node with no data that eliminates the special case

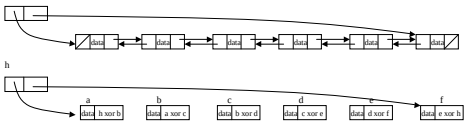


Linked List Code

```
class DLinkedList {
    private DoublyLN head;
    // Find same as SLinkedList
    public void insert(Object item) {
        DoublyLN nn =
            new DoublyLN();
        nn.data=item;
        nn.next=head.next;
        head.next.prev=nn;
        nn.prev=head;
        head.next=nn;
    }
```

```
    public void delete(Object item) {
        DoublyLN current = head.next;
        while (current!=head &&
                item!=current.data)
            current=current.next;
        if (current==head) return;
        current.prev.next=current.next;
        current.next.prev=current.prev;
    }
    DLinkedList() {
        head = new DoublyLN();
        head.next=head.prev=head;
    }
}
```

Doubly Linked Lists in One Field



h xor (h xor b) = b
a xor (a xor c) = c
b xor (b xor d) = d
d xor (b xor d) = b
c xor (a xor c) = a
a xor (a xor h) = h

Does not work in Java

Pointers as Arrays

- Old languages do not have dynamic memory
- O/S kernel might not either
- Implement your own dynamic memory with large array
  - Pointers are indices into array
  - Free list of available array entries

Trees

- Linked structure with more than one "next"
- If balanced then logarithmic
  - e.g. binary tree of depth *k* holds 2^k items
- Can have parent pointers like doubly linked lists
- Binary trees have 2 children
- *k*-ary trees have *k* children

Tree Code

```
class TreeNode {
    Object data;
    TreeNode left, right;
}
TreeNode find(TreeNode tree, Object key) {
    while (tree!=null)
        if (tree.data==key) return tree;
        else if (tree.data<key) tree=tree.right;
        else tree=tree.left;
    return null;
}
```

Variable Breadth Trees

- Nonfixed number of children
- If fixed at node creation time use array
- Otherwise use a Vector or a linked list

```
class TreeNode {
    Object data;
    TreeNode leftChild, rightSibling;
    TreeNode parent, leftSibling;          // For doubly linked
}
```

Trees with Linked Children