IE 495 Lecture 9

September 26, 2000

Reading for This Lecture

- Primary
  - Horowitz and Sahni, Chapter 2, Section 2

Basic Data Structures

What is a data structure?

- Data structures are schemes for organizing and storing sets.
- Data structures make it easy to perform certain set operations.
- Examples of set operations.
  - add
  - delete
  - find_min
  - delete_min
  - union

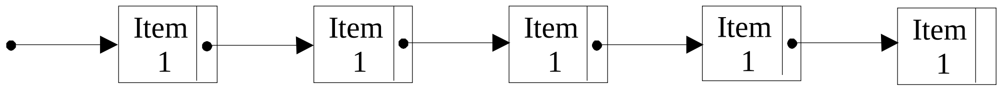
Choosing the right data structure

- Data structures consist of
  - a scheme for storing the set(s), and
  - algorithms for performing the desired operations
- Hence, each set operation has an associated complexity
- To choose a data structure, you should know
  - something about the elements of the set, and
  - what operations you will want to perform on the set.

Example: Lists

- A list is a finite sequence of elements drawn from a set
- List operations
  - *insert()*
  - *delete()*
  - *concatenate()*
  - *split()*
- List storage
  - array
  - linked list

Linked Lists



	NAME	NEXT
0	-	1
1	Item 1	3
2	Item 2	0
3	Item 3	4
4	Item 4	2
5	Empty	0

Linked List Operations

INSERT

	NAME	NEXT
0	-	1
1	Item 1	3
2	Item 2	0
3	Item 3	5
4	Item 4	2
5	New Item	4

DELETE

	NAME	NEXT
0	-	1
1	Item 1	5
2	Item 2	0
3	Empty	0
4	Item 4	2
5	Item 5	4

Linked List Analysis

- *make_list*$(a_1, a_2, \ldots, a_n)$
- *insert(a, i)*
- *delete(i)*
- *concatenate(ptr1, ptr2)*
- *split(ptr1, i)*

Data structures in algorithms

- Typically, data structures are part of a larger algorithm.
- In order to choose a data structure, you should also know something about the algorithm.
- The data structure should be efficient for the operations that will be performed most often.
- The same algorithm can have different running times using different data structures.

Arrays vs. Linked Lists

- Linked lists
  - Efficient to add, delete, concatenate, split.
  - Don't have to know the number of data items in advance.
- Arrays
  - Less storage space.
  - Fewer memory allocations.
  - More efficient to locate i^{th} data item.
- Can do hybrid schemes

Using lists

- Insertion sort
- Merge sort/quick sort
- Binary search
- Circular lists
- Doubly linked lists

Graph Data Structures

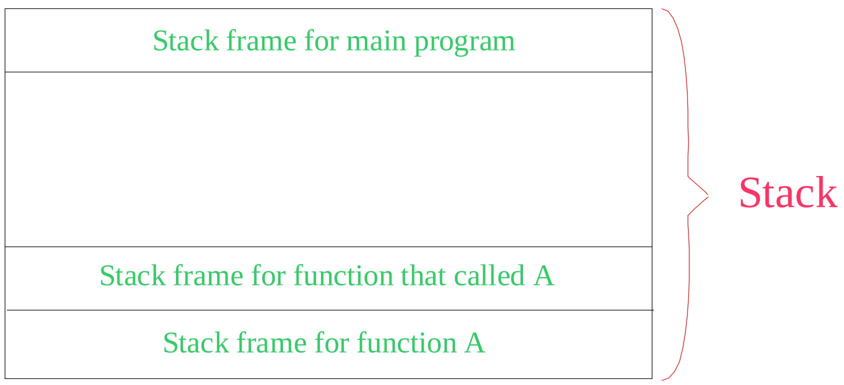
- Recall: Graph consists of
  - A set of *nodes* or *vertices* V.
  - A set of *edges* $E \subseteq V \times V$.
- Adjacency matrix
  - Efficient for determining whether a particular edge is present.
  - Requires $O(|V|^2)$ storage and initialization time.
- Adjacency lists
  - Usually the method of choice.
  - More efficient for sparse graphs.

Stacks

- A list data structure in which insertions and deletions are made at one end is called a *stack*.
- This is also known as a Last In First Out (LIFO) list.
- Insert and delete operations are often called *push* and *pop*.
- Stack Data Structures
  - Array
  - Linked list
- Stacks can be used to keep track of data in recursion (stack frames).

Stack Frames

- Local data for each function call is stored on the *stack.*
- Each function gets a *stack frame* to store data.
  - space for local variables.
  - pointers to the parameters the function was called with.
  - pointer to the instruction to return to in the calling function.
  - pointer to the localtion to store the return value.



Queues

- A queue is a list in which insertions take place at one end and deletions at the other.
- Also known as First In First Out (FIFO) lists.
- Queue data structures
  - Array
  - Circular array
  - Linked list

Priority Queues

- A queue where each item has a specified *priority*.
- Additional operations for priority queues
  - find_min()
  - delete_min()
- Applications
  - sorting
  - greedy algorithms
- We will discuss these in future lectures

Graph Terminology

- Given a directed graph $G = (V, E)$, we define
  - a *path* is a sequence of edges $(v_1, v_2), (v_2, v_3), \ldots, (v_{n-1}, v_n)$.
  - such a path is said to go *from vertex* 1 *to vertex* n.
  - A path is *simple* if no two edges on the path share a common endpoint, with the exception that we allow $v_1 = v_n$.
  - A simple path in which $v_1 = v_n$ is called a *cycle*.
  - A directed graph with no cycles is called a *directed acyclic graph*.
  - For vertex w, the number of edges (v, w) in G is called the *in-degree* of w.
  - Simlarly for *out-degree*.

Trees

- A (directed) tree is a directed acylic graph satisfying the following:
  - There is exactly one vertex called the root with in-degree 0.
  - Every other vertex has in-degree 1.
  - There is a path from the root node to every other node.
- Trees also have a natural recursive definition.
- Tree terminology
  - If $(u, v) \in E$, then u is called the *father / mother / parent* of v and v is called the *son / daughter* of u.
  - If there is a path from u to v, then v is a *descendant* of u and u is an *ancestor* of v.

More Tree Terminology

- A tree in which each node has out-degree 0, 1, or 2 is called a *binary tree*.
- A tree in which the sons are ordered is called an ordered tree.
- In an ordered binary tree, the two sons are usually called the *left son* and the *right son*.
- The *depth* or *level* of a vertex v is the length of the (unique) path from the root to v.
- The depth of a tree is the maximum depth of any node.

Trees and data structures

- Trees are an element of many different data structures.
- Trees are naturally associated with recursive and divide and conquer type algorithms.
- We have already seen how trees can help us partition the elements of a set.
- Tree storage
  - arrays
  - pointers

Traversing a Tree

- Many common algorithms involve traversing or searching a tree.
- Traversal schemes
  - preorder
  - postorder
  - depth-first
  - breadth-first