Searching & Sorting

Week 11

Gaddis: 8, 19.6,19.8

CS 5301
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Definitions of Search and Sort

- Search: find a given item in a list, return the position of the item, or -1 if not found.
- Sort: rearrange the items in a list into some order (smallest to biggest, alphabetical order, etc.).
- "list" could be: array, linked list, string, etc.
- There are various methods (algorithms) for carrying out these common tasks.

Linear Search
(week 6)

- Compare first element to target value, if not found then compare second element to target value . . .
- Repeat until: target value is found (return its position) or we run out of items (return -1).

```
int searchList (int list[], int size, int value) {

  for (int i=0; i<size; i++)
  {
    if (list[i] == value)
       return i;
  }
  return -1;
}
```


Other forms of Linear Search

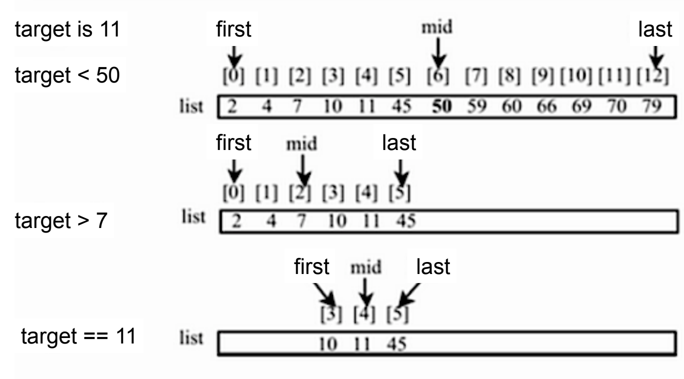
- Recursive linear search over arrays
  - Gaddis ch 19, Prog Challenge #8: isMember
- Linear search over linked list
  - Gaddis ch 17, Prog Challenge #5: List search
- Recursive linear search over linked list
  - Another good exercise

Binary Search

- Works only for SORTED arrays
- Divide and conquer style algorithm
- Compare target value to middle element in list.
  - if equal, then return its index
  - if less than middle element, repeat the search in the first half of list
  - if greater than middle element, repeat the search in last half of list
- If current search list is narrowed down to 0 elements, return -1

Binary Search Algorithm

example



Binary Search in C++

Iterative version

```
int binarySearch (int array[], int size, int target) {

  int first = 0,           //index to (current) first elem
      last = size – 1,     //index to (current) last elem
      middle,              //index of (current) middle elem
      position = -1;       //index of target value
  bool found = false;      //flag

  while (first <= last && !found) {

    middle = (first + last) /2;    //calculate midpoint

    if (array[middle] == target) {
       found = true;
       position = middle;
    } else if (target < array[middle]) {
       last = middle – 1;          //search lower half
    } else {
       first = middle + 1;         //search upper half
    }
  }
  return position;
}
```


Binary Search in C++

Recursive version

```
int binarySearchRec(int array[], int first, int last, int value)
{
    int middle; // Mid point of search

    if (first > last)           //check for empty list
        return -1;
    middle = (first + last)/2;  //compute middle index
    if (array[middle]==value)
        return middle;
    if (value < array[middle])    //recursion
        return binarySearchRec(array, first,middle-1, value);
    else
        return binarySearchRec(array, middle+1,last, value);
}

int binarySearch(int array[], int size, int value) {
    return binarySearchRec(array, 0, size-1, value);
}
```

What is sorting?

- Sort: rearrange the items in a list into ascending or descending order
  - numerical order
  - alphabetical order
  - etc.

55 112 78 14 20 179 42 67 190 7 101 1 122 170 8

1 7 8 14 20 42 55 67 78 101 112 122 170 179 190

Selection Sort

- There is a pass for each position (0..size-1)
- On each pass, the smallest (minimum) element in the rest of the list is exchanged (swapped) with element at the current position.
- The first part of the list (the part that is already processed) is always sorted
- Each pass increases the size of the sorted portion.

Selection sort

Example

- 36 24 10 6 12 pass 1: minimum is 6, swap
- 6 24 10 36 12 pass 2: minimum is 10, swap
- 6 10 24 36 12 pass 3: minimum is 12, swap
- 6 10 12 36 24 pass 4: minimum is 24, swap
- 6 10 12 24 36 sorted

Note: first n elements are sorted after pass n

Selection sort: code

```
// Returns the index of the smallest element, starting at start
int findIndexOfMin (int array[], int size, int start) {
   int minIndex = start;
   for (int i = start+1; i < size; i++) {
      if (array[i] < array[minIndex]) {
         minIndex = i;
      }
   }
   return minIndex;
}

// Sorts an array, using findIndexOfMin
void selectionSort (int array[], int size) {
   int minIndex;
   for (int index = 0; index < (size -1); index++) {
      minIndex = findIndexOfMin(array, size, index);
      swap(array[minIndex],array[index]);
   }
}
```

Bubble sort

- On each pass:
  - Compare first two elements. If the first is bigger, they exchange places (swap).
  - Compare second and third elements. If second is bigger, exchange them.
  - Repeat until last two elements of the list are compared.
- Repeat this process until a pass completes with no exchanges

Bubble sort

Example

- 7 2 3 8 9 1 7 > 2, swap
- 2 7 3 8 9 1 7 > 3, swap
- 2 3 7 8 9 1 !(7 > 8), no swap
- 2 3 7 8 9 1 !(8 > 9), no swap
- 2 3 7 8 9 1 9 > 1, swap
- 2 3 7 8 1 9 finished pass 1, did 3 swaps

Note: largest element is in last position

Bubble sort

Example

- 2 3 7 8 1 9 2<3<7<8, no swap, !(8<1), swap
- 2 3 7 1 8 9 (8<9) no swap
- finished pass 2, did one swap

2 largest elements in last 2 positions

- 2 3 7 1 8 9 2<3<7, no swap, !(7<1), swap
- 2 3 1 7 8 9 7<8<9, no swap
- finished pass 3, did one swap

3 largest elements in last 3 positions

Bubble sort

Example

- 2 3 1 7 8 9 2<3, !(3<1) swap, 3<7<8<9
- 2 1 3 7 8 9
- finished pass 4, did one swap
- 2 1 3 7 8 9 !(2<1) swap, 2<3<7<8<9
- 1 2 3 7 8 9
- finished pass 5, did one swap
- 1 2 3 7 8 9 1<2<3<7<8<9, no swaps
- finished pass 6, no swaps, list is sorted!

Bubble sort

how does it work?

- At the end of the first pass, the largest element is moved to the end (it's bigger than all its neighbors)
- At the end of the second pass, the second largest element is moved to just before the last element.
- The back end (tail) of the list remains sorted.
- Each pass increases the size of the sorted portion.
- No exchanges implies each element is smaller than its next neighbor (so the list is sorted).

Bubble sort: code

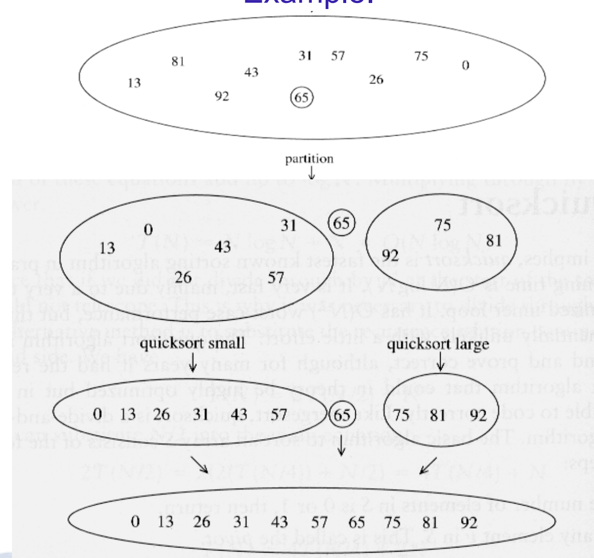
```
template<class ItemType>
void bubbleSort (ItemType a[], int size) {

    bool swapped;
    do {
        swapped = false;
        for (int i = 0; i < (size-1); i++) {
            if (a[i] > a[i+1]) {
                swap(a[i],a[i+1]);
                swapped = true;
            }
        }
    } while (swapped);
}
```


Quick sort

- Divide and conquer!
- 2 (hopefully) half-sized lists sorted recursively
- the algorithm:
  - If list size is 0 or 1, return. otherwise:
  - partition into two lists:
    - pick one element as the pivot
    - put all elements less than pivot in first half
    - put all elements greater than pivot in second half
  - recursively sort first half and then second half of list.

Quicksort

Example.



Quicksort: partitioning

- Goal: partition a sub-array so that:
  - A[x]<=A[p] for x<p and A[x]>=A[p] for x>p
- 4 8 5 6 3 19 12 pick middle as pivot, swap to front
- compare each elem to pivot, if elem<6, increment pivotIndex, swap
- 6 8 5 4 3 19 12 8>6, continue
- 6 8 5 4 3 19 12 5<6, pivotIndex++ and swap
- 6 5 8 4 3 19 12 4<6, pivotIndex++ and swap
- 6 5 4 8 3 19 12 3<6, pivotIndex++ and swap
- 6 5 4 3 8 19 12 19 and 12 not less than 6, don't swap
- After the scan, swap A[start] with A[pivotIndex], return pivotIndex
- 3 5 4 6 8 19 12 return 3 as index of pivot (6)

Quicksort: code

```
void quickSort(int set[], int start, int end) {

  if (start < end)
   {
      // Get the pivot point (and partition the set).
      int pivotPoint = partition(set, start, end);
      // Sort the first sub list.
      quickSort(set, start, pivotPoint - 1);
      // Sort the second sub list.
      quickSort(set, pivotPoint + 1, end);
   }
}

void quickSort (int set[], int size) {
    quickSort(set, 0, size-1);
}
```


Quicksort: code

```
int partition(int set[], int start, int end)
{
   int mid = (start + end) / 2;  // locate the pivot value
   swap(set[start], set[mid]);
   int pivotIndex = start;
   int pivotValue = set[start];
   for (int scan = start + 1; scan <= end; scan++)
   {  // finds values less than pivotValue and
      // moves them to the (left of the) pivotIndex
      if (set[scan] < pivotValue)
      {
         pivotIndex++;
         swap(set[pivotIndex], set[scan]);
      }
   }
   swap(set[start], set[pivotIndex]); //put pivot back in place
   return pivotIndex;
}
```


Sample Problem

Sorting Benchmarks: Write a program that uses three identical arrays of at least 20 integers. It should call a different function to sort each array in ascending order, one that uses the **bubble** sort algorithm, one that uses the **selection** sort algorithm, and one that uses the **quicksort** algorithm. Each function should keep a count of the number of exchanges (swaps) it makes. Display these values on the screen.