Searching & Sorting

Week 11

Gaddis: 8, 19.6,19.8 (8th ed)
Gaddis: 8, 20.6,20.8 (9th ed)

CS 5301
Fall 2018

Jill Seaman

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

- 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

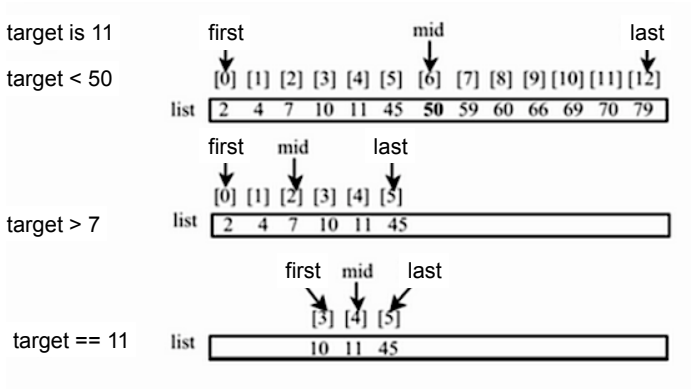
- Recursive linear search over arrays
  - Gaddis ch 19/20, Prog Challenge #8: isMember
- Linear search over linked list
  - Gaddis ch 17/18, Prog Challenge #5: List search
- Recursive linear search over linked list
  - Another good exercise

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

- 7 2 3 8 9 1 — 1 is the min a[5], swap with a[0]
- 1 2 3 8 9 7 — 2 is the min a[1], self-swap a[1]
- 1 2 3 8 9 7 — 3 is the min a[2], self-swap a[2]
- 1 2 3 8 9 7 — 7 is the min a[5], swap with a[3]
- 1 2 3 7 9 8 — 8 is the min a[5], swap with a[4]
- 1 2 3 7 8 9 — sorted

Note: underlined portion of list is sorted.

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]);
   }
}
```

Note: saving the **index**

We need to find the **index** of the minimum value so that we can do the swap

Selection Sort in C++
compact version

```
void selectionSort(int array[], int size)
{
   for(int i=0; i<size; i++)
   {
      for(j=i+1; j<size; j++)
      {
         if(array[i]>array[j])
         {
            temp=array[i];
            array[i]=array[j];
            array[j]=temp;
         }
      }
   }
}
```

For each element, it scans the remainder of the array

If the next element is smaller than the element at the current position (i), then **swap** them

This finds the smallest element in the remainder of the list, and it ends up in position (i)

This version might do more swapping than the previous one

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

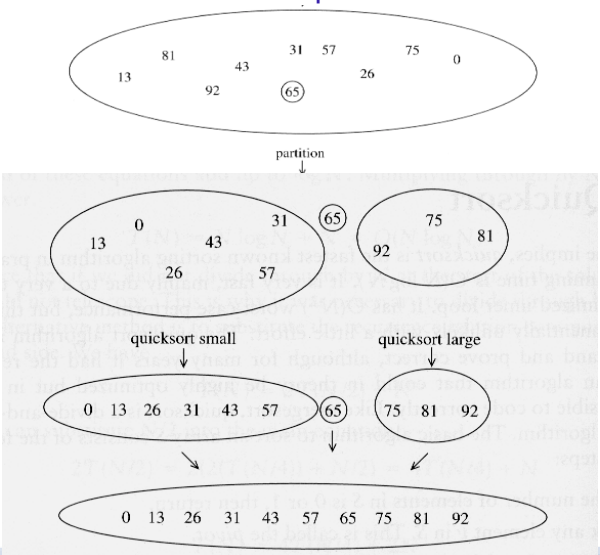
```
template<class ItemType>
void bubbleSort (ItemType a[], int size) {

    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 all x<p and A[x]>=A[p] for all x>p
- 4 8 5 6 3 19 12 pick some element as the pivot
- rearrange the array so that if the value is less than 6 it is placed before the 6, if the value is greater than the 6 it is placed after the 6.
- **For an array**, this might require some swapping and shifting. (See Gaddis text).
- 4 3 5 6 8 19 12 return 3 as **index** of pivot (6)

Quicksort: code

```
int partition (int [], int, int);  //defined in Gaddis

void quickSort(int array[], int start, int end) {
  if (start < end) {
      // Get the pivot point (and partition the set).
      int pivotPoint = partition(array, start, end);
      // Sort the first sub list.
      quickSort(array, start, pivotPoint - 1);
      // Sort the second sub list.
      quickSort(array, pivotPoint + 1, end);
   }
}
void quickSort (int array[], int size) {
    quickSort(array, 0, size-1);
}
```


Quicksort Example