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).

```c
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

target is 11
first
mid
last

<table>
<thead>
<tr>
<th>target &lt; 50</th>
</tr>
</thead>
<tbody>
<tr>
<td>list: [0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12]</td>
</tr>
<tr>
<td>first: 0</td>
</tr>
<tr>
<td>mid: 6</td>
</tr>
<tr>
<td>last: 11</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>target &gt; 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>list: [2, 4, 7, 10, 11, 14, 58, 69, 70, 79]</td>
</tr>
<tr>
<td>first: 0</td>
</tr>
<tr>
<td>mid: 6</td>
</tr>
<tr>
<td>last: 11</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>target == 11</th>
</tr>
</thead>
<tbody>
<tr>
<td>list: [10, 11, 14]</td>
</tr>
<tr>
<td>first: 1</td>
</tr>
<tr>
<td>mid: 2</td>
</tr>
<tr>
<td>last: 3</td>
</tr>
</tbody>
</table>

Binary Search in C++

Iterative version

```cpp
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;
}
```

Recursive version

```cpp
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

```c
// 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

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 9 1
  - finished pass 1, did 3 swaps

Note: largest element is in last position

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 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

2 largest elements in last 2 positions

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**

```cpp
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.**

The diagram shows the partitioning process of quicksort, with an initial list of numbers and the recursive calls to sort the smaller and larger parts of the list.
Quicksort: partitioning

- **Goal:** partition a sub-array so that:
  - \( A[x] \leq A[p] \) for \( x < p \) and \( A[x] \geq A[p] \) for \( x > p \)
- 4 8 5 6 3 19 12  pick middle as pivot, swap to front, pivotIndex = 0
- 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

```c
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);
}
```

```c
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;
}
```