Topic 14
Searching and Simple Sorts

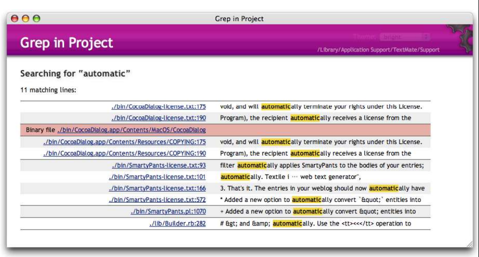
"There's nothing in your head the sorting hat can't see. So try me on and I will tell you where you ought to be."

-The Sorting Hat, *Harry Potter and the Sorcerer's Stone*

Sorting and Searching

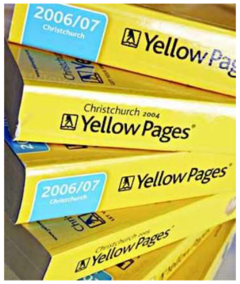
- Fundamental problems in computer science and programming
- Sorting done to make searching easier
- Multiple different algorithms to solve the same problem
  - How do we know which algorithm is "better"?
- Look at searching first
- Examples use arrays of ints to illustrate algorithms

Searching



Searching

- Given an array or list of data find the location of a particular value or report that value is not present
- linear search
  - intuitive approach?
  - start at first item
  - is it the one I am looking for?
  - if not go to next item
  - repeat until found or all items checked
- If items not sorted or unsortable this approach is necessary



Linear Search

```
/*    pre: data != null
      post: return the index of the first occurrence
      of target in data or -1 if target not present in
      data
*/
public int linearSearch(int[] data, int target) {
    for (int i = 0; i < data.length; i++) {
        if (data[i] == target) {
            return i;
        }
    }
    return -1;
}
```


Linear Search, Generic

```
/*    pre: data != null, no elements of data == null
          target != null
      post: return the index of the first occurrence
      of target in data or -1 if target not present in
      data
*/
public int linearSearch(Object[] data, Object target) {
    for (int i = 0; i < data.length; i++)
        if (target.equals(data[i]))
            return i;
    return -1;
}
```

T(N)? Big O? Best case, worst case, average case?

Clicker 1

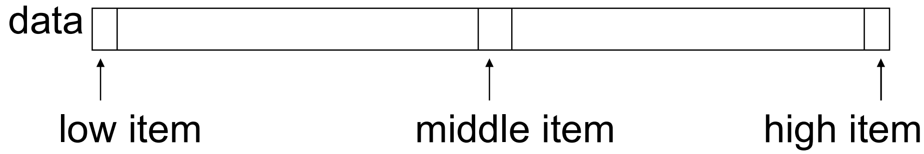
- What is the average case Big O of linear search in an array with N items, if an item is present once?

A. O(1)
B. O(logN)
C. O(N)
D. O(NlogN)
E. $O(N^2)$

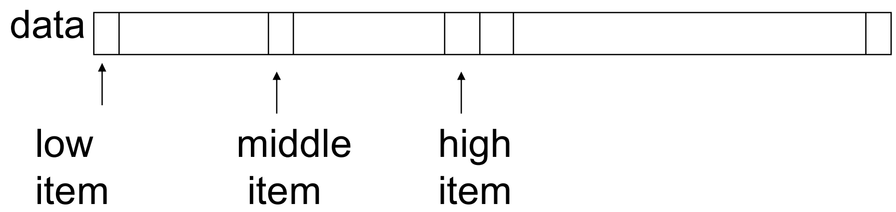
Searching in a Sorted Array or List

- If items are sorted then we can *divide and conquer*
- dividing your work in half with each step
  – generally a good thing
- The Binary Search with array in ascending order
  – Start at middle of list
  – is that the item?
  – If not is it less than or greater than the item?
  – less than, move to second half of list
  – greater than, move to first half of list
  – repeat until found or sub list size = 0

Binary Search



Is middle item what we are looking for? If not is it more or less than the target item? (Assume lower)



and so forth…

Binary Search in Action

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2	3	5	7	11	13	17	19	23	29	31	37	41	43	47	53

```
public static int bsearch(int[] data, int target) {
        int indexOfTarget = -1;
        int low = 0;
        int high = data.length - 1;
        while(indexOfTarget == -1 && low <= high ) {
                int mid = low + ((high - low) / 2);
                if( data[mid] == target )
                        indexOfTarget = mid;
                else if( data[mid] < target)
                        low = mid + 1;
                else.
                        high = mid - 1;
        }
        return indexOfTarget;
}
// mid = (low + high) / 2; // may overflow!!!
// or mid = (low + high) >>> 1; using bitwise op
```


Trace When Key == 3
Trace When Key == 30

Variables of Interest?

Clicker 2

What is the worst case Big O of binary search in an array with N items, if an item is present?

A. O(1)
B. O(logN)
C. O(N)
D. O(NlogN)
E. O(N^2)

Generic Binary Search

```
public static <T extends Comparable<? super T>> int
            bsearch(T[] data, T target) {

      int result = -1;
      int low = 0;
      int high = data.length - 1;
      while( result == -1 && low <= high ) {
            int mid = low + ((high - low) / 2);
            int compareResult = target.compareTo(data[mid]);
            if(compareResult == 0)
                  result = mid;
            else if(compareResult > 0)
                  low = mid + 1;
            else
                  high = mid - 1; // compareResult < 0
      }
      return result;
}
```


Recursive Binary Search

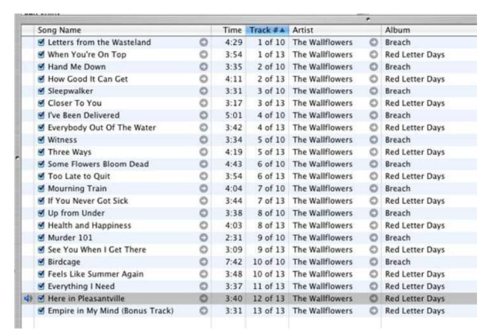
```
public static int bsearch(int[] data, int target) {
    return bsearch(data, target, 0, data.length - 1);
}

public static int bsearch(int[] data, int target,
                              int low, int high) {
    if(low <= high){
        int mid = low + ((high - low) / 2);
        if( data[mid] == target )
            return mid;
        else if(data[mid] > target)
            return bsearch(data, target, low, mid - 1);
        else
            return bsearch(data, target, mid + 1, high);
    }
    return -1;
}
// Clicker 3 Is this a recursive backtracking algorithm?
A. NO
B. YES
```


Other Searching Algorithms

- Interpolation Search
  - more like what people really do
- Indexed Searching
- Binary Search Trees
- Hash Table Searching
- best-first
- A*

Sorting



Sorting

- A fundamental application for computation
- Done to make finding data (searching) faster
- Many different algorithms for sorting
- One of the difficulties with sorting is working with a fixed size storage container (array)
  - if resize, that is expensive (slow)
- The simple sorts are slow
  - bubble sort
  - selection sort
  - insertion sort

Selection sort

- Algorithm
  - Search through the data and find the smallest element
  - swap the smallest element with the first element
  - repeat starting at second element and find the second smallest element

```
public static void selectionSort(int[] data) {

        for (int i = 0; i < data.length - 1; i++) {
                int min = i;
                for (int j = i + 1; j < data.length; j++)
                        if (data[j] < data[min])
                                min = j;
                int temp = data[i];
                data[i] = data[min];
                data[min] = temp;
        }
}
```


Insertion Sort in Practice

44 68 191 119 119 37 83 82

What is the T(N), *actual* number of statements executed, of the selection sort code, given an array of N elements?
What is the Big O?

Generic Selection Sort

```
public static <T extends Comparable<? super T>>
      void selectionSort(T[] data) {


    for(int i = 0; i < data.length - 1; i++) {
      int min = i;
      for(int j = i + 1; j < data.length; j++)
         if( data[min].compareTo(data[j]) > 0 )
            min = j;
      T temp = data[i];
      data[i] = data[min];
      data[min] = temp;
    }
}
```

Insertion Sort

- Another of the O(N^2) sorts
- The first item is sorted
- Compare the second item to the first
  - if smaller swap
- Third item, compare to item next to it
  - need to swap
  - after swap compare again
- And so forth…

Insertion Sort Code

```
public void insertionSort(int[] data) {
     for (int i = 1; i < data.length; i++) {
          int temp = data[i];
          int j = i;
          while (j > 0 && temp < data[j - 1]) {
               // swap elements
               data[j] = data[j - 1];
               data[j - 1] = temp;
               j--;
          }
     }
}
```

- Best case, worst case, average case Big O?

Clicker 4 - Comparing Algorithms

- Which algorithm do you think has a smaller T(N) given random data, selection sort or insertion sort?

A. Insertion Sort

B. Selection Sort

C. About the same