Topic 14
Searching and Simple Sorts

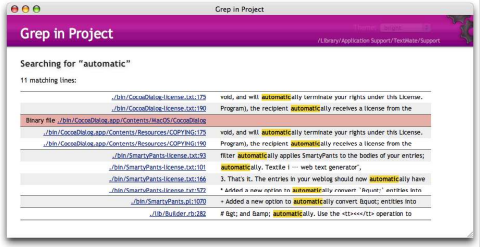
"There's nothing in your head the sorting hat can't see. So try me on and I will tell you where you ought to be."

-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)

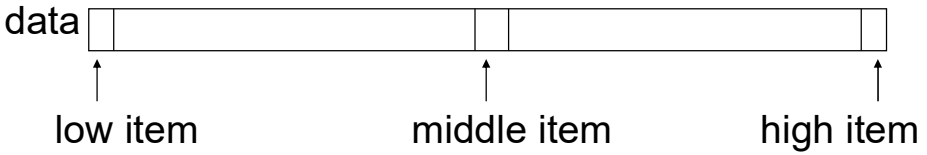
D. O(NlogN)

E. $O(N^2)$

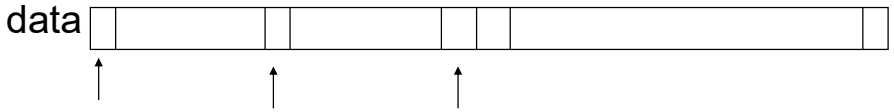
Searching in a Sorted Array or List

- 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)



low item

middle item

high item

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 82 191 45 158 130 76 153 39 25

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