

11. Searching and Sorting (Ch10)

- Objectives - when we have completed this set of notes, you should be familiar with:
 - Linear Search
 - Binary Search
 - Selection Sort
 - Insertion Sort



Searching

- Finding a specific element in a group of items (*search pool*)
 - A student with a certain name in an array of Student objects
 - A bank account with a certain account number in an online database
- Considerations:
 - What if the target is not present? (i.e., will not be found)
 - Which search will be the most efficient?
- If a class implements the Comparable interface, then two objects can be compared using the compareTo method (also implementing the Comparable interface means Collections.sort or Arrays.sort will work on the list or array)



Linear Search

- You have used linear searches in your COMP 1210 projects
- Examines each element in a group starting with the first element
- Elements do not have to be in a specific order
 - Must consider how you will find the specific item
- Search ends when...
 - The element is found
 - The end of the list is reached
- [NumberLinearSearch.java](#)



Linear Search

- Easy to implement
- The search pool does not have to be sorted
- Why not always use linear search?
- If the target is not present, you must go to the end of the search pool
 - Not good if the size of the search pool is large
- What if your target is near the end of the list?
 - Each comparison takes a certain amount of time, which can add up to minutes, days, weeks, or longer on a large database



Binary Search

- An efficient alternative to linear search in some cases
- The search pool **must be sorted**
- Starts at the middle of the candidate pool and then eliminates one half of the pool each time
- For 2^n items, at most n compares are required
 - $16 = 2^4$ so at most 4 compares
 - 4 billion is approx $= 2^{32}$ so at most 32 compares



Binary Search

- Suppose that you are searching for the number 59 in the following array...

2	4	9	23	27	29	30	34	45	59	67	76	89	92	97
---	---	---	----	----	----	----	----	----	----	----	----	----	----	----

- Binary search starts at the middle.

2	4	9	23	27	29	30	34	45	59	67	76	89	92	97
---	---	---	----	----	----	----	----	----	----	----	----	----	----	----

↓

- $59 > 34$, so the entire left side can be eliminated (cuts the candidate pool in half)

2	4	9	23	27	29	30	34	45	59	67	76	89	92	97
---	---	---	----	----	----	----	----	----	----	----	----	----	----	----



Binary Search

- Start again with the second half

2	4	9	23	27	29	30	34	45	59	67	76	89	92	97
---	---	---	----	----	----	----	----	----	----	----	----	----	----	----


- $59 < 76$, so the right half of the new candidate pool can be eliminated

2	4	9	23	27	29	30	34	45	59	67	76	89	92	97
---	---	---	----	----	----	----	----	----	----	----	----	----	----	----



- 59 is the middle of the new candidate pool and is returned

2	4	9	23	27	29	30	34	45	59	67	76	89	92	97
---	---	---	----	----	----	----	----	----	----	----	----	----	----	----



Binary Search

- Binary search would have taken 3 comparisons to find the element

2	4	9	23	27	29	30	34	45	59	67	76	89	92	97
---	---	---	----	----	----	----	----	----	----	----	----	----	----	----

- Linear search would have taken 10

2	4	9	23	27	29	30	34	45	59	67	76	89	92	97
---	---	---	----	----	----	----	----	----	----	----	----	----	----	----

- Imagine if there were 4,000,000,000 elements in the search pool ... at most 32 compares
- [NumberBinarySearchArray.java](#)



Binary Search

- Why not always use binary search?
- Recall that it requires a sorted candidate pool
- Great if objects are pre-sorted, but sorting can also take a large number of comparisons
- You'll learn about many sorting algorithms later in the CSSE program
- Next, let's take a look at the details of sorting



Sorting

- Sorting is the process of placing items in order based on one or more sort keys.
- When you invoke `Collections.sort` or `Arrays.sort`, the code has been written for you, but it will still take time to perform the sort
- How are elements sorted?
- Which sort is "better" given certain conditions?
- Let's look at two sorting algorithms:
 - Selection Sort
 - Insertion Sort



Selection Sort

- The approach of Selection Sort:
 - select a value and put it in its final place into the list
 - repeat for all other values
- In more detail:
 - find the smallest value in the list
 - switch it with the value in the first position
 - find the next smallest value in the list
 - switch it with the value in the second position
 - repeat until all values are in their proper places



Selection Sort

- An example:  Indicates that the two elements should be swapped

```

original:      3  9  6  1  2
smallest is 1: 1  9  6  3  2
smallest is 2: 1  2  6  3  9
smallest is 3: 1  2  3  6  9
smallest is 6: 1  2  3  6  9
  
```

- Each time, the smallest remaining value is found and exchanged with the element in the "next" position to be filled



Swapping

- The processing of the selection sort algorithm includes the *swapping* of two values
- Swapping requires three assignment statements and a temporary storage location:

```
temp = first;  
first = second;  
second = temp;
```

- See [NumberSelectionSort.java](#) [Sorting.java](#)
- See [NumberSelectionSortExample.java](#)



Insertion Sort

- The approach of Insertion Sort:
 - pick any item and insert it into its proper place in a sorted sublist
 - repeat until all items have been inserted
- In more detail:
 - consider the first item to be a sorted sublist (of one item)
 - insert the second item into the sorted sublist, shifting the first item as needed to make room to insert the new addition
 - insert the third item into the sorted sublist (of two items), shifting items as necessary
 - repeat until all values are inserted into their proper positions



Insertion Sort

- An example:

← Indicates where the next element should be inserted

original:	<div style="border: 1px solid black; padding: 2px;">3</div>	9	6	1	2
insert 9:	<div style="border: 1px solid black; padding: 2px;">3</div>	← 9	6	1	2
insert 6:	← 6	<div style="border: 1px solid black; padding: 2px;">9</div>	1	2	
insert 1:	<div style="border: 1px solid black; padding: 2px;">1</div>	← 3	<div style="border: 1px solid black; padding: 2px;">6</div>	<div style="border: 1px solid black; padding: 2px;">9</div>	2
insert 2:	1	2	3	6	9

- See [NumberInsertionSort.java](#) [Sorting.java](#)



Comparing Sorts

- The Selection and Insertion sort algorithms are similar in efficiency
- They both have outer loops that scan all elements, and inner loops that compare the value at the outer loop index with almost all values in the list
- Approximately n^2 number of comparisons are made to sort a list of size n -> *order n^2*
- Other sorts can be more efficient:
order $n \log_2 n$

