Data Structure and Algorithms

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Array Operations

- Insertion
  - Operation of adding another element to an array
  - How many steps in terms of n (number of elements in array)?
    - At the end
    - In the middle
    - In the beginning
  - n steps at maximum (move items to insert at given location)
- Deletion
  - Operation of removing one of the elements from an array
  - How many steps in terms of n (number of elements in array)?
    - At the end
    - In the middle
    - In the beginning
  - n steps at maximum (move items back to take place of deleted item)

Array Operations: Search Algorithms

- Operation of locating a specific data item in an array
  - Successful: If location of the searched data is found
  - Unsuccessful: Otherwise

- Complexity (or efficiency) of a search algorithm
  - Number of comparisons f(n) required to locate data within array
  - n is the number of elements within array

- Two algorithms for searching in arrays
  - Linear search (or sequential search)
  - Binary search

Linear Search

- Very intuitive and simple algorithm

- **Algorithm works as follows:**

  - Starts from the first element of the array

  - Uses a loop to sequentially step through an array

  - Compares each element with the data item being searched

  - Stops when data item is found or end of array is reached

Linear Search Algorithm

```
// numElems – maximum number of elements in the array
// value– integer data (item) to be searched
// position– array subscript that holds value (if success)
//                    -1 if value not found

int searchList(int list[], int numElems, int value) {
                    int index = 0;
                    int position = -1;
                    bool found = false;

                    while (index < numElelments && !found) {
                                        if (list[index] == value) {
                                                            found = true;
                                                            position = index;  }
                                        index++;  }
                    return position; }
```

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Calling Function searchList

```
#include <iostream.h>
// Function prototype

int searchList(int [], int, int);

const int arrSize = 5;
void main(void)
{
        int tests[arrSize] = {87, 75, 98, 100, 82};
        int result;
        result = searchList(tests, arrSize, 100);
        if (result == -1)
                cout << "You did not earn 100 points on any test\n";
        else{
                cout <<"You earned 100 points on test ";
                cout<<(result + 1) << endl; } }
```

Program Output:

You earned 100 points on test 4.

Discussion

- Advantage of linear search is its simplicity
  - Easy to understand
  - Easy to implement
  - Does not require array to be in order (i.e., sorted)

- Disadvantage is its efficiency (or complexity)
  - Worst case complexity: $f(n) = n+1$
  - Number of steps are proportional to number n of elements in an array

- If there are 20,000 items in an array
  - Searched data item is stored in the 19,999th element
  - Entire array has to be searched

Binary Search

- Binary search is more efficient than linear search
  - Requires array to be in sorted order (i.e., ascending order)

Algorithm works as follows:

- Starts searching from the middle element of an array

- If value of data item is less than the value of middle element
  - Algorithm starts over searching the first half of the array

- If value of data item is greater than the value of middle element
  - Algorithm starts over searching the second half of the array

- Algorithm continues halving the array until data item is found

Binary Search Example

	[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
list	4	8	19	25	34	39	45	48	66	75	89	95

Sorted list for binary search

key = 89

Iteration	first	last	mid	list[mid]
1	0	11	5	39
2	6	11	8	66
3	9	11	10	89 ⇐ Value is found

key = 34

Iteration	first	last	mid	list[mid]
1	0	11	5	39
2	0	4	2	19
3	3	4	3	25
4	4	4	4	34 ⇐ Value is found

Binary Search Algorithm

```
// numElems – maximum number of elements in the array

// value – integer data (item) to be searched

// position – array subscript that holds value (if success)

//                          -1 if value not found
int binarySearch(int array[], int numelems, int value) {
    int first = 0, last = numelems - 1, middle, position = -1;
    bool found = false;
    while (!found && first <= last){
            middle = (first + last) / 2;
            if (array[middle] == value) {
                    found = true;
                    position = middle; }
            else if (array[middle] > value)
                    last = middle - 1;
            else
                    first = middle + 1; }
    return position; }
```

Calling Function binarySearch

```
#include <iostream.h>
// Function prototype

int binarySearch(int [], int, int);

const int arrSize = 20;


void main(void)
{
	int empIDs[arrSize] = {101, 142, 147, 189, 199, 207, 222, 234, 289, 296, 310, 319, 388, 394, 417, 429, 447, 521, 536, 600};
	int result, empID;
	cout << "Enter the Employee ID you wish to search for: ";
	cin >> empID;
	result = binarySearch(empIDs, arrSize, empID);
	if (result == -1)
		cout << "That number does not exist in the array.\n";
	else {
		cout << "That ID is found at element " << result;
		cout << " in the array\n";
	}
}
```

Program Output:

Enter the Employee ID you wish to search for: 199

That ID is found at element 4 in the array

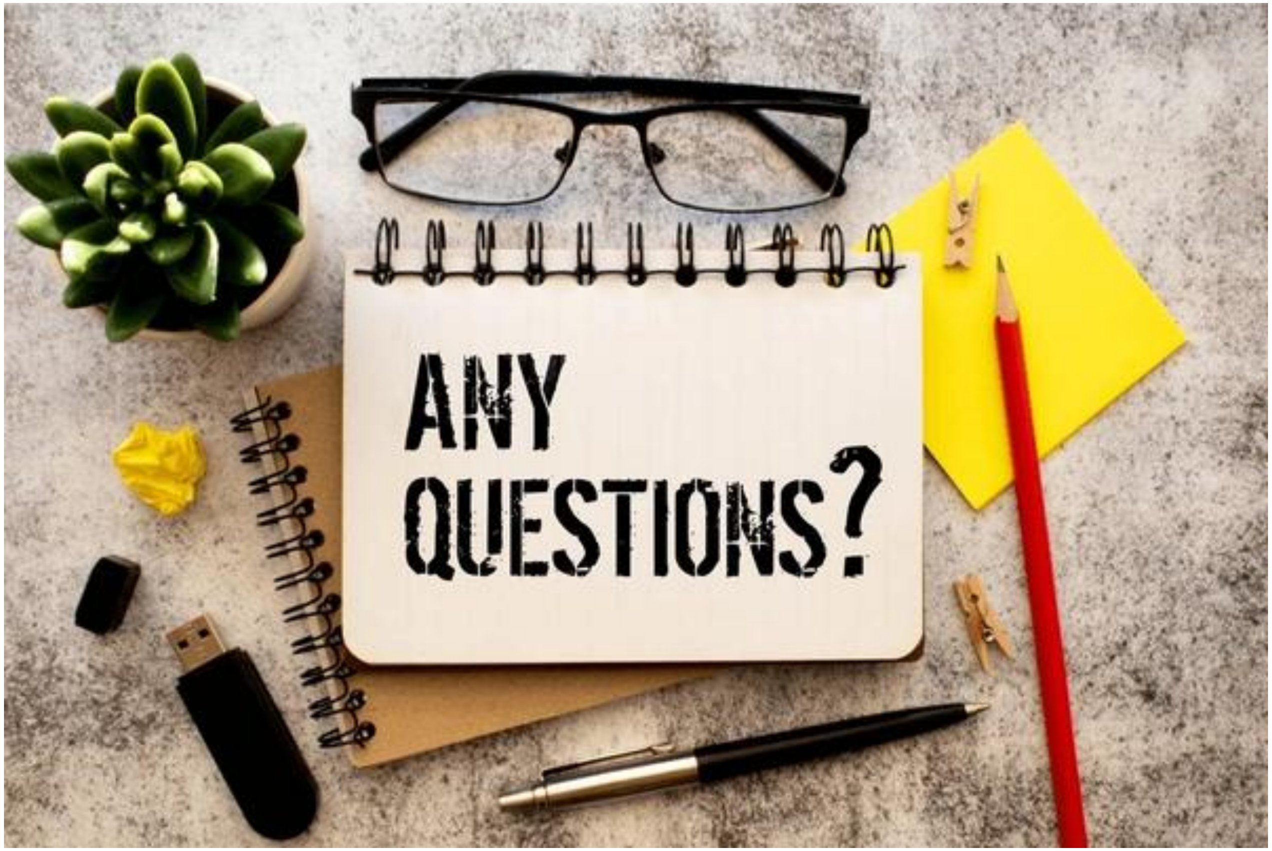
Efficiency Of Binary Search

- Much more efficient than the linear search

- How long does this take (worst case)?
  - If the list has 8 elements
    - It takes 3 steps ($2^3 = 8$)
  - If the list has 16 elements
    - It takes 4 steps ($2^4 = 16$)
  - If the list has 64 elements
    - It takes 6 steps ($2^6 = 64$)

- Worst case complexity: $f(n) = \log_2(n)$
  - Takes $\log_2$ nsteps

Any Question So Far?



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