#### **Data Structures**

#### **5. Array Searching**

#### **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;  // Used as a subscript to search array
  int position = -1; // To record position of search value
 bool found = false; // Flag to indicate if the value was found
 while (index < numElelments && !found)</pre>
  {
        if (list[index] == value) {
           found = true;
           position = index;
        index++;
   return position;
```

### Calling Function searchList

```
#include <iostream.h>
                                              Program Output:
// Function prototype
                                             You earned 100 points on test 4.
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";</pre>
    else{
        cout << "You earned 100 points on test ";</pre>
        cout << (result + 1) << endl;</pre>
```

#### 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 19,999<sup>th</sup> 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

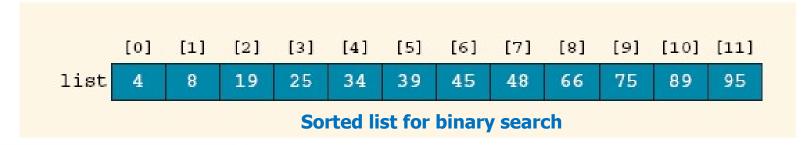
### Binary Search Algorithm

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

    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){</pre>
     middle = (first + last) / 2;  // Calculate mid point
     if (array[middle] == value) {      // If value is found at mid
        found = true;
        position = middle;
     last = middle - 1;
     else
        first = middle + 1;  // If value is in upper half
  return position;
}
```

### Binary Search Example



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	

кеу =	34			
Iteration	first	last	mid	list
1	0	11	5	39

4 4 4 34 Value is found

[mid]

## Calling Function binarySearch

```
#include <iostream.h>
                                 Program Output:
// Function prototype
                                 Enter the Employee ID you wish to search for: 199
int binarySearch(int [], int,
                                 That ID is found at element 4 in the array
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: ";</pre>
    cin >> empID;
    result = binarySearch(empIDs, arrSize, empID);
    if (result == -1)
        cout << "That number does not exist in the array.\n";</pre>
    else {
        cout << "That ID is found at element " << result;</pre>
        cout << " in the array\n";</pre>
}
```

## Efficiency Of Binary Search

- Much more efficient than the linear search
- How long does this take (worst case)?
  - If the list has 8 elements
    - $\triangleright$  It takes 3 steps (2<sup>3</sup> = 8)
  - If the list has 16 elements
    - $\triangleright$  It takes 4 steps (2<sup>4</sup> = 16)
  - If the list has 64 elements
    - $\triangleright$  It takes 6 steps (2<sup>6</sup> = 64)
- Worst case complexity: f(n) = log<sub>2</sub>(n)
  - Takes log<sub>2</sub> n steps

# Any Question So Far?

