Faculty of Computing & Information Technology

Computer Science Department

CPCS 223 Project

Empirical Analysis Between Binary Search & Interpolation Search

Analysis and Design of Algorithms

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Algorithms' Pseudocode:

Binary Search Pseudocode:

```
ALGORITHM BinarySearch(A[0..n − 1], K)
//Implements nonrecursive binary search
//Input: An array A[0..n − 1] sorted in ascending order and
// a search key K
//Output: An index of the array's element that is equal to K
// or −1 if there is no such element
L ← 0; r ← n − 1
while l ≤ r do
      m ← $\lfloor (l + r)/2 \rfloor$
      if K = A[m] return m
      else if K < A[m] r ← m − 1
      else l ← m + 1
return −1
```

Interpolation Search Pseudocode:

```
ALGORITHM InterpolationSearch(A[0..n − 1], v)
//Implements nonrecursive Interpolation Search
//Input: An array A[0..n − 1] sorted in ascending order and
// a search value v
//Output: An index of the array's element that is equal to v
// or −1 if there is no such element
L ← 0; r ← n − 1
while l ≤ r and v ≥ A[l] and v ≤ A[r]do
      x ← $l + \lfloor (v - A[l])(r - l)/(A[r] - A[l]) \rfloor$
      if v = A[x] return x
      else if v < A[x] r ← x − 1
      else l ← x + 1
 return −1
```

Study Design:

Inputs:

- Random **key value** generated in range 0-2000.
- Array with size {0,100000,200000,300000,400000,500000}, and random elements' value generated in range 0-1000.

Procedures:

By using the previews inputs in our source code (JAVA code is in the **appendix**) and run in **NetBeans IDE**, the output of the program is the following:

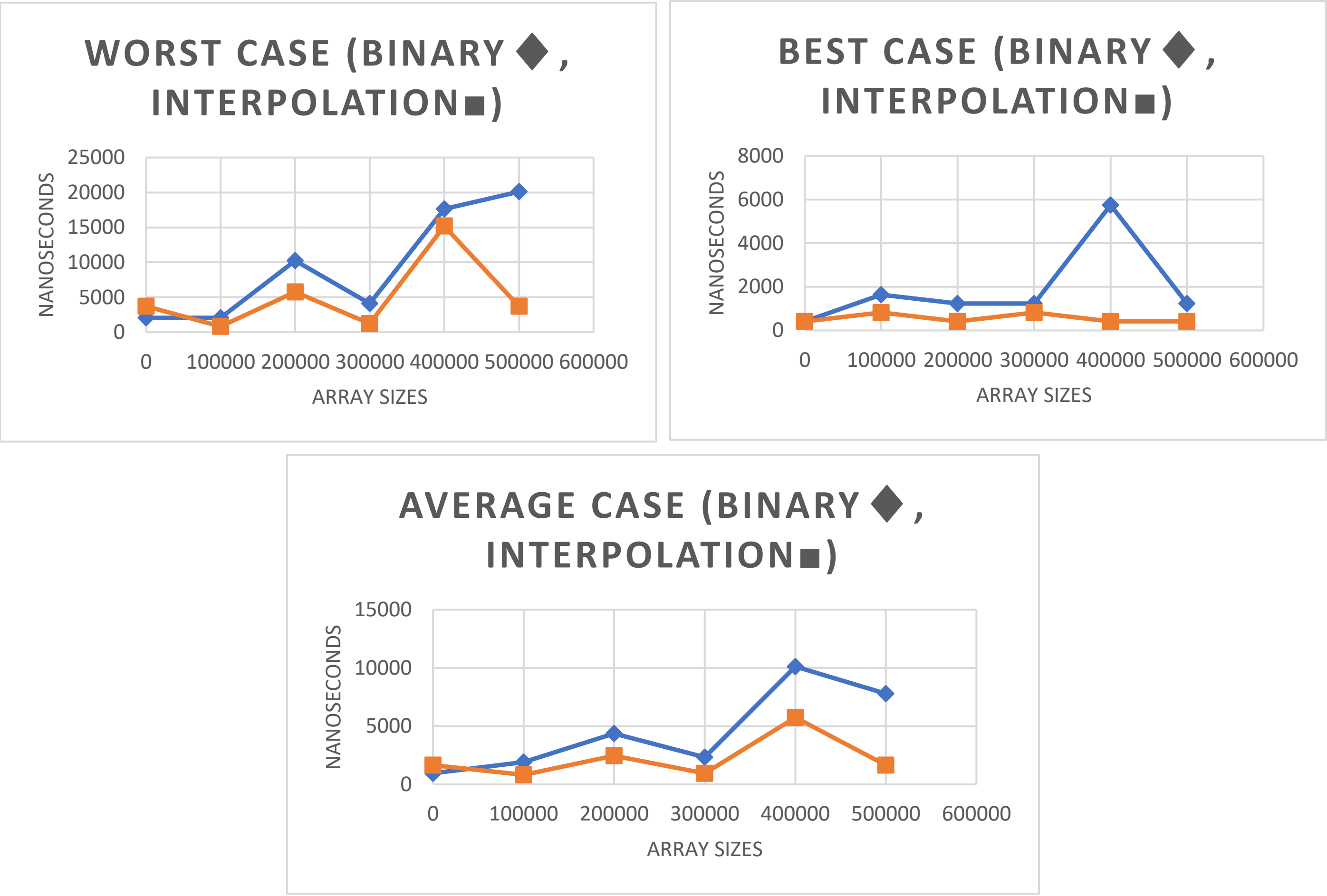
```
For n = 0:
  Binary Search       |   Interpolation Search
  Total Time:   2051  |   Total Time:   3692 (Trial: 1)
  Total Time:    410  |   Total Time:    820 (Trial: 2)
  Total Time:    411  |   Total Time:    410 (Trial: 3)
  ----------------- Cases ------------------
   Best case:    410  |    Best case:    410
   Worst case:  2051  |    Worst case:  3692
   AVG case:     957  |    AVG case:    1641

For n = 100000:
  Binary Search       |   Interpolation Search
  Total Time:   2052  |   Total Time:    820 (Trial: 1)
  Total Time:   1641  |   Total Time:    820 (Trial: 2)
  Total Time:   2051  |   Total Time:    821 (Trial: 3)
  ----------------- Cases ------------------
   Best case:   1641  |    Best case:    820
   Worst case:  2052  |    Worst case:   821
   AVG case:    1915  |    AVG case:     820

For n = 200000:
  Binary Search       |   Interpolation Search
  Total Time:  10257  |   Total Time:   5743 (Trial: 1)
  Total Time:   1231  |   Total Time:    410 (Trial: 2)
  Total Time:   1641  |   Total Time:   1231 (Trial: 3)
  ----------------- Cases ------------------
   Best case:   1231  |    Best case:    410
   Worst case: 10257  |    Worst case:  5743
   AVG case:    4376  |    AVG case:    2461

For n = 300000:
  Binary Search       |   Interpolation Search
  Total Time:   4103  |   Total Time:    821 (Trial: 1)
  Total Time:   1231  |   Total Time:   1230 (Trial: 2)
  Total Time:   1641  |   Total Time:    820 (Trial: 3)
  ----------------- Cases ------------------
   Best case:   1231  |    Best case:    820
   Worst case:  4103  |    Worst case:  1230
   AVG case:    2325  |    AVG case:     957

For n = 400000:
  Binary Search       |   Interpolation Search
  Total Time:  17641  |   Total Time:  15179 (Trial: 1)
  Total Time:   6974  |   Total Time:    410 (Trial: 2)
  Total Time:   5743  |   Total Time:   1641 (Trial: 3)
  ----------------- Cases ------------------
   Best case:   5743  |    Best case:    410
   Worst case: 17641  |    Worst case: 15179
   AVG case:   10119  |    AVG case:    5743

For n = 500000:
  Binary Search       |   Interpolation Search
  Total Time:  20102  |   Total Time:   3692 (Trial: 1)
  Total Time:   1231  |   Total Time:    821 (Trial: 2)
  Total Time:   2052  |   Total Time:    410 (Trial: 3)
  ----------------- Cases ------------------
   Best case:   1231  |    Best case:    410
   Worst case: 20102  |    Worst case:  3692
   AVG case:    7795  |    AVG case:    1641
```

Findings:

The total times shows the amount of time that **Binary Search** and **Interpolation Search** took in nanosecond. Also, the output shows three important info:

- Best Case
- Worst Case
- Average Case

From the previews information that we saw about the three cases (Best, Worst and Average) of **Binary Search** and **Interpolation Search**, we can see that the **Interpolation Search** usually is faster than **Binary Search**.



(Scatter Plots show the difference between **Binary Search** and **Interpolation Search** in term of Time efficiency)

Conclusion:

Although that **Binary Search** algorithm is slower than **Interpolation Search** algorithm, **Binary Search** is still useful if we use with small datasets because the difference between it and **Interpolation Search** algorithm is not that big, actually, it is sometimes better to use **Binary Search** algorithm rather than **Interpolation Search** algorithm because it is more reliable (The **Interpolation Search** algorithm's formula $l + \lfloor (v - A[l])(r - l)/(A[r] - A[l]) \rfloor$ can cause error if $A[r] - A[l] = 0$)

```
//Name: Omar Abdulziz Alqurashi, 1742589, Section: DB
import java.util.Arrays;
public class CPCS223_Project {
    public static void main(String[] args) {
    long startTime, endTime,totalTimeB,
bestCaseB,worstCaseB,
            totalTimeI,bestCaseI,worstCaseI,totalTime;
    int keyValue;
        for(int n = 0; n <= 500000; n = n + 100000){
            int array[]=new int[n]; // size = n
            System.out.println("For n = "+(n)+":\n"
            +"  Binary Search       |   Interpolation
Search");
            // initialization of the following:
            totalTimeB = 0;
            bestCaseB = 2000000000; worstCaseB = -1;
            totalTimeI = 0;
            bestCaseI = 2000000000; worstCaseI = -1;
            for(int i = 0; i < n; i++)
                array[i]= (int)(Math.random()*1001);
            for(int t = 0; t < 3; t++){ // trials
                keyValue = (int)(Math.random()*2001);
                Arrays.sort(array);//sort the array
                startTime = System.nanoTime();
                binarySearch(array, keyValue);
                endTime = System.nanoTime();
                totalTime = endTime - startTime;
                System.out.printf("  Total Time: %6d  |
"
                        , totalTime);//nanoSecond
                totalTimeB += totalTime;
                if(totalTime < bestCaseB)
                    bestCaseB = totalTime;
                if(totalTime > worstCaseB)
                    worstCaseB = totalTime;

                startTime = System.nanoTime();
                InterpolationSearch(array, keyValue);
                endTime = System.nanoTime();
                totalTime = endTime - startTime;
                System.out.printf("Total Time: %6d (Trial:
"
                        +(t+1)+")\n",
totalTime);//nanoSecond
                totalTimeI += totalTime;
```

```
                if(totalTime < bestCaseI)
                    bestCaseI = totalTime;
                if(totalTime > worstCaseI)
                    worstCaseI = totalTime;
            } // end of the inner "for loop"
            System.out.printf("  ----------------- Cases -
-----------------\n"
                    + "   Best case: %6d  |    Best case:
%6d\n"
                    + "   Worst case:%6d  |    Worst
case:%6d\n"
                    + "   AVG case:  %6.0f  |    AVG case:
%6.0f\n\n",
bestCaseB,bestCaseI,worstCaseB,worstCaseI,
(double)totalTimeB/3,(double)totalTimeI/3);
        } // end of the outer "for loop"
    }
    public static int binarySearch(int A[],int k){
        int l = 0; // Lower bound
        int r = A.length - 1; // Upper bound
        while(l <= r ){
            int m = ( l + r ) / 2; // midpoint
            if (A[m] == k)
                return m; // found
            else if (A[m] > k)
                r = m - 1;
            else
                l = m + 1;
        }
        return -1;// if not found...
    } // end of binary search
    public static int InterpolationSearch(int A[],int v){
        int l = 0; // Lower bound
        int r = A.length - 1; // Upper bound
        while(l <= r && v >= A[l] && v <= A[r]){
            int x = l + ((v-A[l])*(r-l)/(A[r]-A[l]));
            if (A[x] == v)
                return x; // found
            else if (A[x] > v)
                r = x - 1;
            else
                l = x + 1;
        }
        return -1;// if not found...
    } // end of Interpolation Search
}
```