CS 3310 – Data and File Structures, Instructor: *<Gupta>*, Western Michigan University Lab TA: *<YG>*

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**SOFTWARE LIFE CYCLE REPORT – FOR LAB ASSIGNMENT** *1*

**Searching in Arrays**

**PHASE 1: SPECIFICATION (“What do we build?”)**

Binary search is a common technique to search in a sorted array. Of course, one can implement binary search iteratively (i.e., using loops) or recursively (i.e., using recursive methods). In this assignment we will get experience in implementing and comparing their performances. We will also gain experience in extending binary search. Here we go.  Write a JAVA application to solve the following problem:

* 1. 1)  Generate n random floating-point numbers from 1 to m i.e., in the range [1, m)  (Hint: http://stackoverflow.com/questions/20389890/generating-a-random-number-between-1-and-10-java);
  2. 2)  Store the generated numbers in an array and sort the array. You may use Java’s Arrays.sort  utility method.
  3. 3)  Exact-match query: Generate a random number x and search x in the sorted array using two implementations of binary search, first is an iterative implementation and the second is a recursive implementation.
  4. 4)  Redo step 3 by extending the binary search to a ternary-search (i.e., “poke” the array at 1/3 and 2/3).
  5. 5)  Redo step 3 by extending the binary search to a quad-search (i.e., “poke the array at 1⁄4, 1⁄2 and 3⁄4).
  6. 6)  Range-Query: Generate two random numbers x and y and binary-search the sorted array to find the number of elements of the array between x and y (i.e., find out the count of the number of values in the range [x, y]).

7)  Perform a theoretical complexity analysis of your design (i.e., count number of operations/instructions and space usage) and then express that using asymptotic notation as a function of the input size (Pause: what are the input and output sizes of your problems?)

8)  Empirically measure the time complexity of your code.

9)  Compare the complexities from steps 7) and 8). (Long pause: in order to compare, what all you will need to do? What all you must compare? We will discuss some alternatives in class, so stay tuned and this write-up may be modified accordingly at a later date.) Input m and r from the console (m is the upper bound on the range of numbers to be generated, and r is the number of times to repeat the computation of steps 3-6 for each value of n for better measurement of average-time); use the following values of n=10, 50, 100, 500, 1000, 5000, 10000, 50000, 100000 etc. – push the limit of your machine to maximum n that your machine can handle for your implementation.

10)  Write a SLC report including at most 2 page write-up on your observations of comparison from step 9; include any graphs/charts that may help express your observation precisely and concisely). This report must be produced using MS-Word or equivalent word-processing applications and must be of professional quality. A link to sample report using SLC has been included in the TopicsCovered page of our class’ web presence.

**PHASE 2: DESIGN**

**Program should have 1 class**

**1. Main method**

**PHASE 3: RISK ANALYSIS (“What can go wrong, and how bad can it be?”)**

Sorting could go wrong and then searching would be off.

There could be multiple numbers giving multiple results.

**PHASE 4: VERIFICATION (“Are the algorithms correct?”)**

Sometimes the iterative solutions don’t end the while loops. This happens for only for ternary and quad. It uses the same while loop but sometimes it doesn’t stop running.

**PHASE 5: CODING**

package assignment1;

import java.util.Random;

import java.util.Scanner;

public class Main {

public static void main(String[] args) {

Random rand = new Random();// call random class

Scanner kbd = new Scanner(System.in);

System.out.println("Please enter the number m from which random integers will be generated from 1 to m");/\*\* gives number range \*\*/

int i = kbd.nextInt();

System.out.println("Please enter the number of integers you want");/\*\* gives number of numbers \*\*/

int k = kbd.nextInt();

System.out.println("Please enter the number you want to search for");/\*\* gets number \*\*/

int x = kbd.nextInt();

System.out.println("Please enter the number you want to be the last number to search for");/\*\* gets range high number \*\*/

int y = kbd.nextInt();

kbd.close();

// gets user input

int l;

int[] array = new int[k];

// generates random numbers. adds to list and array

for (int j = 0; j < k - 1; j++) {

l = rand.nextInt(i);

array[j] = l;

// System.out.println(l);

}

sortArray(array);

for (int p = 0; p < array.length; p++) {

System.out.print(array[p] + ", ");

}

if (bsearch(array, x) == -1) {

System.out.println("\nNumber not found");

System.exit(0);

}

System.out.println("\nNumber of integers between range of " + x + " and " + y + " is "

+ bsearch(array, bsearch(array, x), y));

System.out.println("Binary recursive returns " + bsearch(array, x, 0, array.length - 1));

System.out.println("Ternary recursive returns " + tsearch(array, x, 0, array.length - 1));

System.out.println("Quad recursive returns " + qsearch(array, x, 0, array.length - 1));

System.out.println("Binary iterative returns " + bsearch(array, x));

System.out.println("Ternary iterative returns " + tsearch(array, x));

System.out.println("Quad iterative returns " + qsearch(array, x));

}

public static int[] sortArray(int[] array) {

boolean swapped = true;

int j = 0;

int temp;

while (swapped) {

swapped = false;

j++;/\*\* sort the array \*\*/

for (int i = 0; i < array.length - j; i++) {

if (array[i] > array[i + 1]) {

temp = array[i];

array[i] = array[i + 1];

array[i + 1] = temp;

swapped = true;

}

}

} // sorts array

return array;

}

public static int bsearch(int[] A, int x, int y) {

int count = 0;

for (int i = x; i <= A.length; i++) {

if (A[i] == y || A[i] > y) {

return count;

} else {

/\*\* add to count \*\*/

count = count + 1;

}

}

return -1;

}

public static int bsearch(int[] array, int x) {

int low = 0;

int high = array.length - 1;

while (high >= low) {

int middle = (low + high) / 2;

if (array[middle] == x) {

return middle;

}/\*\* Search each range \*\*/

if (array[middle] < x) {

low = middle + 1;

}

if (array[middle] > x) {

high = middle - 1;

}

}

return -1;

}

public static int bsearch(int[] sorted, int value, int leftIndex, int rightIndex) {

// 1. index check

if (leftIndex > rightIndex) {

return -1;

}

int middle = (rightIndex + leftIndex) / 2;

if (sorted[middle] == value) {

return middle;/\*\* Search each range \*\*/

} else if (sorted[middle] > value) {

return bsearch(sorted, value, leftIndex, middle - 1);

} else if (sorted[middle] < value) {

return bsearch(sorted, value, middle + 1, rightIndex);

} else {

return -1;

}

}

public static int tsearch(int[] A, int x) {

int low = 0;

int high = A.length - 1;

while (high > low) {

int mid1 = (low + high) / 3;

int mid2 = 2 \* ((low + high) / 3);

if (A[mid1] == x) {

return mid1;

}

if (A[mid2] == x) {

return mid2;

}

/\*\* Search each range \*\*/

if (A[mid1] < x) {

low = mid1 + 1;

}

if (A[mid1] > x) {

high = mid1 - 1;

}

if (A[mid2] < x) {

low = mid2 + 1;

}

if (A[mid2] > x) {

high = mid2 - 1;

}

}

return -1;

}

public static int tsearch(int[] A, int value, int start, int end) {

if (start > end)

return -1;

/\*\* First boundary: add 1/3 of length to start \*\*/

int mid1 = start + (end - start) / 3;

/\*\* Second boundary: add 2/3 of length to start \*\*/

int mid2 = start + 2 \* (end - start) / 3;

if (A[mid1] == value)

return mid1;

else if (A[mid2] == value)

return mid2;

/\*\* Search 1st third \*\*/

else if (value < A[mid1])

return tsearch(A, value, start, mid1 - 1);

/\*\* Search 3rd third \*\*/

else if (value > A[mid2])

return tsearch(A, value, mid2 + 1, end);

/\*\* Search middle third \*\*/

else

return tsearch(A, value, mid1+1, mid2-1);

}

public static int qsearch(int[] A, int x) {

int low = 0;

int high = A.length - 1;

while (high > low) {

int mid1 = (low + high) / 4;

int mid2 = 2 \* ((low + high) / 4);

int mid3 = 3 \* ((low + high) / 4);

if (A[mid1] == x) {

return mid1;

}

if (A[mid2] == x) {

return mid2;

}

if (A[mid3] == x) {

return mid3;

}/\*\* Search each range \*\*/

if (A[mid1] < x) {

low = mid1 + 1;

}

if (A[mid1] > x) {

high = mid1 - 1;

}

if (A[mid2] < x) {

low = mid2 + 1;

}

if (A[mid2] > x) {

high = mid2 - 1;

}

if (A[mid3] < x) {

low = mid3 + 1;

}

if (A[mid3] > x) {

high = mid3 - 1;

}

}

return -1;

}

public static int qsearch(int[] A, int value, int start, int end) {

if (start > end)

return -1;

/\*\* First boundary: add 1/4 of length to start \*\*/

int mid1 = start + (end - start) / 4;

/\*\* Second boundary: add 2/4 of length to start \*\*/

int mid2 = start + 2 \* (end - start) / 4;

/\*\* Second boundary: add 3/4 of length to start \*\*/

int mid3 = start + 3 \* (end - start) / 4;

if (A[mid1] == value)

return mid1;

else if (A[mid2] == value)

return mid2;

else if (A[mid3] == value)

return mid3;

/\*\* Search each range \*\*/

else if (value < A[mid1])

return tsearch(A, value, start, mid1 - 1);

else if (value > A[mid1])

return tsearch(A, value, mid1+1, mid2);

else if (value < A[mid2])

return tsearch(A, value, mid1, mid2 - 1);

else if (value < A[mid3])

return tsearch(A, value, mid2, mid3 - 1);

else if (value > A[mid2])

return tsearch(A, value, mid2 + 1, mid3);

else if (value > A[mid3])

return tsearch(A, value, mid3+1, end);

else

return tsearch(A, value, mid1+1, mid2-1);

}

}

**PHASE 6: TESTING (“Did we build it correctly?”)**

Please enter the number m from which random integers will be generated from 1 to m

100

Please enter the number of integers you want

100

Please enter the number you want to search for

0

Please enter the number you want to be the last number to search for

60

0, 1, 2, 2, 3, 4, 5, 7, 7, 8, 9, 11, 12, 12, 13, 17, 17, 17, 18, 19, 19, 21, 21, 21, 22, 24, 24, 25, 26, 26, 30, 30, 31, 32, 35, 35, 38, 39, 40, 40, 40, 41, 41, 43, 45, 45, 46, 47, 48, 49, 49, 50, 51, 51, 51, 51, 52, 54, 55, 56, 56, 57, 57, 58, 61, 61, 65, 65, 65, 66, 68, 69, 69, 70, 70, 71, 73, 75, 75, 76, 78, 79, 79, 81, 83, 84, 85, 86, 86, 87, 89, 89, 90, 93, 94, 94, 95, 96, 98, 99,

Number of integers between range of 0 and 60 is 64

Binary recursive returns 0

Ternary recursive returns 0

Quad recursive returns 0

Binary iterative returns 0

Ternary iterative returns 0

Quad iterative returns 0

Please enter the number m from which random integers will be generated from 1 to m

1000

Please enter the number of integers you want

1000

Please enter the number you want to search for

600

Please enter the number you want to be the last number to search for

999

0, 0, 0, 1, 3, 4, 5, 5, 6, 7, 8, 8, 9, 11, 11, 14, 16, 18, 18, 18, 18, 19, 19, 20, 22, 25, 26, 26, 26, 28, 28, 29, 30, 30, 30, 31, 31, 33, 33, 33, 33, 34, 36, 38, 39, 40, 41, 41, 43, 43, 45, 45, 46, 46, 47, 48, 49, 49, 49, 50, 51, 51, 52, 52, 52, 54, 54, 54, 54, 57, 57, 57, 58, 61, 61, 63, 64, 64, 66, 68, 69, 71, 72, 74, 74, 76, 79, 79, 80, 81, 82, 82, 83, 84, 84, 85, 86, 89, 90, 90, 90, 91, 91, 92, 92, 93, 93, 93, 95, 98, 99, 101, 101, 102, 103, 107, 107, 109, 109, 109, 113, 114, 114, 114, 114, 115, 116, 116, 117, 117, 117, 117, 118, 118, 120, 120, 120, 122, 123, 124, 126, 126, 126, 129, 131, 134, 136, 140, 140, 140, 143, 143, 144, 145, 146, 147, 150, 151, 152, 152, 154, 154, 156, 158, 158, 159, 160, 160, 162, 164, 167, 169, 171, 173, 173, 173, 174, 177, 180, 182, 183, 183, 188, 188, 189, 190, 191, 192, 194, 195, 196, 196, 196, 196, 197, 198, 201, 201, 202, 204, 205, 205, 206, 208, 209, 211, 213, 215, 215, 216, 216, 217, 218, 220, 220, 222, 223, 225, 227, 229, 231, 231, 231, 232, 232, 233, 235, 235, 237, 241, 242, 243, 245, 246, 246, 252, 252, 252, 253, 254, 255, 255, 256, 258, 260, 261, 261, 263, 263, 264, 264, 266, 268, 268, 269, 270, 271, 271, 272, 274, 274, 274, 275, 275, 276, 277, 278, 278, 280, 282, 283, 283, 286, 287, 287, 288, 288, 290, 291, 294, 295, 298, 300, 300, 301, 301, 302, 303, 305, 305, 308, 308, 308, 309, 310, 311, 311, 312, 313, 313, 313, 316, 316, 316, 318, 321, 321, 323, 325, 326, 327, 330, 332, 332, 333, 334, 336, 336, 336, 337, 338, 338, 341, 341, 342, 342, 342, 342, 342, 344, 345, 345, 345, 347, 348, 348, 350, 351, 352, 354, 355, 356, 358, 360, 360, 363, 364, 364, 366, 368, 369, 370, 370, 372, 372, 372, 373, 374, 374, 376, 376, 376, 377, 377, 378, 379, 381, 383, 384, 386, 386, 388, 388, 389, 390, 390, 391, 394, 395, 395, 396, 396, 397, 398, 399, 400, 401, 401, 405, 406, 407, 407, 408, 408, 411, 412, 412, 413, 413, 413, 414, 414, 416, 416, 417, 418, 419, 419, 420, 420, 422, 423, 424, 424, 425, 426, 428, 428, 429, 429, 430, 431, 433, 434, 436, 436, 436, 439, 439, 440, 442, 443, 444, 444, 445, 446, 448, 448, 449, 449, 449, 450, 451, 452, 453, 453, 454, 455, 455, 456, 458, 459, 460, 461, 463, 464, 465, 466, 466, 467, 468, 468, 469, 470, 472, 473, 476, 477, 478, 479, 483, 483, 484, 485, 486, 488, 491, 491, 492, 492, 492, 493, 493, 493, 494, 494, 495, 496, 498, 498, 499, 504, 505, 505, 507, 507, 507, 508, 509, 509, 511, 512, 513, 516, 517, 518, 518, 519, 519, 520, 521, 521, 522, 523, 525, 527, 530, 531, 532, 533, 534, 535, 536, 541, 541, 542, 542, 542, 544, 547, 547, 548, 549, 549, 550, 550, 550, 552, 552, 552, 554, 554, 556, 556, 557, 557, 557, 557, 559, 559, 562, 564, 565, 565, 566, 566, 567, 567, 568, 568, 570, 570, 570, 571, 573, 573, 574, 574, 574, 576, 576, 578, 578, 579, 582, 582, 583, 585, 585, 588, 588, 589, 589, 590, 591, 593, 593, 594, 596, 596, 596, 597, 597, 598, 598, 599, 601, 602, 604, 608, 610, 611, 611, 611, 612, 616, 616, 617, 617, 619, 620, 621, 622, 622, 622, 623, 624, 625, 625, 626, 627, 627, 628, 629, 630, 633, 635, 636, 639, 639, 640, 641, 641, 641, 643, 647, 649, 649, 650, 650, 651, 652, 652, 655, 656, 658, 662, 662, 663, 663, 666, 667, 668, 668, 669, 669, 670, 670, 671, 672, 672, 673, 674, 674, 675, 676, 676, 677, 677, 677, 678, 679, 679, 679, 679, 680, 682, 684, 685, 685, 685, 687, 687, 687, 687, 688, 689, 692, 693, 695, 697, 697, 698, 698, 701, 702, 703, 703, 705, 705, 707, 707, 708, 710, 711, 714, 716, 716, 717, 717, 718, 719, 721, 721, 721, 721, 722, 722, 723, 724, 724, 725, 727, 731, 732, 733, 733, 733, 735, 735, 735, 736, 737, 737, 737, 737, 737, 738, 738, 739, 740, 740, 741, 744, 746, 749, 750, 750, 751, 752, 752, 753, 753, 753, 753, 756, 756, 758, 758, 758, 759, 759, 759, 759, 760, 761, 761, 762, 762, 763, 763, 763, 764, 764, 764, 765, 766, 766, 767, 767, 767, 768, 769, 769, 770, 771, 771, 773, 773, 773, 774, 774, 774, 775, 777, 777, 783, 784, 784, 784, 786, 786, 787, 789, 790, 793, 795, 796, 799, 799, 800, 802, 804, 807, 808, 808, 810, 810, 810, 811, 812, 813, 815, 816, 818, 820, 821, 822, 824, 827, 828, 829, 829, 830, 830, 831, 831, 832, 837, 838, 838, 839, 839, 840, 846, 849, 850, 850, 854, 857, 858, 860, 860, 862, 862, 863, 864, 864, 866, 867, 868, 869, 869, 869, 871, 871, 873, 874, 874, 875, 875, 875, 876, 876, 878, 879, 881, 881, 882, 882, 882, 882, 883, 884, 885, 886, 887, 890, 891, 892, 895, 895, 895, 895, 897, 897, 897, 897, 899, 899, 900, 901, 901, 904, 905, 906, 907, 908, 909, 910, 910, 912, 913, 914, 916, 917, 919, 919, 919, 919, 919, 920, 923, 923, 924, 925, 925, 926, 928, 929, 929, 930, 932, 933, 934, 936, 938, 940, 943, 944, 945, 945, 946, 946, 950, 950, 951, 952, 952, 953, 953, 953, 953, 953, 954, 955, 956, 957, 958, 958, 959, 961, 962, 962, 963, 964, 965, 965, 969, 969, 970, 971, 972, 973, 973, 975, 976, 977, 977, 980, 980, 981, 982, 985, 987, 987, 987, 987, 988, 988, 990, 991, 994, 994, 995, 996, 996, 997, 997, 998,

Number not found

Please enter the number m from which random integers will be generated from 1 to m

10000

Please enter the number of integers you want

10000

Please enter the number you want to search for

3

Please enter the number you want to be the last number to search for

9999

0, 1, 1, 2, 3, 4, 5, 6, 6, 8, 10, 10, 13, 15, 17, 18, 19, 19, 20, 23, 23, 26, 27, 27, 28, 28, 29, 29, 30, 33, 34, 37, 37, 38, 40, 41, 43, 44, 44, 44, 48, 49, 53, 53, 54, 55, 56, 57, 58, 59, 60, 60, 61, 61, 61, 62, 65, 65, 66, 67, 69, 70, 71, 71, 72, 73, 77, 78, 78, 83, 84, 84, 85, 85, 86, 86, 87, 87, 89, 89, 89, 89, 89, 90, 91, 93, 93, 94, 97, 99, 100, 101, 101, 103, 104, 105, 106, 108, 111, 111, 111, 112, 114, 118, 118, 121, 123, 123, 126, 128, 128, 129, 130, 132, 133, 134, 135, 136, 139, 140, 141, 146, 146, 146, 151, 151, 152, 152, 153, 153, 153, 155, 155, 156, 156, 156, 158, 160, 160, 162, 165, 165, 166, 167, 169, 170, 171, 171, 172, 173, 173, 175, 175, 176, 177, 177, 177, 178, 179, 180, 182, 182, 183, 184, 185, 187, 188, 190, 191, 193, 194, 195, 196, 196, 198, 199, 201, 202, 203, 203, 204, 206, 206, 207, 210, 210, 216, 216, 217, 218, 218, 219, 219, 220, 220, 222, 222, 222, 224, 226, 229, 230, 233, 233, 234, 236, 236, 236, 237, 237, 238, 239, 239, 240, 241, 242, 242, 244, 245, 245, 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9985, 9986, 9988, 9989, 9990, 9991, 9992, 9992, 9993, 9994, 9995, 9997, 9997, 9997, 9998, 9998, 9999, 9999,

Number of integers between range of 3 and 9999 is 9994

Binary recursive returns 4

Ternary recursive returns 4

Quad recursive returns 4

Binary iterative returns 4

**PHASE 7: REFINING THE PROGRAM (“Add bells and whistles to the program”)**

Make it look better.

**PHASE 8: PRODUCTION**

I prepared a copy of the entire program for Lab TA’s evaluation, as specified by the TA. Then, I sent electronically the copy to the Lab TA.

**PHASE 9: MAINTENANCE**

Fix the issues with iterative.

**TIME AND SPACE**

Space would be depending on the amount of numbers the user wanted. The number of array elements plus any of the types.

Time would be O(n) in the main, but more for the search methods. O(nlog(n)+n).