Question 1

Given the following function check()which is passed an integer array, arrA[], and its associated size, size, and returns a Boolean (line numbers are included):

```
 L1. bool check(int arrA[], int size)
 L2. {
 L3.     bool checked = true;
 L4.     for (int i = 0; i < size - 1 && checked; i++)
 L5.     {
 L6.         if (arrA[i] > arrA[i + 1])
 L7.         {
 L8.             checked = false;
 L9.         }
L10.     }
L11.     return (checked);
L12. }
```

i) Explain, in your own words, and with reference to the appropriate line numbers, and some sample data, what the function check() does and how it works

Function check takes 2 parameters: array of numbers and size of this array.

In **L3** Boolean variable **checked** is initialized with value true. It is used to determine if array is in ascending order. It is also used in **L4** inside the **for loop** as an condition to stop the loop in case the numbers are not in ascending order.

In **L4** with have a **for loop** that is iterating through the array from index 0 to size -1 to not exceed the array size, but when the variable checked is equals **false** the for loop will stop iterating.

In **L6** there **is if statement** that checks if the values in the array are not ascending order then it changes value of **checked** to **false** which results in stopping the for loop.

Then in **L11** the function returns the value of variable **checked**. If **checked = true** then the array is sorted in ascending order, if **checked = false** then the array is not sorted in ascending order.

```
Suppose we have an array arrA[] = {3, 6, 8, 10, 12}.
Initialization (Line 3):
   checked is initialized to true.
Looping through the Array (Lines 4-10):
   Iteration 1 (i = 0):
      Check if arrA[0] (3) is greater than arrA[1] (6). It's not, so continue.
   Iteration 2 (i = 1):
      Check if arrA[1] (6) is greater than arrA[2] (8). It's not, so continue.
   Iteration 3 (i = 2):
      Check if arrA[2] (8) is greater than arrA[3] (10). It's not, so continue.
   Iteration 4 (i = 3):
      Check if arrA[3] (10) is greater than arrA[4] (12). It's not, so continue.
   Loop ends because i = size - 1, and checked remains true.
Return Statement (Line 11):

The function returns true, indicating that the array is sorted in ascending order.
So, in this example, the function correctly determines that the array {3, 6, 8, 10, 12} is sorted in
ascending order.
```

ii) Perform a time step analysis of the function check() as a function of the size of arrA[], in a best case and a worst case situation. Clearly explain any assumptions made.

Worst case scenario, array is sorted in ascending order, so we have to each element

Line	Cost	numTimes	cost*numTimes	Total
3	1	1	1	
4	1	N	N	
6	1	N	N	
8	1	1	1	
11	1	1	1	
				f(N) = 2N+3

In a **best case** scenario first two elements already wont be in ascending order so the bool checked =false which will cause the for loop to stop.

Line	Cost	numTimes	cost*numTimes	Total
3	1	1	1	
4	1	2	2	
6	1	1	1	
8	1	1	1	
11	1	1	1	
				f(N) = 5

Question 2

Given the following function search() which is passed the integer arrays, arrA[], with non-unique, unsorted values of size, size, and an empty integer array, arrOccur[], the same size as arrA[]. Also passed to the function is an integer value item. (Note line numbers are also included):

```
 L1. int search(int arrA[], int size, int item, int arrOccur[])
 L2. {
 L3.     int location = -1;
 L4.     for (int i = 0; i < size; i++)
 L5.     {
 L6.         if (arrA[i] == item)
 L7.         {
 L8.             ++location;
 L9.             arrOccur[location] = i;
L10.         }
L11.     }
L12.     return (location);
L13. }
```

Function search is a function that searches for an item in non-unique array. It stores index of wanted item in array with occurrences and returns number of occurrences.

In L3 there is initialized variable location that has value -1, but if the item occures in array it will return occurrence count.

In L4 there is an for loop that goes through the array, then in L6 if statemnt checks if elemnt from the array is equal to an item to search.

L8 is responsible for couting occurences and L9 saves an index of element from an array that is equal to the item it serches for.

L12 return the number of occurrences.

```
Suppose we have an array arrA[] = {22, 25, 26, 24, 25, 23, 25}
Initialization (Line 3):
   location is initialized to -1.
Looping through the Array (Lines 4-11):
   Iteration 1 (i = 0):
      Check if arrA[0] (22) is equal to item (25). It's not, so continue.
   Iteration 2 (i = 1):
      Check if arrA[1] (25) is equal to item (25). It is, so:
      Increment location to 0.
      Store index 1 in arrOccur[].
   Iteration 3 (i = 2):
      Check if arrA[2] (26) is equal to item (25). It's not, so continue.
   Iteration 4 (i = 3):
      Check if arrA[3] (24) is equal to item (25). It's not, so continue.
   Iteration 5 (i = 4):
      Check if arrA[4] (25) is equal to item (25). It is, so:
      Increment location to 1.
      Store index 4 in arrOccur[].
   Iteration 6 (i = 5):
      Check if arrA[5] (23) is equal to item (25). It's not, so continue.
   Iteration 7 (i = 6):
      Check if arrA[6] (25) is equal to item (25). It is, so:
      Increment location to 2.
      Store index 6 in arrOccur[].
Return Statement (Line 12):
   The function returns location, which is 3 (the number of occurrences found).
So, in this example, the function correctly determines that the temperature 25 occurs 3 times in the
array {22, 25, 26, 24, 25, 23, 25}.
```

ii) Perform a time step analysis of the function search() as a function of the size of arrA[] in a worst case situation. Clearly explain any assumptions made.

In the **worst-case** scenario, is when all elements in the array are the same and are equal to the item searched for.

Line	Cost	numTimes	cost*numTimes	Total
3	1	1	1	
4	1	N	N	
6	1	N	N	
8	1	N	N	
9	1	N	N	
13	1	1	1	
				f(N)=4N+2

Question 3

Given two test files, file1.txt and file2.txt, (both with 10,000 integers), perform a comparison of the four sorting techniques considered for different values of N (array size) in terms of:

a. time taken

b. number of swaps/data moves

c. number of comparisons

Present your results in a meaningful and clear way so that it is easy to see differences between the algorithms for the same value of N.

In my testing approach I was evaluating 4 sorting algorithms. Testing is performed on array of different size ranging from 1000 to 10000 in increments of 1000, for each size. Numbers are read from given files, first from file1, then from file2.

Counting swaps and comparisons is executed in each soring algorithm. The time taken to sort the array is measured by recording the time before and after the sorting algorithm is executed, and then calculating the difference.

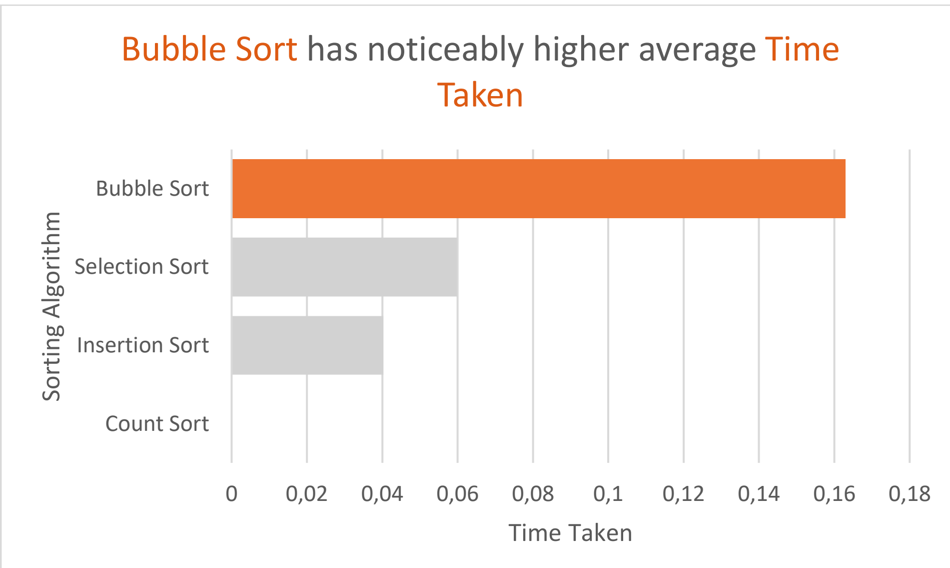
After sorting an array and gathering all data, the sorted array is checked to ensure that it is sorted correctly.

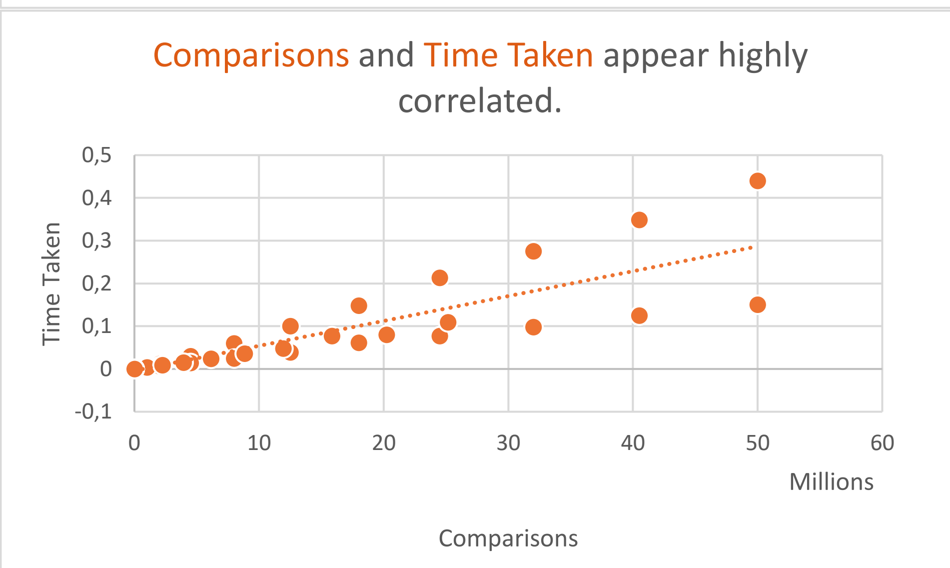
Result are being save to .csv file.

Below I've included analysis of gathered data and parts of code. Full code and csv files are available in the gist at this link: https://gist.github.com/Olszewski-Jakub/de67d4da5595c7e1c763ecce010af7b0

File 1

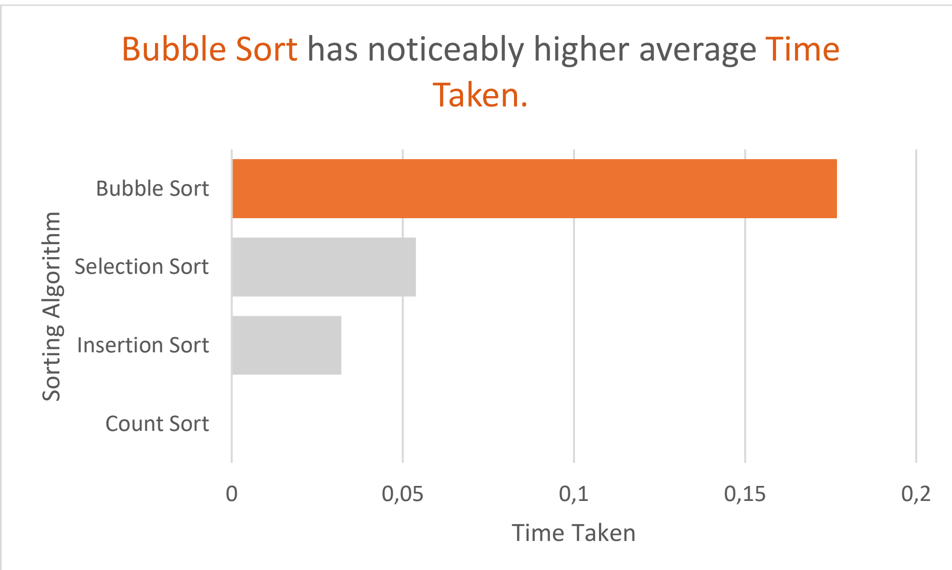
Size	Bubble Sort	Count Sort	Insertion Sort	Selection Sort
1000	0,003	0	0,001	0,002
2000	0,012	0	0,004	0,007
3000	0,03	0	0,009	0,014
4000	0,06	0	0,015	0,025
5000	0,1	0	0,024	0,039
6000	0,148	0	0,036	0,061
7000	0,213	0	0,048	0,077
8000	0,275	0,001	0,077	0,098
9000	0,349	0	0,08	0,125
10000	0,44	0	0,109	0,15

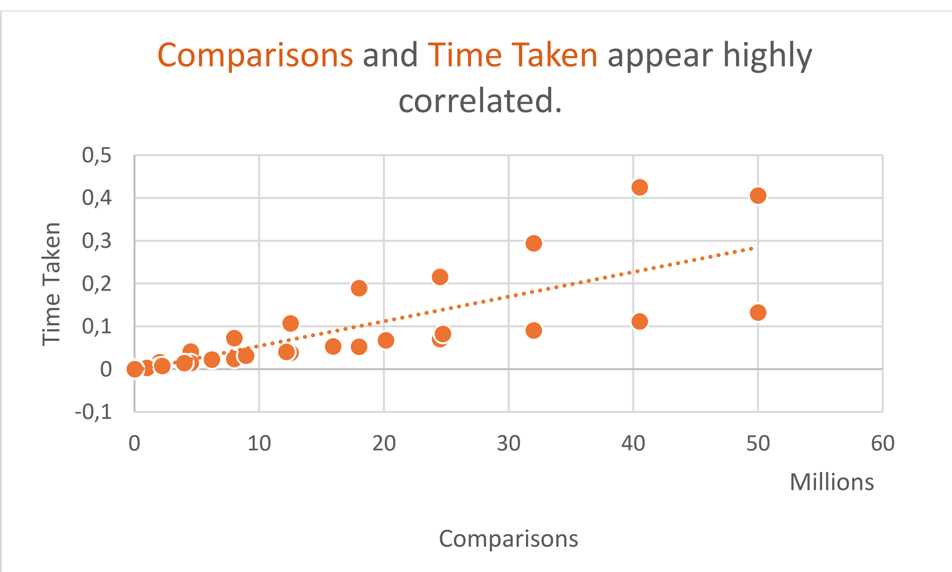




File 2

Size	Bubble Sort	Count Sort	Insertion Sort	Selection Sort
1000	0,005	0	0,001	0,001
2000	0,016	0	0,003	0,006
3000	0,041	0	0,007	0,014
4000	0,072	0	0,014	0,024
5000	0,107	0	0,022	0,038
6000	0,189	0,001	0,031	0,052
7000	0,215	0	0,04	0,07
8000	0,294	0	0,053	0,09
9000	0,425	0	0,067	0,111
10000	0,405	0	0,082	0,132





Data obtained from the code

File 1

Sorting Algorithm	Size	Swaps	Comparisons	Time Taken
Bubble Sort	1000	254554	499500	0.003000
Bubble Sort	2000	1001456	1999000	0.012000
Bubble Sort	3000	2237298	4498500	0.030000
Bubble Sort	4000	3934058	7998000	0.060000
Bubble Sort	5000	6138975	12497500	0.100000
Bubble Sort	6000	8833508	17997000	0.148000
Bubble Sort	7000	11949020	24496500	0.213000
Bubble Sort	8000	15847752	31996000	0.275000
Bubble Sort	9000	20218657	40495500	0.349000
Bubble Sort	10000	25154469	49995000	0.440000
Selection Sort	1000	999	499500	0.002000
Selection Sort	2000	1999	1999000	0.007000
Selection Sort	3000	2999	4498500	0.014000
Selection Sort	4000	3999	7998000	0.025000
Selection Sort	5000	4999	12497500	0.039000
Selection Sort	6000	5999	17997000	0.061000
Selection Sort	7000	6999	24496500	0.077000
Selection Sort	8000	7999	31996000	0.098000
Selection Sort	9000	8999	40495500	0.125000
Selection Sort	10000	9999	49995000	0.150000
Insertion Sort	1000	255552	254554	0.001000
Insertion Sort	2000	1003454	1001456	0.004000
Insertion Sort	3000	2240294	2237298	0.009000
Insertion Sort	4000	3938052	3934058	0.015000
Insertion Sort	5000	6143969	6138975	0.024000
Insertion Sort	6000	8839502	8833508	0.036000
Insertion Sort	7000	11956014	11949020	0.048000
Insertion Sort	8000	15855746	15847752	0.077000
Insertion Sort	9000	20227651	20218657	0.080000
Insertion Sort	10000	25164463	25154469	0.109000
Count Sort	1000	0	0	0.000000
Count Sort	2000	0	0	0.000000
Count Sort	3000	0	0	0.000000
Count Sort	4000	0	0	0.000000
Count Sort	5000	0	0	0.000000
Count Sort	6000	0	0	0.000000
Count Sort	7000	0	0	0.000000
Count Sort	8000	0	0	0.001000
Count Sort	9000	0	0	0.000000
Count Sort	10000	0	0	0.000000

File 2

Sorting Algorithm	Size	Swaps	Comparisons	Time Taken
Bubble Sort	1000	250102	499500	0.005000
Bubble Sort	2000	995574	1999000	0.016000
Bubble Sort	3000	2227207	4498500	0.041000
Bubble Sort	4000	3977576	7998000	0.072000
Bubble Sort	5000	6187299	12497500	0.107000
Bubble Sort	6000	8938260	17997000	0.189000
Bubble Sort	7000	12177890	24496500	0.215000
Bubble Sort	8000	15914238	31996000	0.294000
Bubble Sort	9000	20158364	40495500	0.425000
Bubble Sort	10000	24712201	49995000	0.405000
Selection Sort	1000	999	499500	0.001000
Selection Sort	2000	1999	1999000	0.006000
Selection Sort	3000	2999	4498500	0.014000
Selection Sort	4000	3999	7998000	0.024000
Selection Sort	5000	4999	12497500	0.038000
Selection Sort	6000	5999	17997000	0.052000
Selection Sort	7000	6999	24496500	0.070000
Selection Sort	8000	7999	31996000	0.090000
Selection Sort	9000	8999	40495500	0.111000
Selection Sort	10000	9999	49995000	0.132000
Insertion Sort	1000	251091	250102	0.001000
Insertion Sort	2000	997557	995574	0.003000
Insertion Sort	3000	2230186	2227207	0.007000
Insertion Sort	4000	3981548	3977576	0.014000
Insertion Sort	5000	6192266	6187299	0.022000
Insertion Sort	6000	8944220	8938260	0.031000
Insertion Sort	7000	12184844	12177890	0.040000
Insertion Sort	8000	15922188	15914238	0.053000
Insertion Sort	9000	20167305	20158364	0.067000
Insertion Sort	10000	24722134	24712201	0.082000
Count Sort	1000	0	0	0.000000
Count Sort	2000	0	0	0.000000
Count Sort	3000	0	0	0.000000
Count Sort	4000	0	0	0.000000
Count Sort	5000	0	0	0.000000
Count Sort	6000	0	0	0.001000
Count Sort	7000	0	0	0.000000
Count Sort	8000	0	0	0.000000
Count Sort	9000	0	0	0.000000
Count Sort	10000	0	0	0.000000

Sorting algorithms

```c
// Bubble Sort function
void bubbleSort(int nums[], int size, int *arrIndex, SortingResult sortingResultsFile[]) {
    int swaps = 0;
    int comparisons = 0;

    clock_t start_time = clock(); // Start time

    for (int i = 0; i < size - 1; i++) { // Iterate over each element in the array
        for (int j = 0;
             j < size - i - 1; j++) { // For each element, iterate over the array again, excluding the last i elements
            (comparisons)++; // Increment the comparison count
            if (nums[j] > nums[j + 1]) { // If the current element is greater than the next one
                swap( a: &nums[j],  b: &nums[j + 1]); // Swap the current element with the next one
                (swaps)++; // Increment the swap count
            }
        }
    }

    clock_t end_time = clock(); // End time
    double time_taken = ((double) (end_time - start_time)) / CLOCKS_PER_SEC; // Time taken in seconds

    saveResultInStruct(size, swaps, comparisons,  timeTaken: time_taken,  sortingAlgorithm: "Bubble Sort", arrIndex, sortingResultsFile);
}
```

```c
void selectionSort(int nums[], int size, int *arrIndex, SortingResult sortingResultsFile[]) {
    clock_t start_time = clock(); // Start time
    int swaps = 0;
    int comparisons = 0;

    for (int step = 0; step < size - 1; step++) { // Iterate over each element in the array
        int min_idx = step; // Assume the current element is the smallest
        for (int i = step + 1; i < size; i++) { // For each element, iterate over the rest of the array
            comparisons++; // Increment the comparison count
            if (nums[i] < nums[min_idx]) { // If a smaller element is found
                min_idx = i; // Update the index of the smallest element
            }
        }

        // After finding the smallest element in the unsorted part of the array
        swaps++; // Increment the swap count
        swap( a: &nums[min_idx],  b: &nums[step]); // Swap the smallest element with the first element of the unsorted part
    }
    clock_t end_time = clock(); // End time
    double time_taken = ((double) (end_time - start_time)) / CLOCKS_PER_SEC; // Time taken in seconds

    saveResultInStruct(size, swaps, comparisons,  timeTaken: time_taken,  sortingAlgorithm: "Selection Sort", arrIndex, sortingResultsFile);
}
```

```c
void insertionSort(int nums[], int size, int *arrIndex, SortingResult sortingResultsFile[]) {

    clock_t start_time = clock(); // Start time
    int swaps = 0;
    int comparisons = 0;

    int i, j, current;
    for (i = 0; i < size; i++) { // Iterate over each element in the array
        current = nums[i]; // Store the current element
        for (j = i - 1; j >= 0 && current < nums[j]; j--) { // Iterate backwards from the current element
            nums[j + 1] = nums[j]; // Shift the elements to the right
            swaps++; // Increment the swap count
            comparisons++; // Increment the comparison count
        }
        if (i != j + 1) { // If the current element has been moved
            nums[j + 1] = current; // Insert the current element in its correct position
            swaps++; // Increment the swap count
        }
    }

    clock_t end_time = clock(); // End time
    double time_taken = ((double) (end_time - start_time)) / CLOCKS_PER_SEC; // Time taken in seconds

    saveResultInStruct(size, swaps, comparisons, timeTaken: time_taken, sortingAlgorithm: "Insertion Sort", arrIndex, sortingResultsFile);
}
```

```c
void countingSort(int nums[], int size, int *arrIndex, SortingResult sortingResultsFile[]) {
    clock_t start_time = clock(); // Start time
    int swaps = 0;
    int comparisons = 0; // Counting Sort doesn't involve comparisons

    int max = nums[0]; // Initialize max with the first element of the array
    int min = nums[0]; // Initialize min with the first element of the array
    for (int i = 1; i < size; ++i) { // Iterate over the array starting from the second element
        if (nums[i] > max) { // If the current element is greater than max
            max = nums[i]; // Update max
        }
        if (nums[i] < min) { // If the current element is less than min
            min = nums[i]; // Update min
        }
    }

    // Calculate the range of the count array
    int range = max - min + 1; // The range is the difference between max and min plus 1

    // Allocate memory for count array
    int *count = (int *) malloc(
            Size: range * sizeof(int)); // Allocate memory for the count array with size equal to the range
    // Allocate memory for output array
    int *output = (int *) malloc(
            Size: size * sizeof(int)); // Allocate memory for the output array with size equal to the size of the input array
    if (count == NULL || output == NULL) { // If memory allocation failed for either of the arrays
        printf( format: "Memory allocation failed.\n"); // Print an error message
        return; // Exit the function
    }
```

```c
// Initialize count array with all zeros
for (int i = 0; i < range; ++i) // Iterate over the count array
    count[i] = 0; // Set each element to 0

// Store the count of each element in count array
for (int i = 0; i < size; ++i) // Iterate over the input array
    ++count[nums[i] - min]; // Increment the count of the current element in the count array

// Store the cumulative count of each array
for (int i = 1; i < range; ++i) // Iterate over the count array starting from the second element
    count[i] += count[i - 1]; // Add the count of the previous element to the current element

// Build the output array
for (int i = size - 1; i >= 0; --i) { // Iterate over the input array in reverse order
    output[count[nums[i] - min] -
           1] = nums[i]; // Place the current element in its sorted position in the output array
    --count[nums[i] - min]; // Decrement the count of the current element in the count array
}

// Copy the sorted elements back into original array
for (int i = 0; i < size; ++i) // Iterate over the output array
    nums[i] = output[i]; // Copy each element to the input array

// Free dynamically allocated memory
free( Memory: count); // Free the memory allocated for the count array
free( Memory: output); // Free the memory allocated for the output array

clock_t end_time = clock(); // End time
double time_taken = ((double) (end_time - start_time)) / CLOCKS_PER_SEC; // Time taken in seconds

saveResultInStruct(size, swaps, comparisons, timeTaken: time_taken, sortingAlgorithm: "Count Sort", arrIndex, sortingResultsFile);
```

```c
int readNumbersFromFile(const char *filename, int size, int numbers[]) {
    FILE *file;

    // Open the file for reading
    file = fopen(filename, "r");
    if (file == NULL) {
        printf("Error opening file %s\n", filename);
        return -1; // Error opening file
    }

    // Read integers from the file and store them in the array
    for (int i = 0; i < size; i++) {
        if (fscanf(file, "%d", &numbers[i]) == EOF) {
            printf("Error: Insufficient numbers in file.\n");
            fclose(file);
            return i; // Return the number of integers read
        }
    }

    // Close the file
    fclose(file);
    return size; // Return the size of the array
}
```

I am aware of what plagiarism is and include this here to confirm that this work is my own