

A2 Computer Science Project

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Analysis

Problem Definition

There are many different sorting and searching algorithms used in the computer science industry today. Sorting algorithms provide students with some backbone concepts of computer science such as data structures, big O notation and efficiency. Some of these are taught in GCSE and all the way up to A-level and university classes and may appear to be confusing to some students, especially younger ones.

This solution will present a graphical representation of some common algorithms that are both efficient and inefficient. It will highlight that there is no 'perfect' algorithm and many choices are based on the context of the data used. This solution is intended for educational purposes.

Stakeholders

The stakeholders are made up of those with an interest in Computer Science. With those that are just curious about the subject to those that are studying it at GCSE, Vocational and A-Level. Potential users are those that have an interest in computing and/or maths and want to know how sorting and searching algorithms work, as well as how they perform in comparison to each other.

Teachers and tutors may use this also, to teach their students about these algorithms in a simple way. Users will select an algorithm, give it data to populate the array or have it randomly generated and watch how each one performs. Students will use this program for a few minutes at a time, depending on the algorithm used, how complex the array is and the number of algorithms they want to look at.

This could be a useful revision tool as it gives students quick access to a variety of algorithms from a laptop / desktop pc.

The designer will maintain the code, keep it neat and easy to understand and respond to the feedback of stakeholders/users.

Existing Solutions

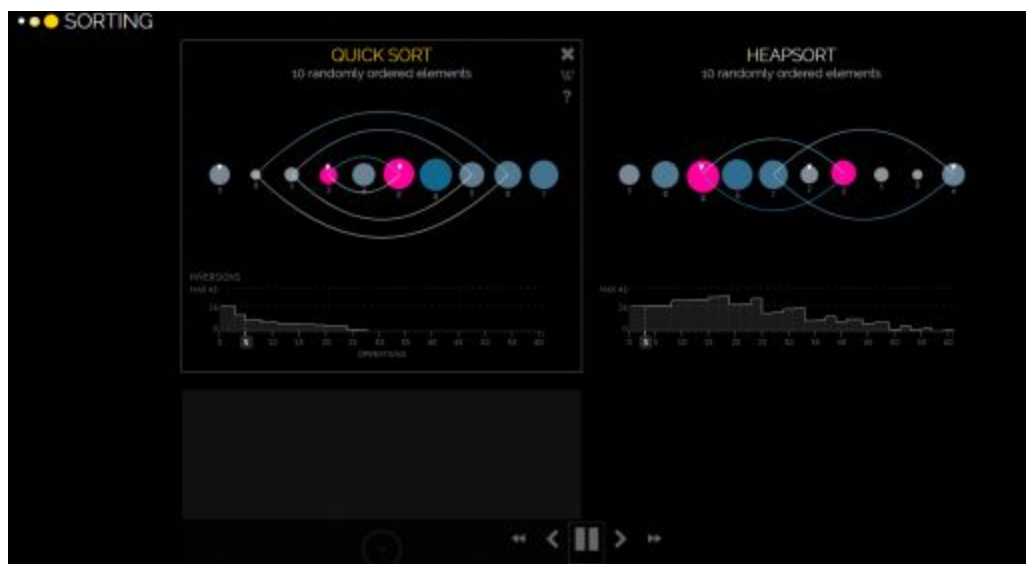
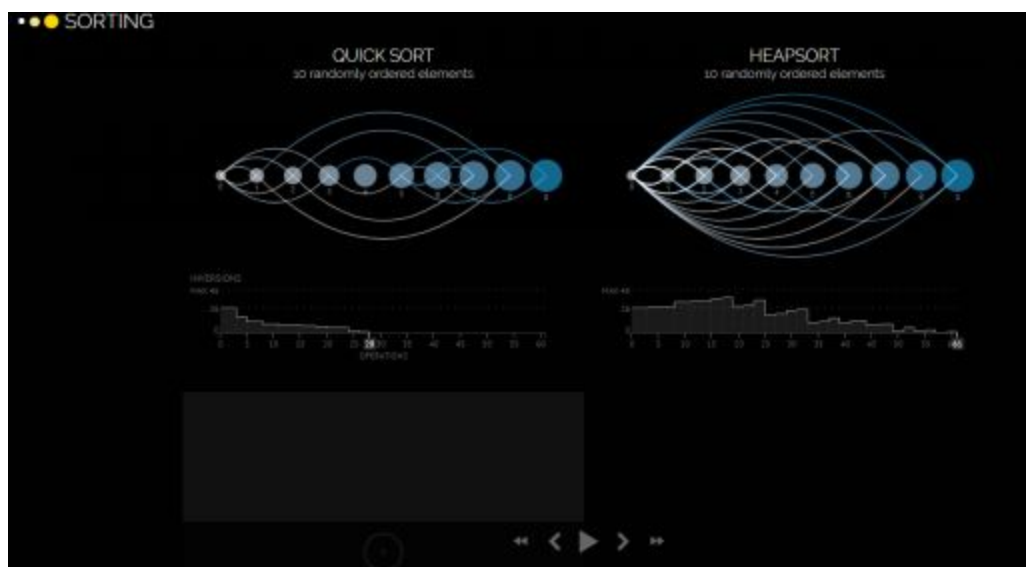
Two current solutions are sorting.at and visualgo.net/bn/sorting. These are both web-based solutions to sorting algorithms. Both of them have a limited amount of input available to the user. Sorting.at can have multiple sorts running at the same time, thanks to this it is easier to see which sort performs better depending on context.

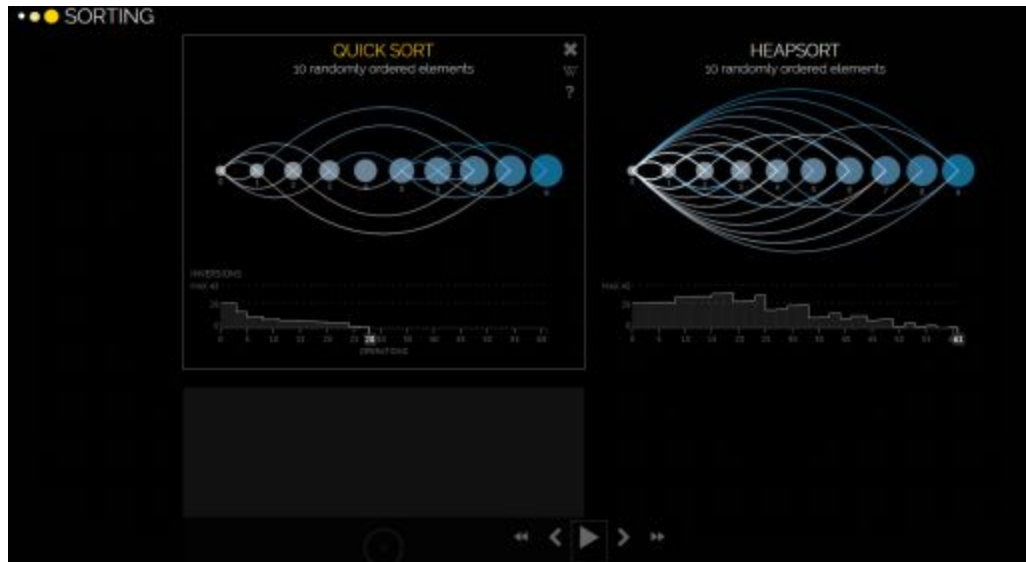
However, it may seem a little complicated at first but it does link to the respective Wikipedia article to explain each sort.

visualgo.net's representation is much more intuitive and the pseudocode for each sort goes alongside the visuals as it runs. It also gives more freedom to the user with the data being used.

From research into existing solutions, I have concluded that my own solution would benefit largely from having pseudocode alongside each sort to aid the explanation process, this is because users are likely to be in the age range of 14 - 18 (and those new to coding concepts) and these users may find it much easier to understand basic pseudocode rather than code in a specific language alongside it. Pseudocode also allows for users to carry it over into another programming language if they wish to try code something similar for themselves.

[Sorting.at](https://visualgo.net)





COLOR

SIZE

5
10
20
50
75
100

INITIAL CONDITION

Random
Nearly sorted
Reversed
Few unique

+
VISUALIZE ALGORITHM

visualgo.net/bn/sorting



Investigation

A questionnaire was posted online and shown to clients in order to gather more data on what potential users wanted from the program. The questions and results are as follows:

- Should both sorting and searching algorithms be in the same program?
 - Yes, put them both together (11)
 - No, make a separate program for each (8)
- how much data would you like to be usable in the program?
 - 10 integers (1)

- 20 integers (4)
 - 30 integers (1)
 - 40 integers (0)
 - 50 integers (4)
 - 100 integers (7)
 - Other (please specify) (1)
 - ◆ As much as the user wants
- Please list any sorting/searching algorithms you would like to see/know of. N/A if you know none
 - Pancake sort (1)
 - Stooge sort (1)
 - Comb sort (1)
 - Bubble sort (9)
 - Merge sort (4)
 - Insertion sort (2)
 - Quick sort (1)
 - Bogosort (2)
 - Stalin sort (1)
 - Binary search (4)
 - Linear search (4)
 - Fibonacci search (1)
 - As many as possible (1)
 - N/A (5)
 - If you own a desktop/laptop computer, what are it's specifications? (RAM and clock speed + cores)
 - <2GB RAM and <1.8Ghz quad-core (6)
 - >= 2GB RAM and >1.8Ghz quad-core (10)
 - N/A (1)
 - Other (please specify) (2)
 - ◆ 4GB RAM 1.7Ghz dual-core (1)
 - ◆ 8GB RAM 1.7Ghz dual-core(1)
 - With a visual representation of sorting and searching algorithms using bars, what colour should the bars and background be?
 - Dark grey background and light blue/purple bars (1)
 - Black background and white bars with different colour to highlight current element (1)
 - Black background and white bars (2)
 - Black background and red bars (1)
 - Grey background and red bars (1)
 - Grey background and white bars (1)
 - Anything with good contrast (2)

- Green bars and white background (1)
 - Blue bars and white background (2)
 - Customisable by user (1)
 - Orange bars and black background(1)
 - N/A (4)
- Should users be able to input their own data or should it be randomised?
 - Yes, users should be able to input their own data (14)
 - No, data should be randomised (4)
 - N/A (1)
- Should pseudocode (simplified version of code) be shown alongside each sort/search?
 - Yes (13)
 - No (5)
 - N/A (1)
- What font and font colour should be used?
 - Roboto, white (2)
 - Ariel, black (2)
 - Comic sans, red (1)
 - Comic sans, black (2)
 - Black colour (1)
 - Carrier, black (1)
 - JetBrains mono, black (1)
 - Consolas, black (1)
 - User decides (1)
 - Times new roman, black (1)
 - N/A (6)
- How large should integers used in the program be allowed to be?
 - <10 (1)
 - <20
 - <30
 - <40 (1)
 - <50 (3)
 - <100 (11)
 - Other (please specify) (3)
 - ◆ >100 (1)
 - ◆ <65535 (1)
 - ◆ As much as the user wants (1)
- Should results be stored in a text file to be referred to afterwards?
 - Yes (14)

- No (4)
- N/A (1)

Solution Requirements and Success Criteria

The solution requirements and success criteria consist of data collected from the research on existing solutions, the research survey and my own thoughts. This may be updated at a later date as development continues.

1. To show a list of all searches and sorts available to the user for ease of use.
 - 1.1. Font size must be large enough so that all users can read it.
 - 1.2. Font must be clear so that all users can read. For example, no joke fonts such as Wingdings.
 - 1.3. Font, background and bars must be in contrasting colours. For example, a black background with white bars (grey when selected) and yellow text
2. To allow users to enter their own data if they want to know how a certain data set is processed with each sort, or let it be randomised.
 - 2.1. data must be integers - strings cannot be sorted, floats cannot due to restraints of library being used.
 - 2.2. data must be positive - negative integers would not work, due to nature of how displaying bars will work.
 - 2.3. integers must not be higher than 400 (previously 100) - due to visual restraints.
 - 2.4. array must contain more than one item - otherwise it will always be sorted
 - 2.5. array must contain no more than 150 (previously 100) items - due to time restrictions, some algorithms can be slow
 - 2.6. Duplicate data is allowed
3. To provide a visual representation of the data, this makes it easier for those who don't understand how sorts/searches work.
 - 3.1. bars must be clear to see - can easily see where bars are and their relative size.
 - 3.2. animation must appear fluid - can't be too slow, may not be possible depending on technical specifications of the user's device.
 - 3.3. bars will be white before the sort begins, red when not sorted, green when fully sorted and grey when highlighted.
4. To provide pseudocode for each sort to allow users to replicate each sort/search in their preferred programming language if they wish to.
 - 4.1. text of pseudocode must appear alongside the visual representation - to know which sort goes with each code
 - 4.2. text must follow some of the same rules as the sort/search list: large and clear. - so users can read it
 - 4.3. colour will be orange - to stand out from other text.

5. To store results in a text file for sorts to allow users to look back on previous data.
 - 5.1. store steps of each sort in the file - see step by step afterwards what happened
 - 5.2. file will be .txt - this keeps file sizes to a minimum, and all devices can read .txt files.

Computational Methods

The program will be created using a divide and conquer approach. It will be split up into several procedures that will each handle an aspect of the solution. This will allow for decomposition and code reuse as one procedure can be used at several points in the program. For example, creating an array will happen a lot during the program depending on how many algorithms the user wants to try. Because of this a procedure will be created to make arrays that can then be called at various stages in the program's execution. Additionally, merge sort and quick sort utilise the divide and conquer approach themselves.

A core concept of the sorting and searching algorithm world is Big O notation, the algorithms used in the program are tractable as none go above $O(n^2)$. As such the use of a heuristic approach is unnecessary. The algorithms used in this program will take a reasonable time to complete e.g. no $O(n!)$ time complexity.

Another instrumental concept in this solution is visualisation, by the end of program development, users will be able to see in a simple - abstracted (reduced from complex inner workings of algorithm to simple bars sized relatively to each other) - way what happens in the various algorithms. This allows (some) complex procedures to be reduced to a simple array of bars, providing a straightforward view for users. This will be especially helpful for younger users who may be interested in the topic but don't yet have the knowledge to understand the inner workings of each algorithm.

System Requirements

- 1.8 GHz or faster processor. Quad-core or better recommended
- 2 GB of RAM; 8 GB of RAM recommended (2.5 GB minimum if running on a virtual machine)

-Taken from <https://docs.microsoft.com/en-us/visualstudio/releases/2019/system-requirements>

→ Actual requirements will be substantially less than this

- A computer using the Windows OS because the file will be .exe so not usable on Linux, Mac or mobile phones

Design

Objective

The interface should look clean and be user friendly. The following are the ways in which I intend to achieve the objective, these were obtained partly through the research survey - though are subject to change until the solution is complete.

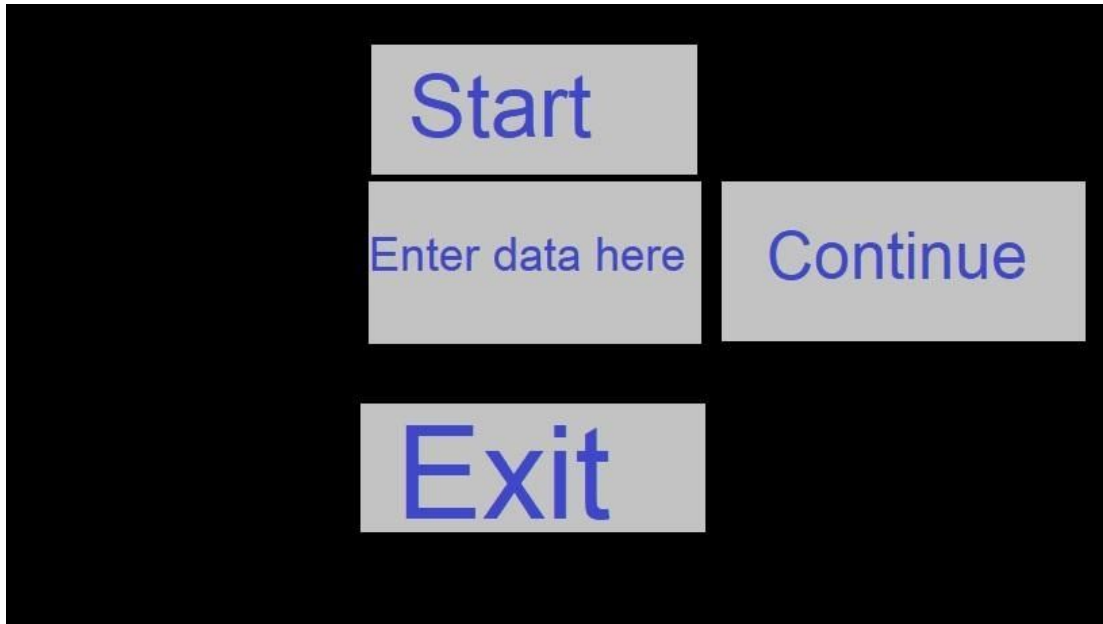
1. Black background so that the screen is not too bright so comfortable for night use
2. White bars to act as a contrast to the background
3. Red bars for when the list is not sorted
4. Green bars for when the whole list is sorted
5. Grey bars for when bar(s) are being selected
6. Grey boxes around menu buttons
7. Yellow (previously blue) text in Comic Sans - Roboto is unavailable in Visual Studio - for menu and more contrast for easy viewing
8. Orange text for pseudocode to separate it from the rest

Interface Design

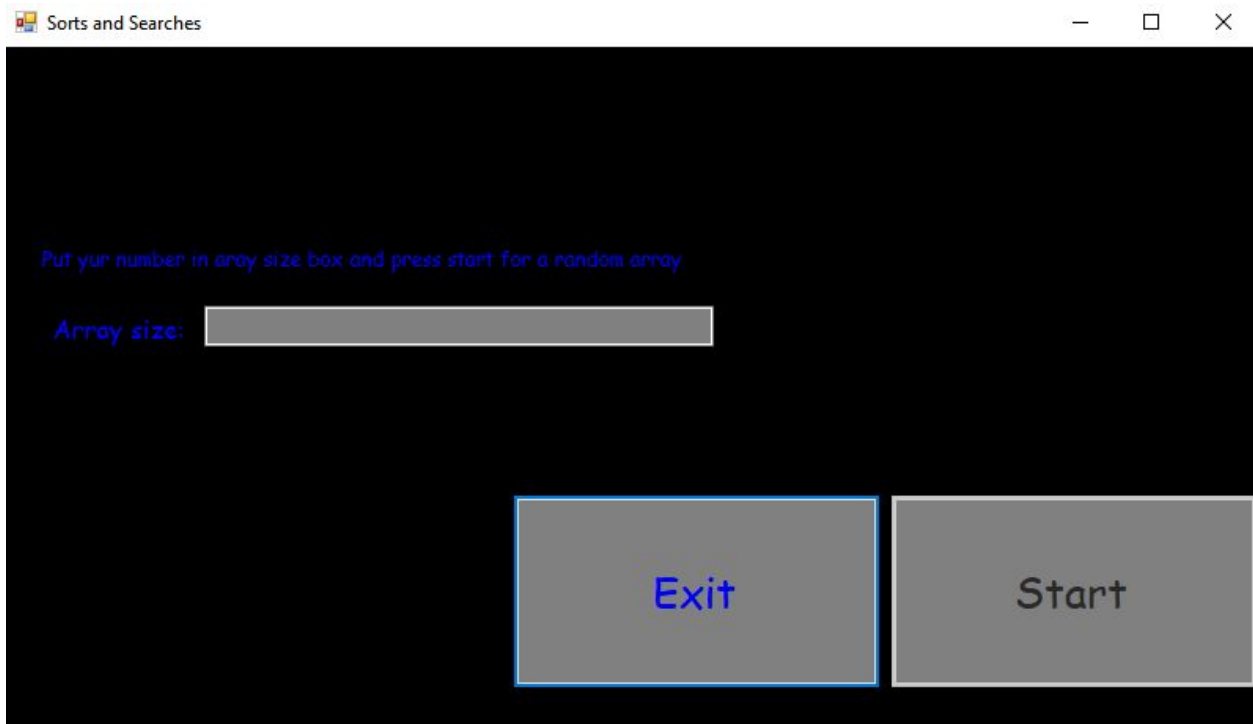
These are some basic designs for the main menu and sort and search screen. These were designed based on the questionnaire sent to stakeholders and other potential users, they were designed with simplicity in mind. They will be updated here when major changes are made.

Main Menu

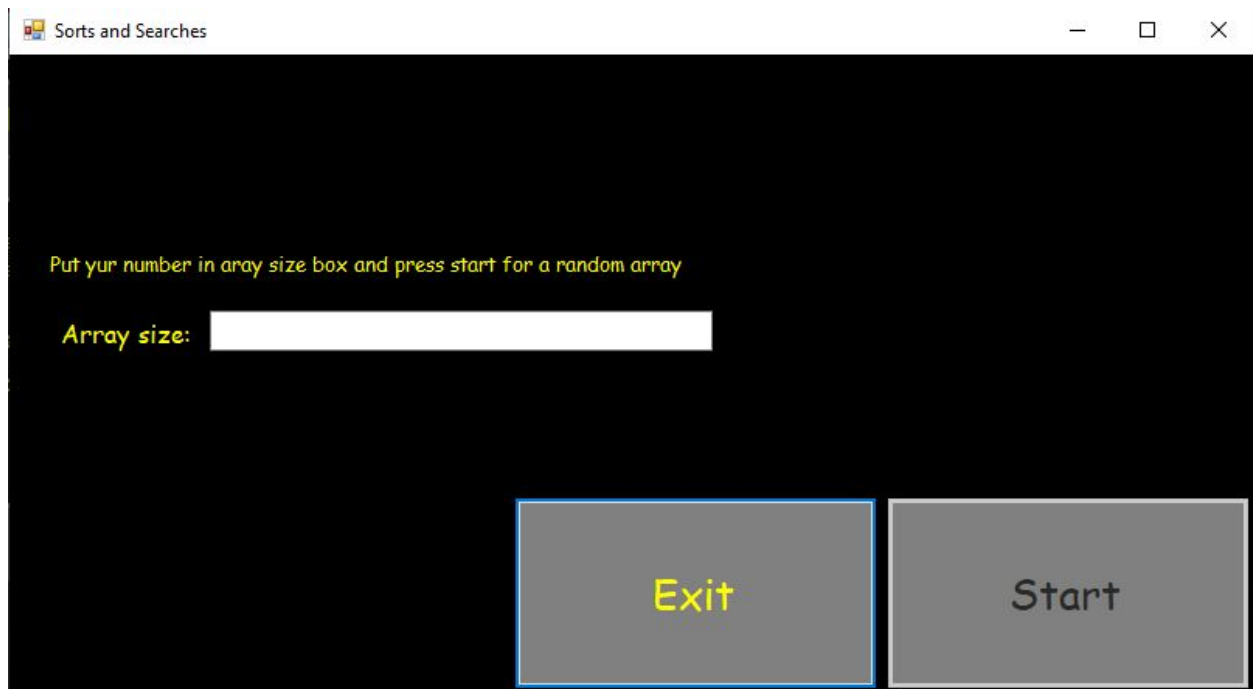
Original design



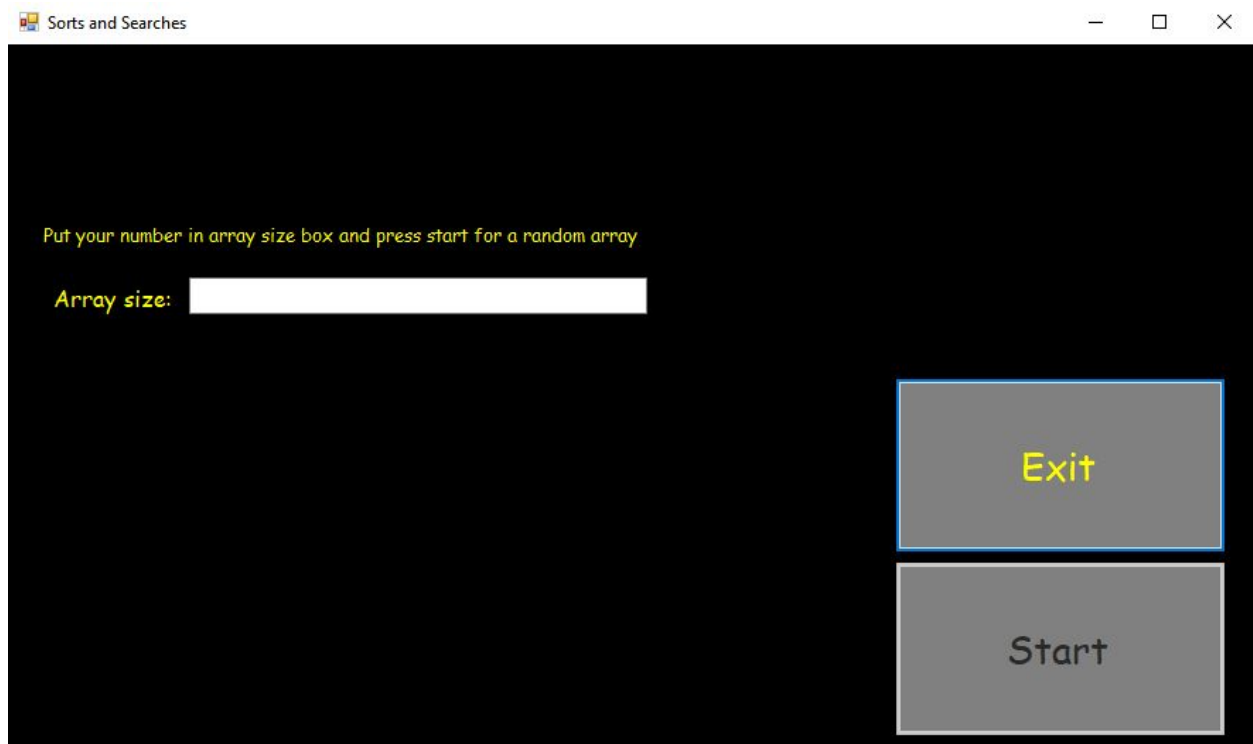
Version 1.1



Version 1.2

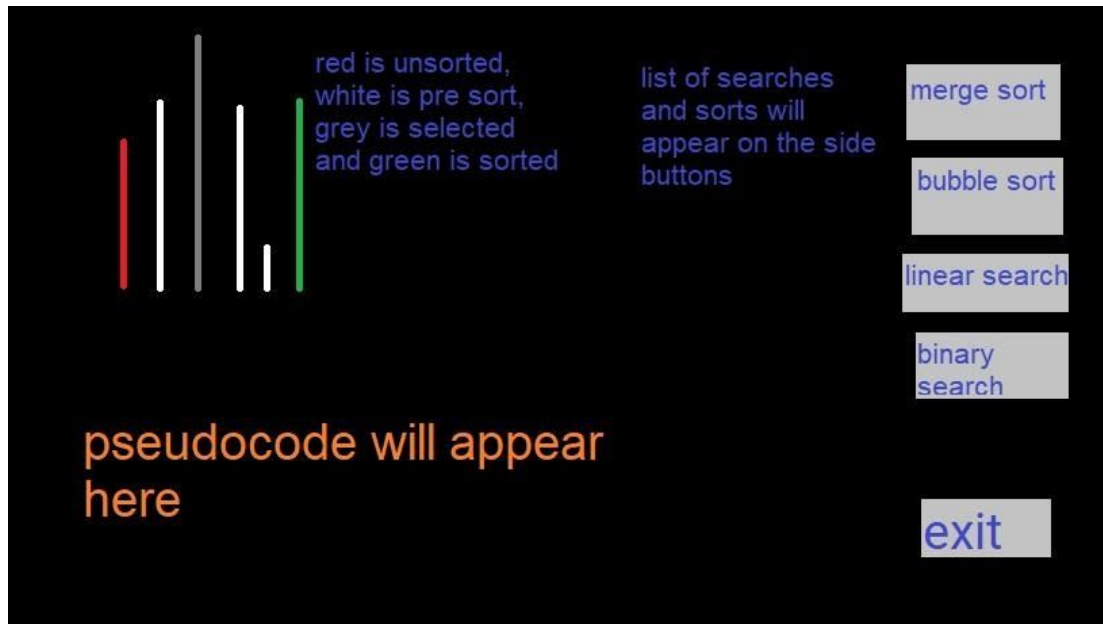


Version 2.3

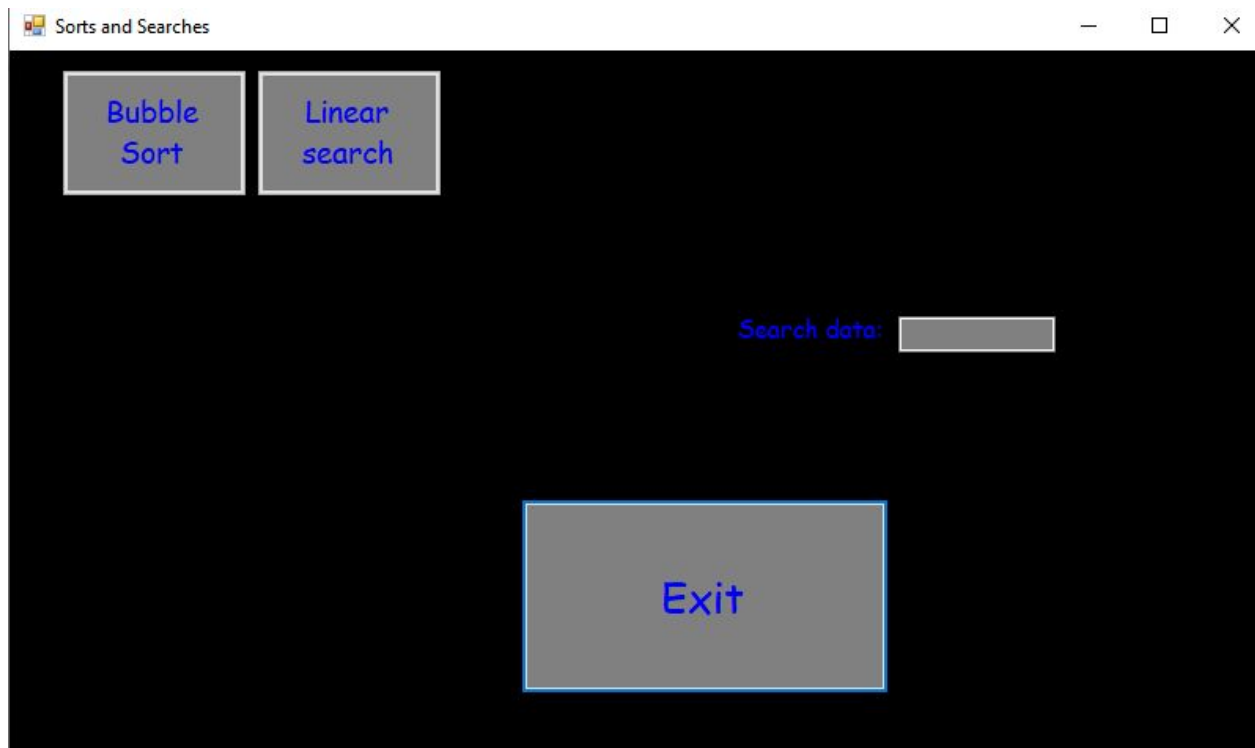


Sorts and searches

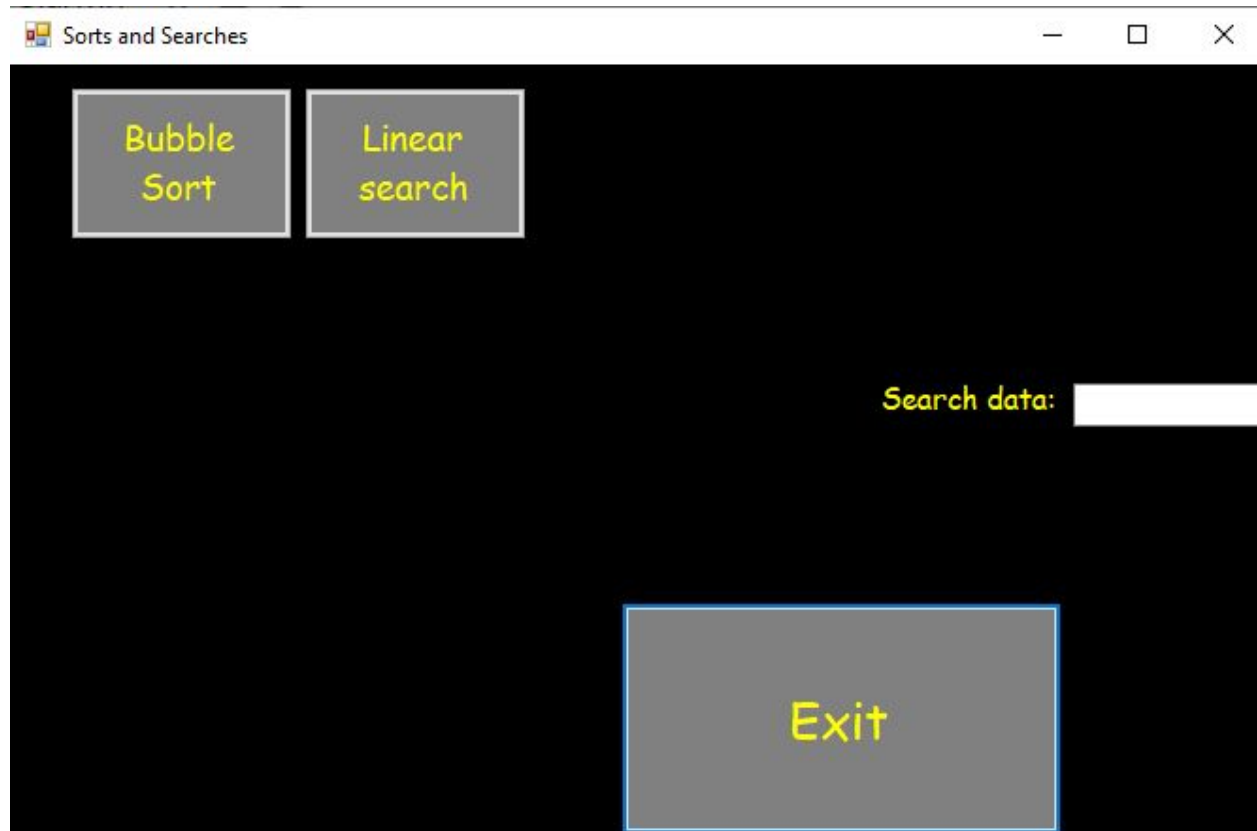
Original design



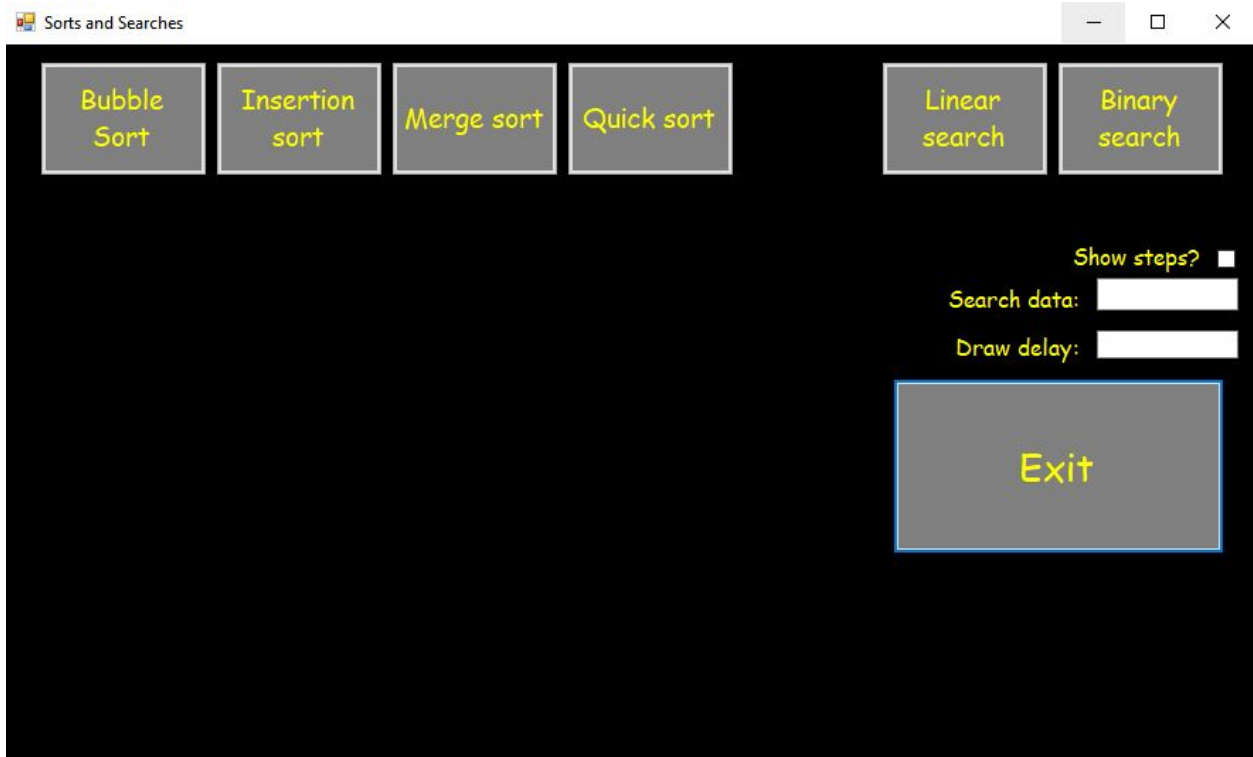
Version 1.1



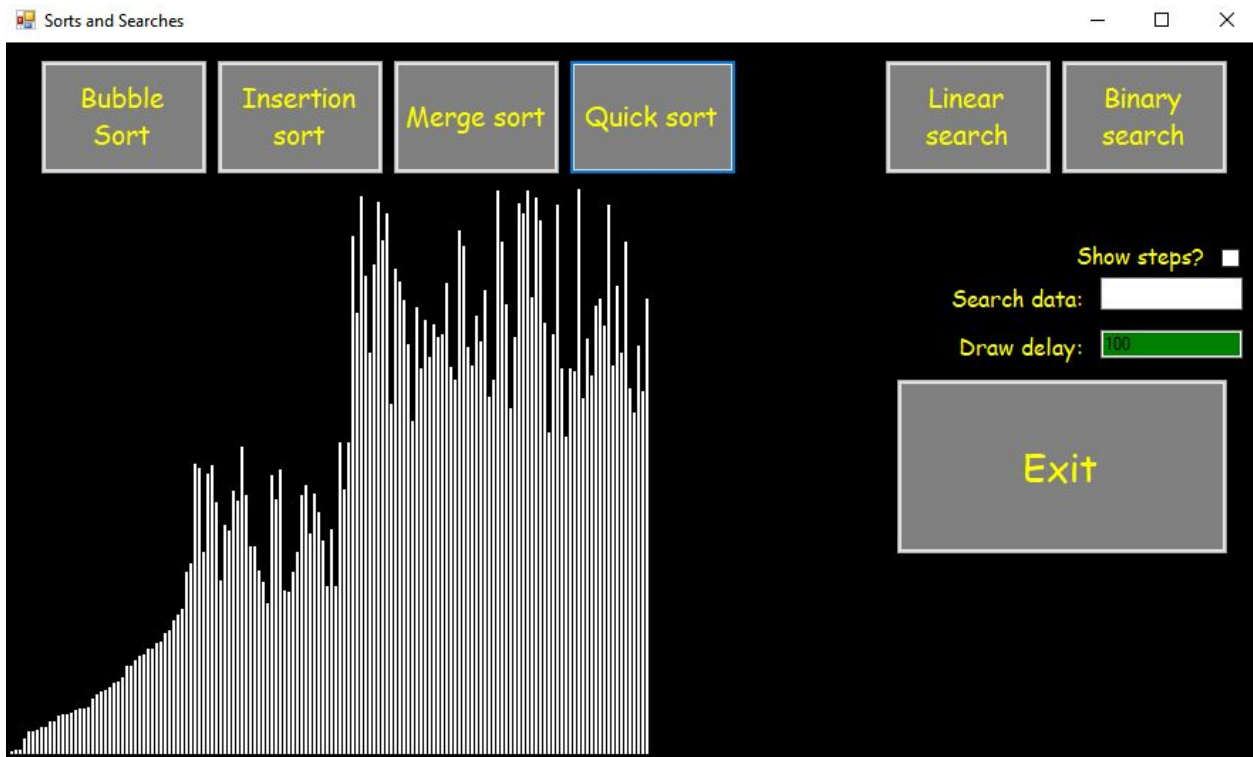
Version 1.2



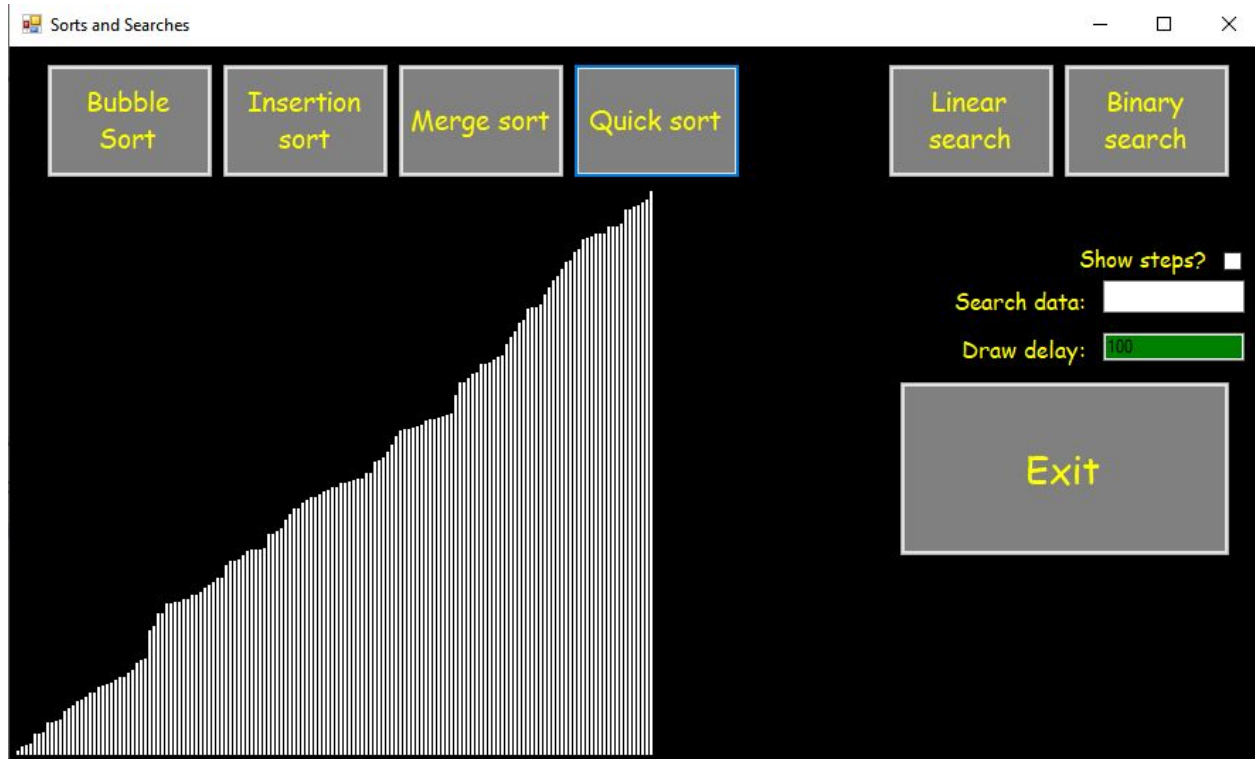
Version 2.3



Mid-sort



Post-sort



Decomposition and Flowcharts

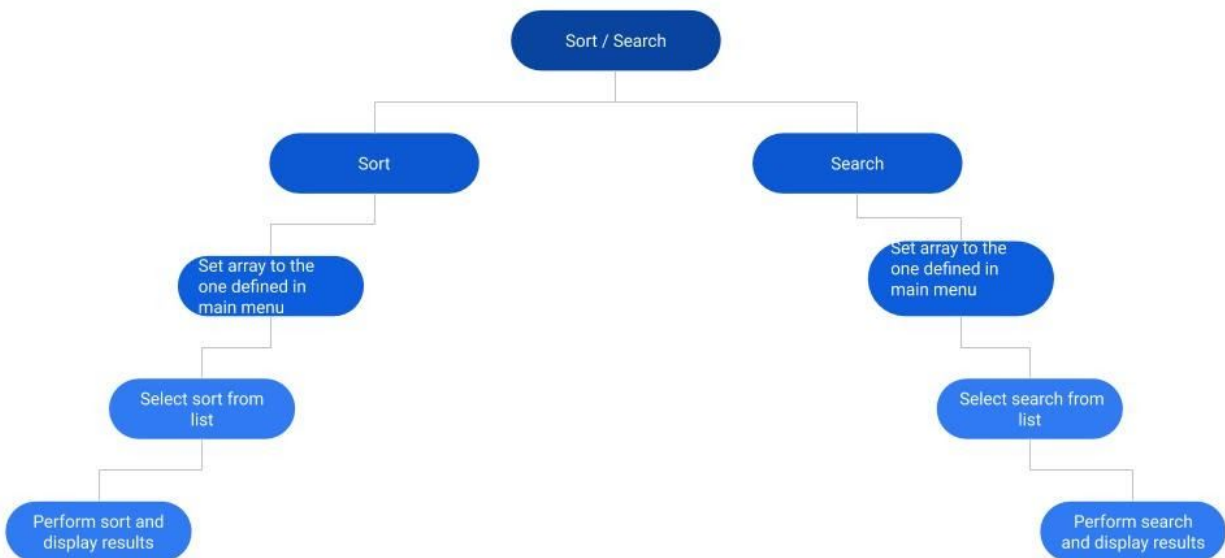
Below are the decompositions and flowcharts of the program. These outline the main features of it in a simple format.

Main Menu Decomposition

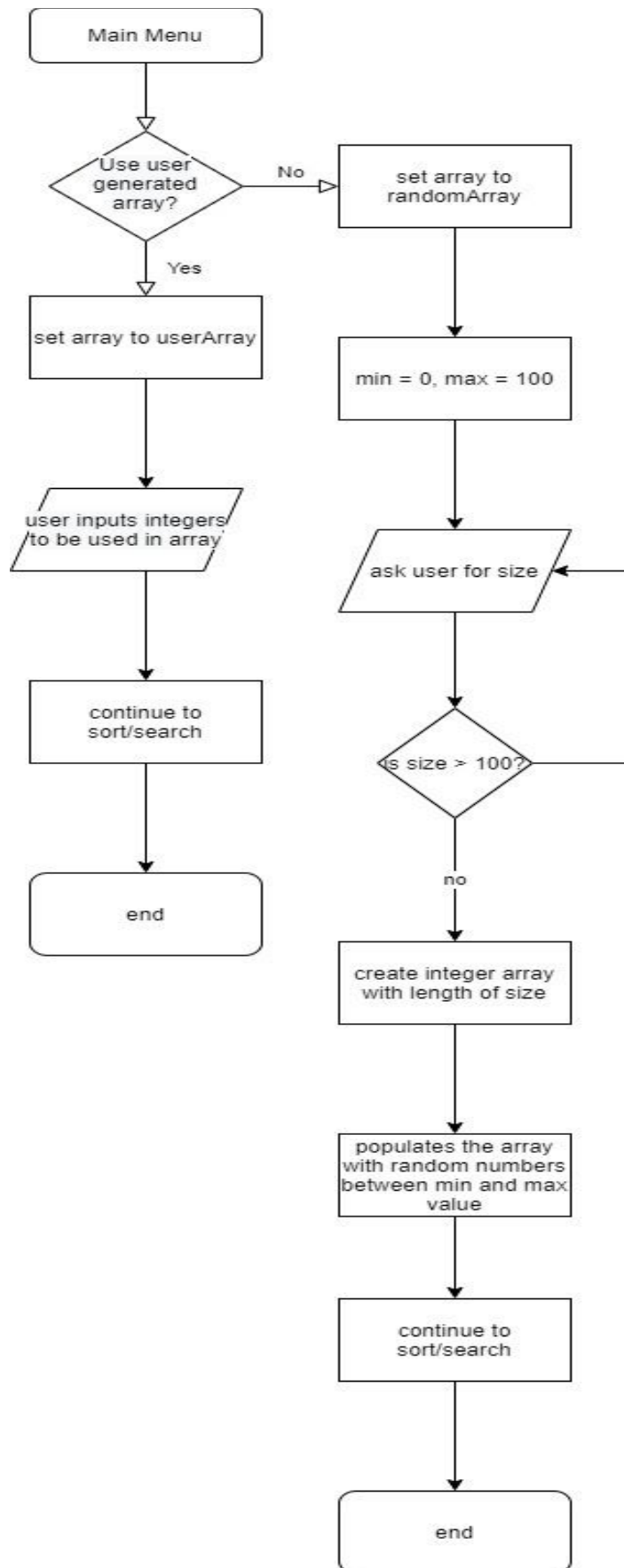


Sort/Search decomposition

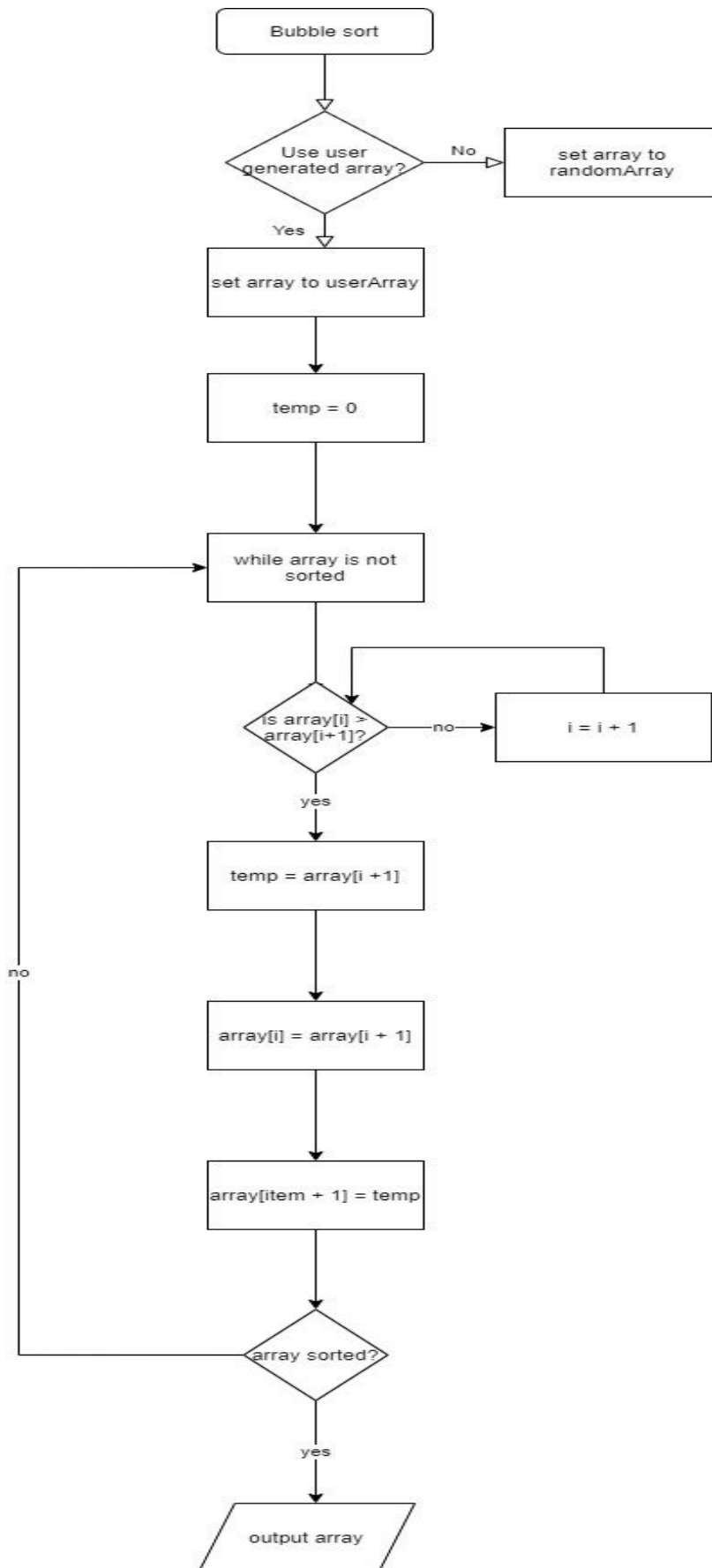
Details of one of each (will be updated with others) sort and search will be displayed through pseudocode.



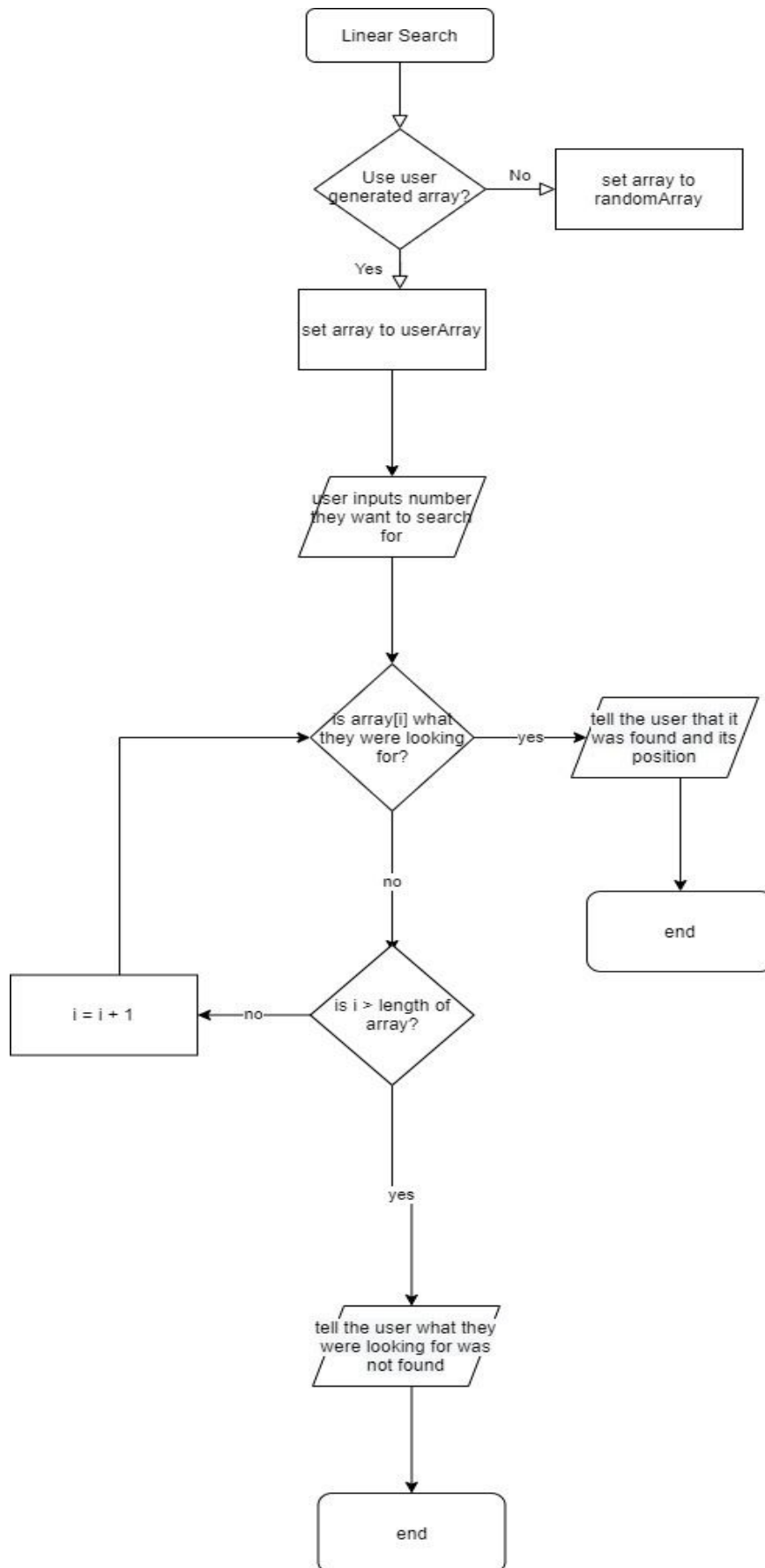
Main Menu Flowchart



Bubble Sort Flowchart



Linear Search Flowchart



Data Dictionary

Pseudocode Data Dictionary:

Identifier	Description	Data type	Validation / specification	Scope
strRandomOrUser	Will be used to store whether the user wants to choose their own array or have it randomly generated by the program	string	"random" or "user" - case will not matter, program will convert it to lowercase	MainMenu
intLength	Stores the length of the randomly generated array	integer	Less than 100	MainMenu
constMin	Stores the lowest number that the random number generator will pick	constant	0	MainMenu
constMax	Stores the highest number that the random number generator will pick	constant	100 - due to visual/memory limits	MainMenu
randomArray	An array of the random numbers	array	Length is decided by user Integers only	MainMenu, BubbleSort, LinearSearch

strData	Stores the integers picked by the user	string	should only contain integers within the string	MainMenu
userArray	Stores the integers picked by the user in an array	array	Integers only	MainMenu, BubbleSort, LinearSearch
strSplit	Splits the string of inputs into individual integers using the .split() function	string	It should turn the string into individual integers	MainMenu
strContinue	Stores if the user wants to continue with the program or exit	string	"continue" or "exit" - case will not matter, program will convert it to lowercase	MainMenu
intTemp	A temporary variable	integer	0 to begin with. Will always be an integer	BubbleSort
strArrayChoice	Stores if the user wants to use random array or user array	string	Y/N case doesn't matter	BubbleSort, LinearSearch
array	Stores all the integers to be sorted	array	integers only	BubbleSort, LinearSearch
intFind	Stores the number that the user wants to search for	integer	between 0 and 100	LinearSearch

Sample Pseudocode

This section contains some sample pseudocode from each area of the program. These have been written as if to be used in a 'console application'. However, the solution will be a 'windows forms application', as such the pseudocode will not strictly follow how the C# code will look, due to the GUI nature of the program rather than a CLI application.

Main Menu

//Main menu

Start MainMenu

strRandomOrUser = input ("Enter your own array data or use a randomised array. Please enter random or user - case is not important") //tells the user they have the choice of choosing their own array and using a random one and gets them to choose

If randomOrUser == "random" do //if the user chooses a random array

 intLength = input ("How long do you want the array to be? Max = 100 due to visual restraints") //asks the user how many integers they want in their array

 constMin = 0 //sets the lowest possible number to 0

 constMax = 100 //sets the highest possible number to 100

 randomArray[] = int[length] //creates an integer array with length specified by the user

 For i in length do //creates a loop with size of array

 randomArray[i] = randomInt (min, max) //sets the first number to a random integer between 1 and 100. This will repeat itself until the array is full of randomly generated numbers.

else //if the user chooses to enter their own integers

 strData = input ("Enter your integers with a space in between each one. Please enter a maximum of 100 that are up under or equal to 100 in size. If you don't do this the program will not work.") //gets the user to input their integers

 userArray = int[] //creates an integer array

 strSplit = data.split() //splits up the input into individual integers from the input string

 For i in split do //for each integer in the splitted list

 userArray[j] = i // sets the first number to the first number from the splitted list. This will repeat until all elements of the split are in the array

```

strContinue = input("Continue to sort or search or exit? Please enter continue or exit - case does
not matter") //asks the user if they want to continue to the sort/search or exit the program
if strContinue == "continue" do
    continue()
else
    exit()

```

Bubble Sort

//Bubble sort

Start BubbleSort

IntTemp = 0 //creates a variable with an integer value of 0

strArrayChoice = input ("Use random array? Y/N") //asks the user if they want to use the random array

```

if arrayChoice == "Y" then //if the user picks yes
    array = randomArray //sets the array used in sort to be a random one
else //if they didn't pick random
    array = userArray //uses a user made array instead

```

```

for item in array do //creates a loop with size of the array
    print(array[item]) //displays each element in the list

```

```

for item in array -1 do //creates a loop with size of the array - 1
    for item in array -1 do
        if array[item] > array[item+1] //if the first number is bigger than the second
            temp = array[item+1] //gives the temporary variable the value of the first
number
            array[item] = array[item+1] //sets the first number to the second number
            array[item+1] = temp //sets the second number to the temporary variable -
the larger number

```

//this swaps the numbers e.g. 7,2 will become 2,7

//this will repeat for each number in the list continuously until all numbers are sorted in ascending order

```

For item in array do
    print(array[item]) //displays all the numbers in the list. At this point they should be in
order

```

End

Linear Search

//Linear search

Start LinearSearch

```
strArrayChoice = input ("Use random array? Y/N") //asks the user if they want to use the
random array
if strArrayChoice == "Y" then //if the user picks yes
    array = randomArray //sets the array used in sort to be a random one
else //if they didn't pick random
    array = userArray //uses a user made array instead

intFind = input ("Search for which number: ") //asks the user to input a number to search for

For item in array do //creates a loop with size of the array
    If array[item] == find //if the current number is the number that is being searched
        print (find+" found at position"+item.position) //displays the number and its
position
    else //if the number was not found
        Print (find+" not found in array") tells the user that it was not found in the array
```

End

Development of the coded solution

Screenshots of **working** code will appear below

Plan for each iteration

Iteration 1

Iteration 1 should include a random array feature and at least bubble sort and linear search for some basic functionality. If possible, it should also have the ability to put in your own array. Some levels of validation should be present. User interface will be basic at this point and may not be the most usable.

Iteration 2

Iteration 2 should include bubble sort, insertion sort, merge sort, quick sort, linear search and binary search. It should have the option to have either a random array or user generated array implemented adequately. The interface should be easy to use and more validation should be present. The program must also display bars to represent the sorting process visually.

Iteration 3

As the final iteration it should involve all sorts and searches mentioned in the analysis section, if that is not possible then all ones mentioned in the AQA A Level CS specification (those in Iteration 2). The interface should be easy to use and understand for anyone, and sufficient help should be provided by the program if users need it, along with pseudocode accompanying the sort/search process. Add the option to save steps/results to a text file.

All of this should have been achieved (by iteration 3) to meet the needs of users:

1. *To show a list of all searches and sorts available to the user for ease of use.*
 - 1.1. *Font size must be large enough so that all users can read it.*
 - 1.2. *Font must be clear so that all users can read. For example no joke fonts such as Wingdings.*
 - 1.3. *Font, background and bars must be in contrasting colours. For example a black background with white bars (grey when selected) and blue text*
2. *To allow users to enter their own data if they want to know how a certain data set is processed with each sort, or let it be randomised.*
 - 2.1. *data must be integers - strings cannot be sorted, floats cannot due to restraints of library being used.*
 - 2.2. *data must be positive - negative integers would not work, due to nature of how displaying bars will work.*
 - 2.3. *integers must not be higher than 400- due to visual restraints.*
 - 2.4. *array must contain more than one item - otherwise it will always be sorted*
 - 2.5. *array must contain no more than 150 items - due to time restrictions, some algorithms can be slow*
 - 2.6. *Duplicate data is allowed*
3. *To provide a visual representation of the data, this makes it easier for those who don't understand how sorts/searches work.*
 - 3.1. *bars must be clear to see - can easily see where bars are and their relative size.*
 - 3.2. *animation must appear fluid - can't be too slow, may not be possible depending on technical specifications of the user's device.*
 - 3.3. *bars will be white before the sort begins, red when not sorted, green when fully sorted and grey when highlighted.*
4. *To provide pseudocode for each sort to allow users to replicate each sort/search in their preferred programming language if they wish to.*
 - 4.1. *text of pseudocode must appear alongside the visual representation - to know which sort goes with each code*

- 4.2. *text must follow some of the same rules as the sort/search list: large and clear. - so users can read it*
- 4.3. *colour will be orange - to stand out from other text.*
- 5. *To store results in a text file for sorts to allow users to look back on previous data.*
 - 5.1. *store steps of each sort in the file - see step by step afterwards what happened*
 - 5.2. *file will be .txt - this keeps file sizes to a minimum, and all devices can read .txt files.*

Main Menu

The purpose of the main menu is to allow the user to input their own array if they choose to or to have a random one generated for them. They must always supply a length of the array (as of iteration 1.1). Arrays can only contain random data for now.

Implementation in iteration 1

Form Initialisation

```
private void Form1_Load(object sender, EventArgs e)
{
    btnBubbleSort.Visible = false; //hides the buttons and labels at the start

    btnLinearSearch.Visible = false;

    btnDrawBars.Visible = false;

    lblSearch.Visible = false;
    txtSearchData.Visible = false;

    lblArrayData.Visible = false;
    txtInput.Visible = false;

    btnShowList.Visible = false;
    btnAddNumber.Visible = false;

    btnArrayHelp.Visible = false;

    lblInput.Visible = false;

    btnStart.Enabled = false;
}
```

Exit

```
private void btnExit_Click(object sender, EventArgs e) //if the exit button is clicked
{
    MessageBox.Show("Closing program"); //opens a message box telling the user the program is going to close
    Application.Exit(); //closes the program
}
```


Creating random array

```
//only array creating function working (18.11.20)
3 references
private int[] createRandomArray() //function for creating a random array
{
    int arraySize = int.Parse(txtArraySize.Text); //sets the size of the array to the number in the array size text box chosen by the user
    int[] arrayData = new int[arraySize]; //creates the array with the size made above
    int min = 1; //sets min number to 1
    int max = 100; //sets max number to 100

    Random randNum = new Random(); //initialises the random class
    for (int k = 0; k < arrayData.Length; k++) //for the length of the array
    {
        arrayData[k] = randNum.Next(min, max); //generates a random number between 1 and 100 for each position in the array. for example size 4: 3,87,14,8
    }

    return (arrayData); //returns the new array
}
```

Array size text box validation

```
//particularly important as is is used for both user input array and random array
1 reference
private void txtArraySize_TextChanged(object sender, EventArgs e)
{
    int parsedValue; //temporary variable for parsing statement
    if (txtArraySize.Text == string.Empty) //if the box is empty
    {
        MessageBox.Show("This box cannot be empty"); //tells the user the box should not be empty empty
        txtArraySize.BackColor = Color.Red; //changes the box colour to red
        btnAddNumber.Enabled = false; //disables the button
        btnShowList.Enabled = false;
        btnStart.Enabled = false;
    }

    else if (!int.TryParse(txtArraySize.Text, out parsedValue)) //this statement was adapted from: https://stackoverflow.com/questions/15399323/validating-whether-a-textbox-contains-only-numbers - it checks if the text in the box is an not an integer
    {
        MessageBox.Show("This is a whole number only box. Please enter a whole number"); //tells the user they need to enter an integer
        txtArraySize.BackColor = Color.Red;
        btnAddNumber.Enabled = false; //disables the button
        btnShowList.Enabled = false;
        btnStart.Enabled = false;
    }
}
```

```
else if (int.TryParse(txtArraySize.Text, out parsedValue))
{
    int arraySize = int.Parse(txtArraySize.Text);
    if (arraySize <= 0 || arraySize > 100)
    {
        MessageBox.Show("Number must be between 1 and 100");
        txtArraySize.BackColor = Color.Red;
        btnAddNumber.Enabled = false; //disables the button
        btnShowList.Enabled = false;
        btnStart.Enabled = false;
    }
    else
    {
        txtArraySize.BackColor = Color.Green; //changes the box colour to green
        btnAddNumber.Enabled = true; //enables the button
        btnShowList.Enabled = true;
        btnStart.Enabled = true;
    }
}
```

Start button with validation

```
//at the moment this only works with the random array due to issues with creating the user array. need to look into passing arrays to functions properly. will come back to that once random array functionality is complete/working sufficiently
//reference:
private void btnStart_Click(object sender, EventArgs e) //when the user presses start
{
    if (txtArraySize.Text == string.Empty)
    {
        MessageBox.Show("Box is empty");
    }
    else
    {
        // string displayArray = string.Join(",", createRandomArray()); //creates a new variable that stores all of the numbers in the array and separates them with ',' to make it easier to read
        //MessageBox.Show(displayArray); //displays the formatted array

        //next section hides all unnecessary parts that won't be used beyond this point

        lblArrayData.Visible = false; //hides the labels
        lblArraySize.Visible = false;
        lblInput.Visible = false;

        txtArraySize.Visible = false; //hides the text boxes
        txtInput.Visible = false;

        btnAddNumber.Visible = false; //hides the buttons
        btnArrayHelp.Visible = false;
        btnShowList.Visible = false;

        btnStart.Visible = false; //hides the start button when you press it

        btnDrawBars.Visible = false; //shows the draw bars button as that option can now be used --keeps false for now

        btnBubbleSort.Visible = true; //shows the bubble sort button as that option can now be used
        btnLinearSearch.Visible = true; ///shows the linear search button as that option can now be used
    }
}
```

```
        lblSearch.Visible = true;
        txtSearchData.Visible = true;

        btnStart.Visible = false;

        lblhelp.Visible = false;
    }
}
```

Implementation in iteration 2

Updated form initialisation

```
private void sortsAndSearches_Load(object sender, EventArgs e)
{
    //hides all buttons and labels not needed at load

    btnBubbleSort.Visible = false;

    btnLinearSearch.Visible = false;

    btnInsertionSort.Visible = false;

    btnMergeSort.Visible = false;

    btnQuickSort.Visible = false;

    btnBinarySearch.Visible = false;

    btnDrawBars.Visible = false;

    lblSearch.Visible = false;
    txtSearchData.Visible = false;

    lblArrayData.Visible = false;
    txtInput.Visible = false;

    btnShowList.Visible = false;
    btnAddNumber.Visible = false;

    btnArrayHelp.Visible = false;

    lblInput.Visible = false;

    lblShowSteps.Visible = false;
    chkShowSteps.Visible = false;

    txtDrawDelay.Visible = false;
    lblDrawDelay.Visible = false;

    btnStart.Enabled = false;
}
```

Updated random array

```
//only array creating function working (18.11.20) - updated 03.01.21 for larger array size and values
7 references
private int[] createRandomArray() //function for creating a random array
{
    int arraySize = int.Parse(txtArraySize.Text); //sets the size of the array to the number in the array size text box chosen by the user
    int[] arrayData = new int[arraySize]; //creates the array with the size made above
    int min = 1; //sets min number to 1
    int max = 400; //sets max number to 400 - previously 100

    Random randNum = new Random(); //initialises the random class
    for (int k = 0; k < arrayData.Length; k++) //for the length of the array
    {
        arrayData[k] = randNum.Next(min, max); //generates a random number between 1 and 100 for each position in the array. for example size 4: 3,87,14,8
    }

    return (arrayData); //returns the new array
}
```

Updated array size box and validation

```
private void txtArraySize_TextChanged(object sender, EventArgs e)
{
    validateInput(sender);
}
```

```
private void validateInput(object sender)
{
    var textBox = (TextBox)sender;
    int parsedValue;
    if (textBox.Text == string.Empty) //if the box is empty - presence check
    {
        MessageBox.Show("This box cannot be empty"); //tells the user the box should not be empty empty
        textBox.BackColor = Color.Red; //changes the box colour to red
        btnStart.Enabled = false;
    }

    else if (!int.TryParse(textBox.Text, out parsedValue)) //format check -- this statement was adapted from: https://stackoverflow.com/questions/15399323/validating-whether-a-textbox-contains-only-numbers - it checks if the text in the box is an not an integer
    {
        MessageBox.Show("This is a whole number only box. Please enter a whole number"); //tells the user they need to enter an integer
        textBox.BackColor = Color.Red;
        btnStart.Enabled = false;
    }

    else if (int.TryParse(textBox.Text, out parsedValue)) //range check
    {
        int arraySize = int.Parse(textBox.Text);
        if (arraySize <= 0 || arraySize > 150)
        {
            MessageBox.Show("Number must be between 1 and 150");
            textBox.BackColor = Color.Red;
            btnStart.Enabled = false;
        }
        else
        {
            textBox.BackColor = Color.Green; //changes the box colour to green
            btnStart.Enabled = true;
        }
    }
}
```

Updates start button and validation

```
private void btnStart_Click(object sender, EventArgs e)    //when the user presses start
{
    if (txtArraySize.Text == string.Empty)
    {
        MessageBox.Show("Box is empty"); //not needed anymore, but just in case validation fails this acts as a failsafe
    }
    else
    {
        lblArrayData.Visible = false;
        lblArraySize.Visible = false;
        lblInput.Visible = false;

        txtArraySize.Visible = false;
        txtInput.Visible = false;

        btnAddNumber.Visible = false;
        btnArrayHelp.Visible = false;
        btnShowList.Visible = false;

        lblhelp.Visible = false;

        btnStart.Visible = false;
    }
}
```

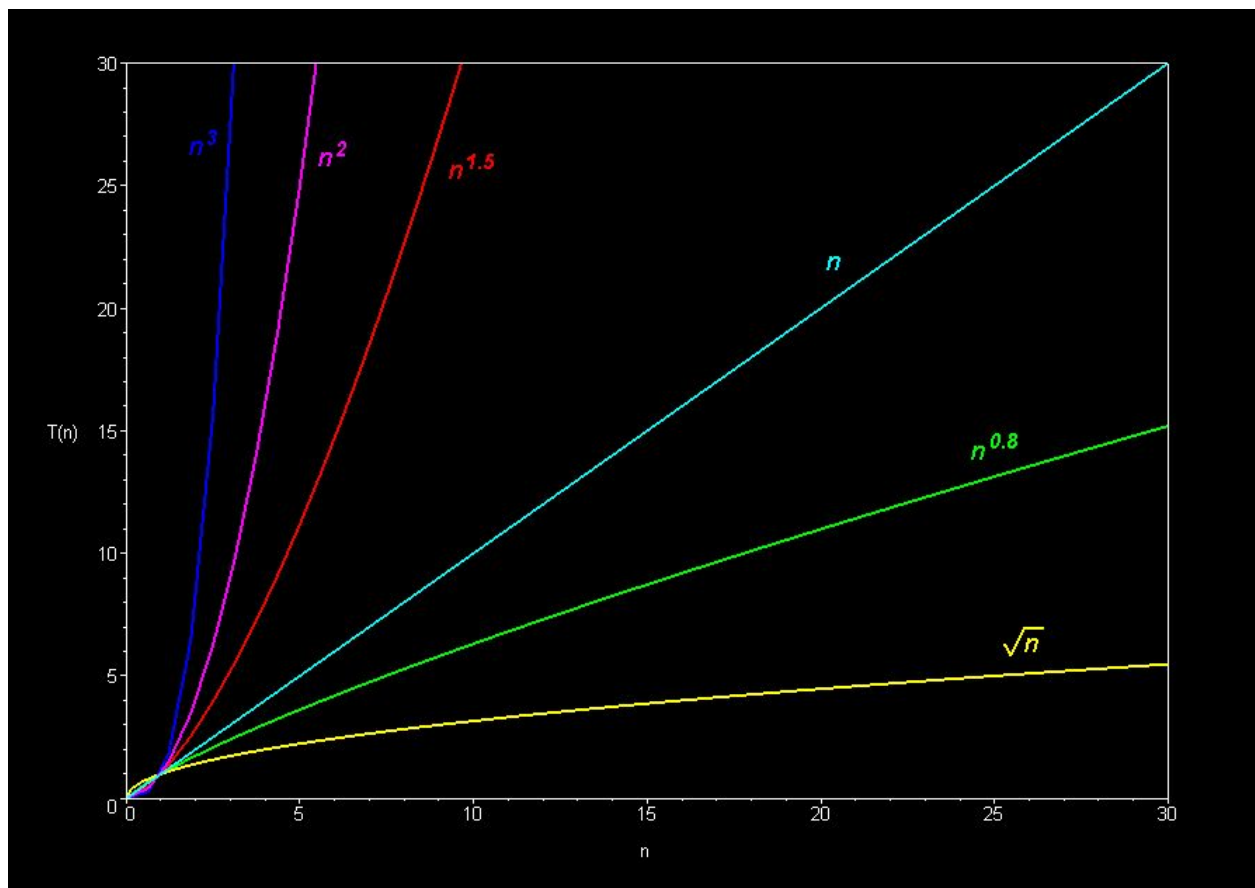
```
        btnBubbleSort.Visible = true;
        btnLinearSearch.Visible = true;
        btnInsertionSort.Visible = true;
        btnMergeSort.Visible = true;
        btnQuickSort.Visible = true;
        btnBinarySearch.Visible = true;

        lblSearch.Visible = true;
        txtSearchData.Visible = true;

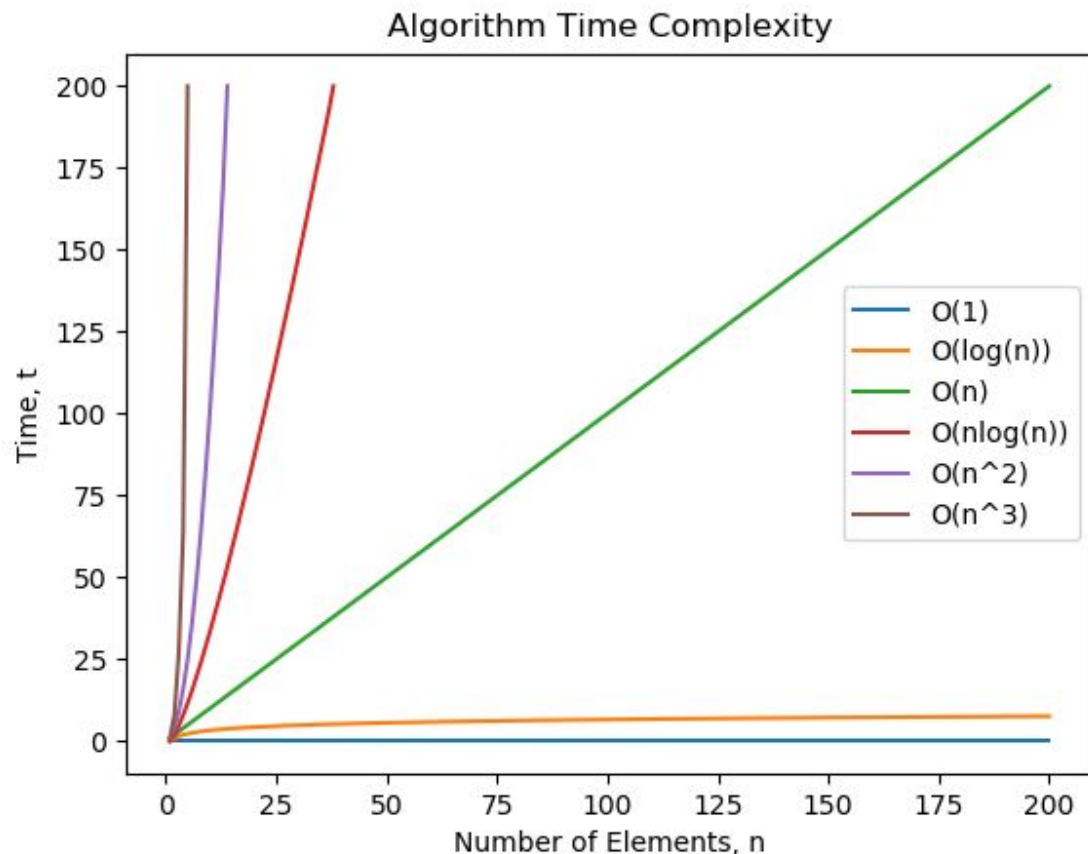
        lblShowSteps.Visible = true;
        chkShowSteps.Visible = true;

        txtDrawDelay.Visible = true;
        lblDrawDelay.Visible = true;
    }
}
```

Run-time graphs



- <http://science.slc.edu/~jmarshall/courses/2002/spring/cs50/BigO/index.html>



- <https://blog.mbedded.ninja/programming/algorithms-and-data-structures/algorithm-time-complexity/>

Sorts

Bubble Sort

Information

The Bubble sort is an extremely simple comparison polynomial sorting algorithm which works by comparing two adjacent values $[n]$ and $[n+1]$ and swaps them if they are in the wrong order. This is repeated until every item in the array is in its correct position.

Its simplicity makes it very useful for educating students as an introduction to sorting algorithms but that is where its use ends. Bubble sort is very slow when working with large data sets.

This is due to its worst case and average time complexity (expressed with Big O notation) of $O(n^2)$, where n = the number of items being sorted. This means the time it takes on average to complete the algorithm goes up with the square of the amount of items in the data set.

For example the time it would take to perform a bubble sort on 10 items would be 10^2 so 100. Whereas with 50 items it would be 50^2 so 2500, 25 times longer. The difference in time

becomes massive the larger your data set is, the Bubble sort is already quite inefficient so each step takes longer to begin with.

Button

```
1 reference
private void btnBubbleSort_Click(object sender, EventArgs e)
{
    int[] arrayData = createRandomArray();

    bubbleSort(arrayData);
}
```

Function

```
private void bubbleSort(int[] arrayData)
{
    int temp; //temporary value used for swapping two values
    string displayArray = string.Join(",", arrayData);
    MessageBox.Show("Unsorted array is " + displayArray);

    for (int i = 0; i < arrayData.Length - 1; i++) //loop will repeat as many times as length of array -1
    {
        for (int j = 0; j < arrayData.Length - 1; j++) //loop will repeat as many times as length of array -1
        {
            if (arrayData[j] > arrayData[j + 1]) //if first number is larger than second number
            {
                temp = arrayData[j]; //sets temp to the first (larger) number
                arrayData[j] = arrayData[j + 1]; //sets the first number to the second (smaller) number
                arrayData[j + 1] = temp; //sets the second number to the temp number (first number) which completes the swap

                displayArray = string.Join(",", arrayData);
                MessageBox.Show("Sorting: " + displayArray);
            }
        }
    }

    MessageBox.Show("The sorted array is " + displayArray); //shows the (hopefully) sorted array
}
```

Insertion Sort

Information

Insertion sort is another simple comparison polynomial sorting algorithm. At each iteration, insertion sort removes one element from the input data, finds the location it belongs within the sorted list, and inserts it there. It repeats until no input elements remain.

It shares the same weaknesses and strengths of bubble sort, it is slow on large lists/arrays, with its worst case and average time complexity of $O(n^2)$. It is still relatively quick on small arrays. It may share the same time complexity with bubble sort on average but it is a more efficient algorithm, therefore it completes its steps quicker, leading to it being faster than bubble sort but still heavily outclasses by sorts like merge sort and quicksort.

Variations of insertion sort include the shell sort which has variations of itself. These are generally more efficient but their time complexity depends on the gap used when comparing values.

Button

```
1 reference
private void btnInsertionSort_Click(object sender, EventArgs e)
{
    int[] arrayData = createRandomArray();
    insertionSort(arrayData);
}
```

Function

```
1 reference
private void insertionSort(int[] arrayData)
{
    int i = 0;
    int j = 0;

    int temp = 0;
    string displayArray = string.Join(",", arrayData);
    while (i < arrayData.Length) //while i is smaller than the length of the array
    {
        j = i;
        while (j > 0 && arrayData[j - 1] > arrayData[j])
        {
            temp = arrayData[j];           // }
            arrayData[j] = arrayData[j - 1]; // } swaps the two numbers
            arrayData[j - 1] = temp;        // }
            displayArray = string.Join(",", arrayData);
            MessageBox.Show("Sorting: " + displayArray);
            j -= 1;
        }
        i += 1;
    }
    MessageBox.Show("Sorted array is " + displayArray);
}
```

Merge Sort

Information

Merge sort is an efficient comparison linearithmic sorting algorithm that works by process of 'divide and conquer'. It splits the array into n (number of items in array) sublists. So each sublist contains one item to begin with. It then repeatedly merges sublists to produce new sorted sublists until there is only one sublist remaining. This will be the sorted list.

This scales well to very large lists/arrays, because its worst-case and average time complexity is $O(n \log n)$

Merge sort relies on using two functions:

1. Recursively splitting the array
2. Sort and merging the arrays into one

Despite it being a more complex algorithm it was fairly simple to implement.

Button

```
1 reference
private void btnMergeSort_Click(object sender, EventArgs e)
{
    int[] arrayData = createRandomArray();
    int[] sortedArrayData = new int[arrayData.Length];
    string displayArray = string.Join(",", arrayData);
    MessageBox.Show("Original array is " + displayArray);

    sortedArrayData = mergeSort(arrayData);

    displayArray = string.Join(",", sortedArrayData);
    MessageBox.Show("Sorted array is " + displayArray);
}
```

Functions

Splitting

```
private static int[] mergeSort(int[] arrayData)
{
    int[] left; //creates 'left' array
    int[] right; //creates 'right' array

    if (arrayData.Length <= 1) //if there is one element
    {
        return arrayData; //returns the array as it is just one element so is already sorted
    }

    int midpoint = arrayData.Length / 2; //sets midpoint to half of the array size
    left = new int[midpoint]; //sets the length of the left array to the midpoint value, so half of the numbers
    if (arrayData.Length % 2 == 0) //if there are an even number of elements in the array
    {
        right = new int[midpoint]; //sets the size of right to be midpoint value
    }
    else
    {
        right = new int[midpoint + 1]; //sets right size to one more than midpoint
    }

    for (int i = 0; i < midpoint; i++)
    {
        left[i] = arrayData[i]; //fills the left array with numbers up to midpoint
    }

    int j = 0;
    for (int i = midpoint; i < arrayData.Length; i++)
    {
        right[j] = arrayData[i]; // fills the right array with numbers from midpoint to the end
        j++;
    }

    left = mergeSort(left); //recursively splits
    right = mergeSort(right); //recursively splits
    return merge(left, right); //calls merge function to merge the lists and sort them, passing the left and right arrays
}
```

Splitting with showing steps - shows changed code

```
left = mergeSort(left); //recursively splits
right = mergeSort(right); //recursively splits
string displayLeft = string.Join(",", left);
string displayRight = string.Join(",", right);
MessageBox.Show(displayLeft + " " + displayRight);
return merge(left, right); //calls merge function to merge the lists and sort them, passing the left and right arrays
```

Merging

```
private static int[] merge(int[] left, int[] right)
{
    int sortedArrayLength = right.Length + left.Length;
    int[] sortedArray = new int[sortedArrayLength];

    int leftPos = 0;
    int rightPos = 0;
    int sortedArrayPos = 0;
    //while either array still has an element
    while (leftPos < left.Length || rightPos < right.Length)
    {
        //if both arrays have elements
        if (leftPos < left.Length && rightPos < right.Length)
        {
            //If item on left array is less than item on right array, add that item to the sortedArray array
            if (left[leftPos] <= right[rightPos])
            {
                sortedArray[sortedArrayPos] = left[leftPos];
                leftPos++;
                sortedArrayPos++;
            }
            // else the item in the right array will be added to the sortedArrays array
            else
            {
                sortedArray[sortedArrayPos] = right[rightPos];
                rightPos++;
                sortedArrayPos++;
            }
        }
    }

    //if only the left array still has elements, add all its items to the sortedArrays array
    else if (leftPos < left.Length)
    {
        sortedArray[sortedArrayPos] = left[leftPos];
        leftPos++;
        sortedArrayPos++;
    }

    //if only the right array still has elements, add all its items to the sortedArrays array
    else if (rightPos < right.Length)
    {
        sortedArray[sortedArrayPos] = right[rightPos];
        rightPos++;
        sortedArrayPos++;
    }
}

return sortedArray;
```

Merging with showing steps - shows changed code

```
}  
    string displayArray = string.Join(",", sortedArray);  
    MessageBox.Show(displayArray);  
}  
return sortedArray;
```

Quick Sort

Information

Quicksort is another divide and conquer linearithmic algorithm, however this one relies on a partition operation. To partition an array, an element called a pivot is selected. All elements smaller than the pivot are moved before it and all greater elements are moved after it. The lesser and greater sublists are then recursively sorted.

This yields an average time complexity of $O(n \log n)$ when a favourable partition is chosen. However its worst-case is $O(n^2)$. This is usually when the partition is the end or start of the list, otherwise it is very rare. In practice choosing a random pivot almost certainly yields $O(n \log n)$ performance.

Efficient implementations of quicksort are somewhat complex, but are among the fastest sorting algorithms in practice. Even a poorly optimised quick sort easily outperforms algorithms like bubble and insertion sort, despite them having the same worst case performance.

There are however faster sorting algorithms that do not rely on comparison such as radix sort, these algorithms are quite complex. They are also not required to be learnt for the AQA CS A-level or GCSE specification. Because of this they will not be covered in this program because users (if they are in high school or college) will not need to know them. They will only be included if there is sufficient time before project submission.

Many implementations of quick sort use a pivot of the first or last element of the array. Whilst this is simple and does function, it will likely lead to the time complexity of $O(n^2)$. This is the worst case scenario, as such a random pivot will be chosen to hopefully reach the average time complexity of $O(n \log n)$ - a much more favourable outcome as it will scale better with larger lists. This will use Lomuto's partition Scheme (probably).

-Currently the last element is being used.

Button

```
private void btnQuickSort_Click(object sender, EventArgs e)
{
    int[] arrayData = createRandomArray();
    string displayArray = string.Join(",", arrayData);
    MessageBox.Show("Original array is " + displayArray);

    quickSort(arrayData, 0, arrayData.Length-1); //passes the array, start position and end position
    displayArray = string.Join(",", arrayData);
    MessageBox.Show("Sorted array is: " + displayArray);
}
```

Functions

Quick Sort

```
private static void quickSort(int[] arrayData, int start, int end)
{
    if (start < end)
    {
        int pivot = partition(arrayData, start, end);

        if (pivot > 1)
        {
            quickSort(arrayData, start, pivot - 1);
        }
        if (pivot + 1 < end)
        {
            quickSort(arrayData, pivot + 1, end);
        }
    }
}
```


Partition

```
private static int partition(int[] arrayData, int start, int end)
{
    int pivot = arrayData[start];
    while (true)
    {
        while (arrayData[start] < pivot)
        {
            start++;
        }

        while (arrayData[end] > pivot)
        {
            end--;
        }

        if (start < end)
        {
            if (arrayData[start] == arrayData[end]) return end;

            int temp = arrayData[start];
            arrayData[start] = arrayData[end];
            arrayData[end] = temp;
        }
        else
        {
            return end;
        }
    }
}
```

Partition allowing for duplicate numbers

```
private static int partition(int[] arrayData, int start, int end)
{
    int pivot = arrayData[start];
    while (true)
    {
        while (arrayData[start] < pivot)
        {
            start++;
        }

        while (arrayData[end] > pivot)
        {
            end--;
        }

        if (start < end)
        {
            int temp = arrayData[start];
            arrayData[start] = arrayData[end];
            arrayData[end] = temp;

            if (arrayData[start] == arrayData[end])
            {
                start++;
            }
        }
        else
        {
            return end;
        }

        string displayArray = string.Join(",", arrayData);
        MessageBox.Show("Partitioning " + displayArray);
    }
}
```

Graphical representation of sorts

All sorts now call the drawBarsNew function to draw and update their array as of the end of iteration 2. This replaces the messageBox way of showing array updates.

Searches

Linear Search

Information

Linear search is a simple search algorithm that sequentially checks each element in a list until a match is found. It is effective on short lists but is much weaker when compared to binary search.

Its average time complexity is $O(n/2)$ but worst is $O(n)$. A benefit of linear search is that, unlike binary search, the list does not have to be sorted beforehand.

Button

```
1 reference
private void btnLinearSearch_Click(object sender, EventArgs e)
{
    if (txtSearchData.Text == string.Empty)
    {
        MessageBox.Show("Box is empty");
    }

    int[] arrayData = createRandomArray();
    linearSearch(arrayData);
}
```

Function

```
1 reference
private void linearSearch(int[] arrayData)
{
    int search = int.Parse(txtSearchData.Text); //sets the variable used to hold what we search for to the number the user put in the text box specified
    string displayArray = string.Join(",", arrayData); //formats the array to a single string
    MessageBox.Show("searching for: " + search + " in " + displayArray); //tells the user what they are searching for and what the array is

    bool found = false; //sets found to false
    for (int i=0; i<arrayData.Length; i++) //for length of the array
    {
        if (arrayData[i] == search) //if the current position holds the number we are looking for
        {
            found = true; //sets found to true
            MessageBox.Show("found "+search + " at position "+ i); //tells the user the number has been found along with its position
        }
    }
    if (found == false) //if found is false
    {
        MessageBox.Show(search + " not found"); //tells the user the number was not found
    }
}
```

Binary Search

Information

Binary search is a logarithmic algorithm that works by splitting a list and comparing its middle element to the target value. If they are not equal, the half in which the target cannot lie is eliminated and the search continues on the remaining half, again taking the middle element to compare to the target value, and repeating this until the target value is found. Its average and worst case time complexity is $O(\log n)$. Binary search performs well with large lists and there are very few downsides to it. If you are searching through a very small list then linear search would be better and the list must be sorted. But with the use of an efficient sorting algorithm such as quick sort or merge sort - merge would be more favourable due to its time complexity being constant - the time spent is still minimal.

Button

```
private void btnBinarySearch_Click(object sender, EventArgs e)
{
    if (txtSearchData.Text == string.Empty)
    {
        MessageBox.Show("Box is empty");
    }

    int[] arrayData = createRandomArray();
    int search = int.Parse(txtSearchData.Text); //sets the variable used to hold what we search for to the number the user put in the text box specified
    string displayArray = string.Join(", ", arrayData); //formats the array to a single string
    MessageBox.Show("searching for: " + search + " in " + displayArray); //tells the user what they are searching for and what the array is
    binarySearch(arrayData, search);
}
```

Function

```
private void binarySearch(int[] arrayData, int search)
{
    //binary search, whilst very quick, relies on having data sorted beforehand. Which means an additional (small) amount of time must be expended sorting the
    array. Merge sort will be used to do this because of its reliability compared to quick sort. However with an efficient implementation of Quick sort, it is
    faster.

    //performs merge sort on the list
    mergeSort(arrayData);

    //***** Binary Sort *****\

    int left = 0; //sets left position to 0 - start of array
    int right = arrayData.Length - 1; //sets right most pos to array length -1 - end of array

    while (left < right) //while the end pos is larger than the start pos
    {
        int mid = (left + right) / 2; //set midpoint to the floor of (l+r)/2
        if (search == arrayData[mid]) //if value being looked for is the midpoint
        {
            MessageBox.Show(search + "found at position " + mid); //tells the user the position of the value
        }
        else if (search < arrayData[mid]) //if the value being looked for is smaller than the midpoint
        {
            right = mid - 1; //sets the new 'end' of array to be the value before the midpoint
        }
        else //if neither of the above conditions are met (if value is bigger than the midpoint)
        {
            left = mid + 1; //sets the new 'start' of the array to be the value after the midpoint
        }
    }
    MessageBox.Show(search + " not found"); //if after everything it was not found then the user will be told
}
```

Drawing bars

Drawing bars and having them update is a major part of the program. However there were issues creating the bars in the first place. After much troubleshooting it was implemented successfully towards the end of the second iteration.

Function

```
private void drawBarsNew(int[] arrayData)
{
    DoubleBuffered = true; //should slightly reduces flicker, but not by much. increasing delay helps a little bit, but can be slow of course

    Graphics draw = CreateGraphics(); //initialises graphics
    draw.TranslateTransform(0, Height); //flips
    draw.ScaleTransform(1, -1); //coords

    // 0,0                                end,end
    // -----
    // |                                     |
    // |                                     |
    // |                                     |
    // |                                     |
    // |                                     |
    // -----                               -->>
    // |                                     |
    // |                                     |
    // |                                     |
    // |                                     |
    // |                                     |
    // -----                               0,0
    //          end,end                      0,0

    //this allows bars to be drawn properly in proportion to their relative size

    SolidBrush brush = new SolidBrush(color.White); //creates the brush and sets colour to white

    for (int i = 0; i < arrayData.Length; i++) //for each item in the array
    {
        Rectangle rectangle = new Rectangle(i * 3 + 5, 50, 2, arrayData[i]); //creates a new rectangle that is filled. arguments: start x, start y, width, height.
        draw.FillRectangle(brush, rectangle); //draws the rectangle

        //Thread.Sleep(0);
    }

    Thread.Sleep(int.Parse(txtDrawDelay.Text)); //sleeps for the amount of ms the user specified

    draw.Dispose(); //disposes of the graphics
    brush.Dispose(); //and brush
    //this isn't totally necessary in a program as basic as this where not a lot is going on but it is considered good practice to do so
    //as these processes can eat through memory
}
```

Testing

Test key:

1.2

Where 1 is the test number and 2 is any **reiteration** of the test e.g. 1.3 is test 1, iteration 3 (not program iteration)

Testing Table

~~Testing table is [here](#)~~

Link may not work - doc is not public to view - so raw table will be pasted below

[Updated link](#) for testing table that is public

Updated screenshot link is in testing sheet link above

Test	Iteration	Section Tested	Test Data	Reason For Test	Expected Result	Actual Result	Action Taken	Additional Details - if needed
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1	1	Main Menu - array size box	Leave arraySize text box empty and click Start button	Empty data should break the program. Creating an array with no size shouldn't be done	Program crash	Program crashed	Added Validation See test 1.1 for retest	
1.1	As above	As above	As above	Retest of test 1. arraySize text box should now only be accepted when there is data in there	Program does not crash	Program did not crash	None	Validation only allows for box to not be empty - presence check
2	As above	Main Menu - array data box	Leave arrayData a text box empty and click Start button	Empty data should break the program. Creating an array with no data shouldn't be done	Program crash	Program crashed	Added Validation See test 2.1 for retest	
2.1	As above	As above	As above	Retest of test 2. arrayData text box should now only be accepted when there is data in there	Program does not crash	Program did not crash	None	Validation only allows for box to not be empty - presence check

3	2	Main Menu - array size box	Put negative number in arraySize text box e.g. -2	testing validation function	As above	Program did not crash	None	Validation only allows integers from 1 - 100. A negative number goes outside those bounds. - range check
4	As above	As above	Put number above range allowed e.g. 101	As above	as above	as above	None	Validation only allows integers from 1 - 100. Numbers above this go outside those bounds. - range check
5	as above	as above	Put word into text box e.g. Hello	as above	as above	as above	None	Validation only allows for integer input. no strings allowed -format check
6	as above	as above	Put decimal number into box e.g. 23.4	as above	as above	as above	none	Validation only allows for integer input. no floats allowed -format check
7	as above	Sort/searches Screen - search data box	Put negative number in searchData text box e.g. -2	testing validation function	As above	Program did not crash	None	Validation only allows integers from 1 - 100. A negative number goes outside those bounds. - range check
8	as above	as above	Put number above range allowed e.g. 101	As above	as above	as above	None	Validation only allows integers from 1 - 100. Numbers above this go

								outside those bounds. - range check
9	as above	as above	Put word into text box e.g. Hello	as above	as above	as above	None	Validation only allows for integer input. no strings allowed -format check
10	as above	as above	Put decimal number into box e.g. 23.4	as above	as above	as above	none	Validation only allows for integer input. no floats allowed -format check
11	as above	Sort/searches Screen - quick sort	Testing quick sort with array with some duplicate numbers	testing quick sort process	program does not crash	Program did not crash but sort failed. some numbers not in order	adapt sort to work with duplicate numbers. see test 11.1 for retest	see TestingCwScreenshots
11.1	as above	as above	as above	retest of test 11. quick sort should now work with duplicate integers	program does not crash and sorts as intended	program does not crash and sorts as intended	None	as above
12	as above	Sort/searches Screen - bubble and insertion sort	testing of checking if steps are enabled	testing new feature - turning on and off showing steps	program does not crash and sorts as intended, showing steps if the tickbox is ticked and not showing	program does not crash but sort does not continue as it should if unticked	see test 12.1 for retest	see TestingCwScreenshots

					them if it is unticked			
12.1	as above	as above	as above	retest of test 12	program does not crash and sorts as intended	program does not crash and sorts as intended	None	see TestingCwScreenshots
13	as above	drawing bars	arrayData	testing if bars are drawn correctly	program does not crash and draws as intended	program does not crash but draws bars upside down	multiply height value by -1 to 'flip' bars. see test 13.1 for retest	see TestingCwScreenshots
13.1	as above	as above	as above	retest of test 13	program does not crash and draws as intended	program does not crash but no bars get drawn	mirror graphics object so that bars get drawn vertically	see TestingCwScreenshots
13.2	as above	as above	as above	retest of 13.1	program does not crash and draws as intended	program does not crash and draws bars as intended		see TestingCwScreenshots Windows form application windows have their 0,0 at top left and end,end at bottom right. flipping the graphics object made start bottom left and end top right, as it should be

14	3	sorting	run a sort outside of visual studio	users commented on it going into not responding after drawing and updating bars for a few seconds. once it begins responding the sort is complete and the result is shown in the intended text box but the visual representation is not there	Not responding after a few seconds of displaying sorting	Not responding after a few seconds of displaying sorting	Unsure of what action there is to take to fix this	array size makes no difference. Differences in draw delay changes nothing. as long as the sort goes on for around 6 seconds it will stop responding
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Evaluation

Results of each iteration

Iteration 1

Iteration 1 did not go entirely as planned. This was mostly due to issues with creating graphics and with passing the array into functions. Users could not fully create their own array at this stage. Because of this those options are hidden but remain in code until fixed. However a random array could successfully be produced. And a linear search or bubble sort can be shown via text on that array. The issues mentioned should be resolved by iteration 2.

Iteration 2

Iteration 2 included an overhaul of the validation system in the main menu. Rather than each text box having its own personalised procedure that it would follow, it simply called the validate function which utilised objects (for now this function only validates a single text box, but that is all that is needed in iteration 2. With a few tweaks it will be able to handle other boxes throughout the form). Due to this, code is more clean.

Merge sort, quick sort and binary search were also added.

The main addition to iteration 2 was the graphical representation of bars to act out the sorts. With this came the increase of array size up to 150, and the highest value of the array to 400, now that the knowledge of how large bars will be and how many can fit into the interface

Iteration 3

Iteration 3 should have included:

- A way to represent searches visually
- Exporting of results from each sort to a .txt file
- Showing pseudocode alongside each sort/search

However this was not possible due to time restrictions.

More validation was included to help prevent crashes in the program noted by users.

Feedback from users

Iteration 1

The user interface had some issues with it which were mostly to do with the colour choices. "Blue on black is not easy on the eyes." Because of this the general text colour will be yellow to add more of a contrast.

The text box background colour was grey, when trying to click in the box using the mouse, the cursor disappeared, so the background colour of text boxes will be changed to white. The background colour of buttons will remain grey as they do not suffer from the same issue.

A major issue with the program is that when sorting through large amounts of data, the program takes a while to complete and cannot be closed without the use of Task Manager or Command Prompt. This is because the only available sort (currently) is bubble sort which is very slow when being used on a large data set. To resolve this there will be a button or checkbox to disable/enable showing steps to prevent this

Iteration 2

As requested by users, a checkbox to toggle message box steps for sorts (31/12/2020 - bubble and insertion only at this stage) was added. As of 07/01/2021 all steps are disabled by default due to the graphical representation taking over the job of the message boxes.

Users are generally pleased with how the visual representation of each sort looks, but say that merge sort should show the full array at all times, rather than the sub arrays. However they are understanding that this may not be possible due to how it is implemented.

Other comments on the visuals included the flickering when redrawing the bars. This is likely caused by the program being unable to draw the array of bars in $<1/60$ th of a second and trying to redraw too quickly. So with no delay there is a lot of screen flicker, even with a higher delay of around 200ms before redrawing there can still be a considerable amount of flicker. Sadly not much can be done about this. Increasing the delay helps but then the bars take much longer to update. Using different methods for forcing redraws has done little to resolve the situation.

Sorts like bubble sort and insertion sort can take around 20 minutes with the recommended delay of 200ms

If the draw delay box is empty the program will crash when a sort is selected. To fix this the sort buttons will be disabled until the box isn't empty

Iteration 3

- Awaiting feedback from users for iteration 3 (21/01/2021)

Limitations

- A key element of the program should have been that users could enter in their own data for the array. However, this was not possible as having a random array implemented was easier to work with given the time restrictions.
- The program only works on the Windows operating system because it is compiled as a .exe file. It will not run on Mac, mobile phones or distributions of Linux without 1. The use of a program like Wine to act as a compatibility layer between Unix and the Windows program or 2. Running the program within a Windows virtual machine.
 - There has been no testing of either of the two alternative options, however they should work.
- An array length of 150 was chosen due to visual and time restrictions on the program. Algorithms like bubble sort can take a very long time to complete because of how inefficient they are.
- The maximum value available to be in an array was 400, this was again for visual restrictions imposed by the window size.
- Only sorts can be shown visually with the program; searches cannot.
- An issue with merge sort in particular is that while drawing the bars, only the sub arrays are shown until the array is fully sorted. This has been an issue since the beginning of its implementation. In the text based version, the sub arrays were also the only ones to be shown until the end. Attempts to fix this were made but were unsuccessful.

- There is a significant amount of screen flicker when drawing and redrawing bars during sorts. As mentioned in the second iteration feedback section [here](#), attempts to resolve this were unsuccessful.
- The implementation of quicksort was inefficient, likely leading to the time complexity of $O(n^2)$ rather than $O(n \log n)$
- (if not included by 21/01/2021)
 - Show steps in text file
 - Show pseudocode
- When being run outside of Visual Studio the program can go into a non-responsive state shortly after beginning the sort process. This happens despite the program using ~ 5MB of RAM, very little of the CPU along with none of the GPU (in my case with 200ms delay - uses around 40% of CPU with no delay). The program then begins to respond once the sort is complete. The final array is shown in text form but no bars appear at the end. This has been a problem with the program since the second iteration. There does not seem to be an issue with the size of the array as a small array with a large delay still causes the program to stop responding after around the same time as the largest array without delay (6 seconds). As such I have no idea how to fix this issue. Though it might be caused by calling Thread.Sleep constantly. Slowing down the rate of bar drawing seemed like the solution at first but as mentioned this had no effect.

Improvements

Notes to format

- List data type instead of array
- Allow users to enter their own data
- Fix merge sort
- Fix screen flicker
- Use random partitioning in quicksort
- (if not included by 21/01/2021)
 - Show steps in text file
 - Show pseudocode

Other notes

Due to restrictions imposed throughout 2020 and 2021 due to the Covid 19 pandemic, I was unable to formally meet with users. Because of this all questionnaires and testing of the program were done online. This made responding to feedback and giving feedback much slower than it should have been. This also lowered the rate at which I could make changes to the program and fix issues raised. Instead of potentially being in a room with users taking notes on how they found the program and any issues they might have had, I had to upload the program after each change to a group with the users in and wait for them all to come online to use the program.

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