

**CO3015 Computer Science Project**

**Dissertation**

**Jigsaw puzzle Web application**

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**Abstract**

This project is all about creating a jigsaw puzzle web application from start to finish. This is a challenge in many ways as not only is there a strong need for image manipulation techniques but also the tracking of multiple separate pieces along with the constant user input is very hard to achieve efficiently. Not only that but to create a jigsaw that truly looks like a jigsaw the pieces must have the traditional jigsaw shape. This is extremely challenging to achieve as computers are very much used to having square objects. To consider the square shape with both tabs or holes on every side of every piece and then make functions that allow the pieces to interact based on these odd shapes is a true challenge.

The basis of a jigsaw is to be a fun puzzle game that people can enjoy. This is essential as otherwise there is no use to this project. It must take an image and divide it into pieces of traditional shape, this also includes the flat edges for both corners and edge pieces. This is a necessity as this is where most people choose to start when building a jigsaw puzzle.

I aimed to develop a jigsaw puzzle game and make it fun, competitive, educational and high quality. This was a real challenge as a final year project, but it was enjoyable to complete as after all it is a game that I can now say I have made.

This project has shown me all about the end to end completion of a software system and the challenges that are in everything that can be coded.

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# **1.0 Introduction**

Jigsaw puzzles are a tiled puzzle game made up of lots of different shaped pieces. They can be made to have any number of pieces with any picture or pattern to suit varied levels of difficulty and ages. Jigsaw puzzles are a fun way of increasing your problem-solving abilities and coordination.

The main aim of my project is to learn about how to effectively split up an image and merge those pieces back together without problems to allow for the most optimum playing experience for the users.

I am going to create an online, fun, competitive and educational learning platform in which users will be able to race against the clock to try and beat their best time completing a puzzle or just play for fun with no timer. This will allow for some level of competition if users want to see how they rank against others, as well as allowing casual users to play without the pressure of a timer.

My software will have a professional, user friendly, high quality graphical user interface that users will be able to personalise by selecting different colours. This will allow users to view my software the way they want for it to be most appealing.

## 1.1 Objectives

I am going to meet my aims through completion of multiple objectives:

* Research image manipulation techniques
* Research examples of web-based graphical user interfaces.
* Develop a user friendly and professional graphical user interface, utilising CSS.
* Design multiple different themes to suit different users.
* Design a web-based Spring MVC project using Gradle and Java.
* Design image manipulation techniques.
* Evaluate if the interface displays the puzzle and controls in a clear way.

## 1.2 Challenges

Through completion of these objectives I will be able to overcome the challenges that are involved in completion of this project.

The biggest challenge being how the images will be split up and merged back together. As it is a jigsaw puzzle this will happen frequently and will need to work no matter the size of image. I will also have to deal with complex shapes when splitting up the image as jigsaw pieces are not just squares, they have a traditional shape to the pieces that I will follow.

These pieces will then have to be merged together with another piece when within the right distance. This will be a challenge as it must be the correct piece in the correct place before the merge can take place. Once in the correct place the pieces must be merged together and now form one piece rather than two separate pieces so they can be moved around as one and then merged to more pieces to eventually complete the puzzle.

## 1.3 Originality

After conducting some background research, I have come across many similar versions of both web-based and mobile applications that all used pre-defined images and puzzle piece shapes. There are some websites that will create new shapes for their puzzle pieces based on the time of year, (e.g. pumpkins at Halloween or snowmen at Christmas), and others will have different variations of simple shapes **[1]**, but in general they all have just the standard shaped jigsaw pieces.

My original aim to make my puzzles different from the rest was to allow users to draw their own puzzle piece shapes which will then be used to split the image up into however many pieces they want. The difficulty was in splitting the image as the user desires, this will increase the more times they split the image up and will also increase the difficulty of their puzzle once split. From what I have researched, I cannot find any web page or mobile application that has this feature.

Upon reflection I decided this would not benefit the user experience as much as I hoped as it could create very complex puzzles that they would not enjoy trying to complete, causing them to give up. Instead, I replaced this idea with the user having the ability to upload their own images to play. This is much more enjoyable for the user as they get to enjoy completing a puzzle of their favourite image, whether this be of their friends, a pet or their family.

I have also implemented another feature into my puzzle that a lot of other websites do not have. This will be the option to change the colour scheme of the interface the puzzle is played on. This feature will give the user a personal playing experience. They could choose a bright coloured theme as they are in a happy mood and enjoy bright colours, they could choose darker colours if they are in a dark room and wouldn’t enjoy the bright lights or they could choose a more neutral theme that all users would enjoy. I have also chosen colours that could make the puzzle easier to play for people that are colour blind.

# **2.0 Survey of Literature/Information Sources**

## 2.1 Information Sources

Most of the research I have done for this project is based around website development. Therefore, my primary information source has been w3schools **[2]** as this website shows most, if not all functions involved in developing a web app. It has a very easy to search list down the left-hand side of the screen at all times allowing you to scroll through and look at other functions that you think may be useful based on the name. It will then give a description on what this function will do, the syntax involved in using the function as well as some very basic examples.

When developing a web app there are three different files to develop that make their own changes to the page you are working on; HTML, CSS and JavaScript.

The HTML files are a basic template of all the containers within the page, with very basic positioning control. You create these containers using elements known as tags. Each type of element has its own unique tag, e.g. <head> is for the header of a page, <p> is for writing a paragraph on the page. I used the HTML w3schools **[3]** website to find extra information on some of the tags I was using, such as finding the height of a <img> element.

The CSS file has more control on the positioning and aesthetics of elements on the page compared to HTML but cannot create new elements. CSS involves calling the id of a HTML element (#mydiv), it is then able to place exactly where on the page relative to other elements mydiv is placed. It can also change things like “background-color” to any hexadecimal colour. I used CSS w3schools **[4]** as I have basic knowledge on CSS and I needed information on properties such as “position”, as there are many moveable elements to my project and “position” must be set for each to allow this.

The JavaScript file is used to create functions that can be called within the HTML file. These functions can do almost anything to the page as and when you call them, e.g. my startUp function creates a new <img> tag and appends it to the HTML file allowing you to see the images. I will talk more about this in my **4.0 System Specification and Design** and **5.0** **Implementation and Testing** sections. I found JS w3schools **[5]** extremely helpful when creating functions as it outlines many functions useable in JavaScript allowing me to piece them together to build my own.

To ensure the validity of w3schools **[2]** I found another website in which I could look up the functions found in w3schools, this was mozilla **[6]**. Using this website, I was able to search for a function I found on w3schools to ensure it worked the way I needed it too. Mozilla sometimes had diagrams to help with the understanding of the function which w3schools did not, but I found this website much harder to navigate as each method was within subcategories such as “Intermediate” or “Advanced”. This made it harder to search through looking for methods that may be useful to me as I was not always sure on what I was looking for.

As I developed my puzzle more, I moved onto creating the shapes of the puzzle pieces and changing them from squares to the traditional shaped pieces. In researching how I can go about completing this task I used more resources. The first resource I found was information on sprites **[7].** Sprites were usually used in animation where you have a sequence of images that constantly refresh, and it creates the illusion that the image is moving. This was not what I wanted but the way sprites worked would be very beneficial to what I need. I will talk more about Sprites and the process I went through in **4.4.1 System Specification and Design** as they were an essential part in me understanding how I should progress further in my project.

I then needed to create a sprite that wasn’t just square. I did this through research into the Java Shapes class **[8]**. This resource showed me all the different shapes I could create using polygons, squares, Bezier curves. Through practicing making different shapes I found Bezier curves the hardest to use and the most essential to my project. To improve how I used the curves I found another resource on specifically Bezier curves **[9]**. This resource allowed me to fully understand how these curves work and eventually create the shape I wanted before implementing it into my main project.

I then needed a way to take the shape I created and the image the user has selected and make the pieces for the puzzle. I did some research into JavaScript canvas elements as these contained a function “.drawImage” and found webplatform **[10]**. This resource showed me different possibilities when using the “.drawImage” function and explained in detail how to use it. I found this to work very well in my project as canvas elements were also able to be “clipped” to a pre-defined shape before the image was drawn onto the canvas.

## 2.2 Background Research

To have a better understanding of what other online jigsaw puzzles are like I did some research before starting my project. I found JigsawPlanet **[11]** and TheJigsawPuzzles **[12]**. I looked at these sites in particular as JigsawPlanet had a very simple and easy to use GUI which is what I would like to accomplish with my project. Whereas TheJigsawPuzzles I did not find as easy to use as it is full of writing and you cannot see the different puzzle images as easily. However, it does have the added feature of different shapes for its puzzle pieces which was very interesting. This gave me the idea of users being able to draw their own shaped pieces as discussed previously.

To aid with the creation of different themes I used the website tableau **[13]** that has information on designing visuals that are colour blind friendly. Being colour blind is a very common thing, affecting 8% of men and 0.5% of women. This is why I wanted my puzzle to have the option to be colour blind friendly. Within this article it discusses different combinations of colours and what not to use together. Red and Green is one of the most problematic colour schemes as people with a colour vision deficiency struggle to determine between these two colours, this is why you should use colours such as blue and orange because the majority of people can distinguish between these colours.

# **3.0 Requirements**

|  |  |  |
| --- | --- | --- |
| **Functional Requirements** | | |
| **Requirements** | **Completion** | **Evaluation** |
| A user is greeted with a welcome page upon start up. | 100%  Checkmark | When a user visits my website, they are greeted with a welcome page. |
| A user will have the option to play casually or competitively. | Checkmark100% | On the welcome page the user has three options. “Casual”, “Timed” and “Play Your Own Image”. |
| If playing competitively the user will be timed when completing a puzzle. | 100%  Checkmark | Upon load up of the puzzle a timer will start counting up until completion of the puzzle. |
| The users time will be entered into the database and compared to others. The user will then be showed the leader board. | 100%  Checkmark | The user is given a box to enter their name into. Upon submission their name and time is inserted into the database. The leader board is shown on this page so they can see how other people have found it |
| A user will be able to upload their own image and play it as a casual puzzle. | 50% | A user can upload their image and select the number of pieces. Due to an unknown bug the pieces load with the correct shape but do not contain the image uploaded. The image is in the server-side file system and should work like the rest. |
| A user will be able to select a pre-set theme that their UI will follow until changed in the settings page. | Checkmark80% | A user can select a theme from the settings page but only to increase the puzzle experience. The theme does not carry on through other pages. |
| A user will be able to click and drag puzzle pieces around the screen. | Checkmark100% | When a puzzle piece is clicked on, the piece and any other connected piece will follow the mouse around the screen until the click is released. |
| A user will be able to join puzzle pieces together once close enough to the correct piece. | 95%  Checkmark | When placed in the correct place the current piece and any other pieces in the correct place in relation to that piece will merge together. It does not 100% work though as if the pieces are rotated, they do not always merge correctly. |
| A user will be able to rotate a puzzle piece by selecting the piece and then selecting the rotate button. | 100%Checkmark | If the user is currently “holding” a puzzle piece and they select the “R” key the piece will rotate clockwise by 90 degrees. |
| A user will be able to click randomise to randomise all pieces on the screen. | 0% | After reflection I did not think this would add to my project as the pieces are already randomised on start-up of the puzzle. |
| A user will be able to view a completed picture of the puzzle as a transparent guide. | Checkmark100% | The user can select the “Ghost” button and a transparent image of the current puzzle is displayed. |
| **Non-Functional requirements** | | |
| The puzzle will take less than a second to load after the pieces have been scrambled. | 50% | The puzzle consistently loads in less than a second when using a pre-defined image. The puzzle does not always load when a user uploaded image is played. |
| The system can hold jpeg images up to 2Mb in size. | Checkmark100% | When I add images greater than 2Mb |
| The system will not crash | 50% | The system may crash when a user actively tries to crash it. |
| All pages will load | 100%Checkmark | All pages load efficiently |

# **4.0 System Specification and Design**

Within this chapter I am going to discuss the development methodology I followed when completing my project. I will also discuss the design stage of my project, this will include both how each function works and how I reached that solution.

In sub section 4.1 I am going to discuss the development methodology I followed throughout this project. In 4.2 I am going to discuss how my database structure is designed. Sub section 4.3 will be focussed on the structure of my websites for ease of navigation. Sub section 4.4 will be about the main puzzle page, of which contains all sections that play a part in how the puzzle is made and works, along with other features that are present on that page.

4.1 Methodology

For my project I developed using the Waterfall methodology. I did this as I knew I needed to develop the basic foundation of my project first before any additional features could be added. My Gaant chart **appendix 1** shows very strongly that I followed the waterfall methodology as it is in the shape of a waterfall. I used this over methodologies like Agile as I wanted a more rigid structure to my project to ensure success of all features, I knew the features I wanted to create from the start of the project and so the flexibility of Agile was not needed. All of my features were building on one another to reach the final project. This also meant that I would have to test features differently if I tested features as and when I created them, as if one feature uses another this could affect the test results and the test for the previous feature and so the test would need updating.

## 4.2 Database Design

My data base only contains information on the leader board for each separate puzzle and piece number. All the Jigsaw puzzle images are saved inside a server-side folder. The database is only used if the user is playing the “Timed” game mode.

The database schema is comprised of many different tables, each of which have the puzzle name and piece amount as part of the title. For example, if a user is playing the puzzle “leaves” puzzle with 16 pieces the database table their time and name will be inserted into will be “leaves16”. This created many tables within my database but as the names are simple and the information is always the save being entered into them it made my system easy to navigate.

I access my database through a server-side Java controller class, “DatabaseController”. This class uses Java JDBC **[14]** to handle all insertions into the database tables. It will create the connection upon start-up of my project when a new instance of the database controller class is created. To do this it uses the IP address, port number, database name, username and password.

Once the connection is established the database can be accessed through database queries. These are made through a function in my database controller class that accepts the table name, name of the user and the time they completed the puzzle in. The function will then create a prepared statement that will make use of the connection made previously. The prepared statement will contain the key words “INSERT INTO”, as these words are what let SQL know something is going to be added to a table, followed by the table name, another key word “VALUES” and then the values wanted to be entered into the table, e.g. name and time. The prepared statement will then be executed to get SQL to add these values to the table.

## 4.3 Website Navigation

My website was made to be as simple as possible as to be able to be an educational learning platform it must be easy to use for users of any age. This means that even a young person must be able to use all features of my project.

With this in mind the home page of my project is a welcome page that gives three different options for the user to select, “Casual”, “Timed” and “Play Your Own Image”.

Casual will take the user to a page where you can select any image that you want to play with any of the pre-made number of pieces from the drop-down menu. Once the user selects the image the puzzle will begin and will have access to all features that I will discuss in section **4.4 puzzle**. Once the puzzle is finished, they will be shown the finish page where they can select the home button to return to the home page.

Timed will take the user through a very similar sequence of pages, the only difference is that when the puzzle starts a timer will be in the navigation bar at the bottom of the screen counting up from 0 until the final piece is put into the correct position. This will cause the finish page to appear but this time with a form for the user to input their name that will then be added to the database on submission and they will be returned to the home page.

Play your own image is an extra mode for my project in which the user is able to upload any jpeg image file, choose a number of pieces from the drop-down menu and select submit to then play that image with that number of pieces. Once the user has selected a file from their file system to be uploaded the image will be displayed below the options they are choosing from. The user will have full functionality of the puzzle page even with their own uploaded image. The finish page will be displayed the same as with the Casual game mode.

A view map can be found in **appendix 2.**

## 4.4 Main Puzzle

The puzzle is the main focus of this project. It is where almost all of the features of my project are. In this section I will be going over the main functions of the puzzle, both how I got to the final solution and what the final solution is.

### 4.4.1 StartUp

“StartUp” is one of the first functions called when the puzzle page is loaded up. It is responsible for splitting the image up into pieces of the traditional jigsaw shape, randomising the starting location of each piece and calling the function that will make the pieces moveable around the screen, **DragElement 4.4.2.**

Originally splitting up the image was not part of my startUp function and startUp just dealt with adding the pieces to the page that another function had already created. This is how my prototype demonstration worked. I had made a function that split the image into pieces using the BufferedImage “.subImage” function and then added each piece to the server-side folder that contained all of the completed puzzle images. This was not very efficient as at the time I had to manually delete all of the sub images from the server folder after I completed the puzzle. It also made creating the traditional piece shape very challenging as the sub image function could only create square pieces.

Rather than continuing down this path and finding a very complex solution using server-side piece creation I decided to look into creating the images from within the Javascript file.

I found information on objects called Sprites **[7]**. As I mentioned in my **2.1 Information Sources,** they are used in animation by refreshing the current image. This is not what I wanted as I do not need to refresh the image. But the way they work is by having a line of similar images and every time they refresh, they take the next section on the line. This is what I needed as I need all the different sections of my image, just all of them at once.

Again, as mentioned in my **2.1 Information Sources,** I found that they accept Java Shapes **[8]** so I began working on creating a shape that looked like a traditional jigsaw shape. I managed to create this using Bezier curves and straight **lines appendix 3 and 4.**

I will discuss more about the implementation of these traditional pieces in **5.0 Implementation and Testing.**

### 4.4.2 DragElement

DragElement is the only function responsible for the pieces being able to be moved around the page. It is a relatively simple function that uses browser events to know whether the user has clicked or released the mouse button. I added functions inside the overall DragElement function as it made it simpler by separating each event.

It starts off with 4 variables set to 0 (pos1, pos2, pos3 and pos4). As the user clicks down on the current element pos1 and pos2 are set to the current position of the mouse through the “mouseDown” function. Then if the mouse button is released the “closeDragElement” function is called in which both onmouseup and onmousemove are set to null to ensure no other movement of the current element. But if the mouse button is not released and the cursor is moved around the screen the “elementDrag” function is called.

The elementDrag function will set pos3 to pos1-the current x coordinate of the mouse and pos4 to pos2-the current y coordinate. These are temporary values used to calculate the new position of the element. After these are set pos1 and pos2 get their coordinates updated with the cursors new position. Using pos4 and pos3 as the difference between the old position and the new, the position of the current clicked element is calculated. If pos3 is negative it means the new position is to the right of the old position so when you minus that from the current offsetLeft the result is greater than previously, which is correct. Pos4 works in the same way just a negative value means it is below the previous position. Again, once the mouse has stopped moving the current element will be left in place as closeDragElement is called.

### 4.4.3 Merge Elements

Throughout my project I found this to be the hardest part as it had many challenges associated with this task. I started off trying to find a way to merge two separate square images as this is what I had during my prototype demonstration. This wasn’t much of an issue if I knew the direction in which they should join.

The problems came when I had multiple pieces that could be joined together in all different directions. I had to keep track of which piece could be in each direction but also once two pieces were joined, I struggled to keep track of where exactly all the pieces that could join to that double piece could join.

I tried many different methods, mainly using arrays where each piece had its own part to the array containing another array of the id of all the pieces that piece could merge too. This worked for very simple puzzles as the order in which I had the ids for a specific piece’s array was the direction that piece could join to the piece matching the id.

This method became very complex as the way I had my merge function working was the pieces would actually merge to become one piece. This meant when you search the page for a piece that had been merged to another piece it was no longer findable causing many errors. I worked around this by replacing the id of the merged piece with (-1, id) so I knew if it was paired with a -1 it was already merged. Again, this worked for slightly more complex puzzles but had more and more problems the more pieces that merged together.

Eventually I came to the conclusion this method will not work or that it is going to be way to complex if I keep creating fixes for the current solution.

I attempted to find fixes for this trying to stay around the idea of a direction for each piece in an array. I believed this would be the most effective way to store information on what piece can go where. After many weeks of trying different solutions I came to a coordinate-based system. This would be where again each piece had a part of an array but this time rather than information on other pieces it can join to, I placed its coordinates in the array (e.g. The top left corner will be 0,0. The piece below it will be 0,1 and so on). I also changed how the images will be merged together, instead of the pieces properly merging into one they now stay separated but they are all individually placed into their own div element. Now when they “merge” I can instead just move one image into the others div element and position it to the correct position in relation to the image it is merging too. This allows me to still be able to find the position of all images in the puzzle no matter how many pieces have merged to them, this is a very scalable solution so no matter how large the puzzle is the solution I have will work.

# **5.0 Implementation and Testing**

In this section I am going to discuss an overhead view of my system and how all of my functions work together. I am also going to discuss the ways in which I tested my project and display the results from my test log.

## 5.1 Implementation

As I have already discussed the majority of my website navigation in **System Specification and Design,** I am going to jump to how the main puzzle page functions all work together, starting from when the page first loads up.

Upon loading of the puzzle page, two sometimes three functions from my Javascript page are called. Two are crucial to the puzzle working and will call other critical functions, the third is an additional feature if the user has selected the timed game mode. This third function will start a timer counting up from zero and add it to the navigation bar at the bottom of the page.

The first function called is a very simple function “arrayCreate” I briefly mentioned this in the final paragraph of **4.4.3 Merge Elements**. This function will create a public 3D array inside my Javascript file. Each part of the array will belong to a piece of the puzzle. This function will fill each space of the array with coordinate positions of that piece in relation to the final puzzle (e.g. piece with id img0 will be in space 0 of the array and will contain coordinates 0,0). The function takes the width and height in number of pieces as parameters and has two loops, one being a nested loop inside the other. This is a simple way of filling in their coordinate’s **appendix 5**.

The second function called will be startUp. StartUp takes in 6 parameters, these are: the total number of pieces (count), the puzzle name (puzzle), the number of pieces across (numberWidth), the number of pieces down (numberHeight), the width of each piece (pieceWidth) and the height of each piece (pieceHeight), See **appendix 6** for clarity. It starts off by creating a nested loop using the numberWidth and numberHeight as limits. This is so I can calculate whether I have reached an edge or corner piece. The function starts off by creating the canvas element that will become the first piece and giving it its id.

The next step is to create the direction array for that piece. The direction array is what takes care of if the jigsaw piece will have a “tab” piece sticking out of the side or if it will be a “hole”. It uses the fact that the loops will start with the piece in the top left corner. It uses this as it will only ever randomise whether it is a tab piece or a hole piece for the bottom side or right side of each piece. The top and left side are always based on the previously randomised piece in that direction.

Once the direction array for that piece has been made, I will set the width, height, startX and startY variables based on a tab or hole. This is because the canvas width and height is not automatically set. The startX and startY variables are to help in creation of the pieces.

As discussed in **4.4.1 startUp** I create the pieces using Java Shapes. Based on the direction array I will draw the shape onto the currently blank canvas using Bezier curves and straight lines. After the correct shape is drawn, I use the “.clip()” function to remove the area around the drawn shape and the “.drawImage” function to give the canvas the image that the user wanted to play.

The final part to startUp is adding the piece to the page, randomising its starting position and calling the dragElement function in order to make the piece moveable around the screen. To randomise the pieces starting position I used “.clientWidth” and “.clientHeight” instead of “offsetWidth” or “offsetHeight” as this is the width and height of the element not including any scrollbar or borders.

Once all of the pieces are loaded up and dragElement is called with the current piece, the total number of pieces, the pieceWidth and pieceHeight as parameters for each piece. It can then work as I have explained in **4.4.2 DragElement**. The only part missed out of DragElement was when the user releases the mouse button and “closeDragElement” is called, this function will call another function, “checkPieces”. This will happen every time a user clicks on a piece or moves one around the page.

CheckPieces is the function that takes care of checking whether there are pieces to be merged together. It does this by looping through all pieces that are inside the div element that had just been moved/clicked on. For each piece it will use the “pieceCoordinates” array created with arrayCreate to find the coordinates its neighbouring pieces. There is then a loop that goes through all pieces in the puzzle. Within this loop it will compare each piece’s coordinates to that of the neighbouring pieces of the original piece. If they match it will then check to see if the distance between the two pieces is within a certain range, the range is 20x20 pixels centred with the exact join position. If the piece is in the correct position a new function “combine” will be called.

The combine and checkPieces function are in a loop together as if two pieces are merged together using the combine function checkPieces is then recalled ensuring all pieces that are in the correct position have been merged together.

Combine takes in 7 parameters, most of which are just used to recall checkPieces, but some are used in both functions. Combine is given the ids of the two pieces that will be merged together. It starts off my checking whether they are in the same div element as if they are, they are already merged together and so can skip the rest of this function. If not the first step is to add the second piece to the firsts div container. This is the pieces essentially merged together as they can now be moved around together. The rest of the function deals with positioning of the new piece so the two pieces fit together perfectly. It does this by calculating the exact distance needed between the two pieces, then it sets offsetTop and offsetLeft of the new piece based on the third parameter combine is given which is the direction in which the merge should take place.

That is essentially how my puzzle works. It relies on the startUp, dragElement, checkPieces and combine all working together and calling each other as the user needs them to be called.

The other features the user can see are additional features that build to the fun and usability of the puzzle game. Such as the hint button, it is a basic function that isn’t essential to the gameplay of the puzzle, but I believe it adds a lot to the enjoyment of the puzzle as if the user is stuck and cannot find two pieces that go together they can click the hint button and two pieces will get highlighted that can be merged together. The pieces that get highlighted are randomly chosen as the function randomly chooses a piece and then randomly chooses a direction from that piece as the second piece to highlight.

Other additional features include a ghost function that will show the user a transparent image of the completed puzzle as guidance for size and how close pieces should be together. When the user selects the Ghost button the image will appear, if the button is clicked again it will disappear. This is done with an if statement checking whether the image with id “ghost” on the puzzle page has a src, if not it will give it the current puzzle location and the image will appear. If it has a src it will change it to be empty therefore “removing” the image from the screen.

The final button select feature of the puzzle page is the settings page. Through this button a div element will appear, similar to Ghost but using the CSS style “display”. The user will then have the ability to change the colours of the background and secondary colours of the current page as well as the opacity of the ghost image through sliding the slide bar.

The last feature, that isn’t a button feature, is the rotate function. This function will rotate any piece by 90 degrees that you are currently “holding” or the last clicked on piece. It does this when you click the “R” key on your keyboard. This function has a few bugs that do currently affect the playing experience, given more time I would find a way around these. Currently if the pieces are rotated, based on how the merge function work it does not take these rotations into account, it also does not change the location of the element being rotated, even if the element is a rectangle shape and does clearly move in a direction. Although this is the case if you do manage to merge the pieces together the merge still works correctly and will place them in the correct position.

## 5.2 Testing

As my project is mostly run on the server-side of the web application and it is extremely reliant on user input I had to do most of my testing through manually. This meant rather than writing unit tests to test each function I had to systematically think of different ways my project functions could be used and then I recorded the results in my test log as seen below.

I started off my test log by testing the homepage to ensure it loads correctly. I then moved onto testing the features of the next pages after you choose an option from the home page, two of these options direct you to the same page (imageSelect). The majority of my test log is to do with features on my puzzle page. The tests ensure the ways in which the functions work. The tests are completed systematically from start to end of my project in the order that the user would see them. Also, if there were multiple ways in which a feature could be used, e.g. the merge function, all of the tests for that function are together.

**Test Log**

|  |  |  |  |
| --- | --- | --- | --- |
| What I am testing | Expected Result | Actual Result | Pass or Fail? |
| On start up the home page is loaded. | The home page will load with a welcome message and three different game mode options. | A screenshot of a social media post  Description automatically generated | Pass |
| In the select Image page, you can click a drop-down menu to display various numbers for puzzle piece amounts. | A drop-down menu of 9, 16, 20 and 25 will appear. | A screenshot of a computer  Description automatically generated | Pass |
| When the user selects the play your own image game mode. | They are taken to the “challengeSelect” page. | A screenshot of a cell phone  Description automatically generated | Pass |
| When the user uploads a jpeg image. | The image they uploaded should appear below the submit button. | A screen shot of a cat  Description automatically generated | Pass |
| When a user selects the home button from the “challengeSelect” page. | They are returned to “modePick” page. | A screenshot of a social media post  Description automatically generated | Pass |
| If the user selects the Timed game mode. Upon start of the puzzle a Timer is present. | A timer will be in the nav bar and start counting up from 0. | A screenshot of a video game  Description automatically generated | Pass |
| If the user selects the Casual game mode. A timer is not present upon start of the puzzle. | A timer is not present. | A screenshot of a video game  Description automatically generated | Pass |
| If the user selects the “Ghost” button a transparent image of the current puzzle is displayed. | A transparent image is displayed on the page. | A picture containing photo, indoor, computer, screenshot  Description automatically generated | Pass |
| If the user “holds” a piece and selects the “R” key the piece will rotate. | The “held” piece will rotate clockwise by 90 degrees. |  | Pass |
| When the Settings button is clicked the settings page should open. | A window should pop up and show colour changes and opacity changer for ghost |  | Pass |
| When the settings page is open, and the settings button is clicked. | The settings page should close. | A picture containing looking  Description automatically generated | Pass |
| When the settings page is open, and they select the close button in the top right corner. | The settings page should close. | A picture containing looking  Description automatically generated | Pass |
| Sliding the slider to the left on the settings page. | If you slide the slider towards the 0.1 the ghost image should decrease in opacity. | A picture containing photo, indoor, table, looking  Description automatically generated | Pass |
| Sliding the slider to the right on the settings page. | If you slide the slider towards the 1.0 the ghost image should increase in opacity. | A picture containing photo, table, sitting, computer  Description automatically generated | Pass |
| The background colour should change based on the button selected | If you select the Baby blue button under background colour the background of the puzzle should change to a baby blue colour | A screen shot of a person  Description automatically generated | Pass |
| The secondary colour should change based on the button selected. | If you select the red button under secondary colour all parts that contain the secondary colour (standard is dark blue) will change to red. | A screen shot of a person  Description automatically generated | Pass |
| When the hint button is selected but no pieces are merged together. | Two pieces that can be merged together will be highlighted with a gold square around them. | A picture containing looking  Description automatically generated | Pass |
| When the hint button is selected but some of the pieces are comprised of more than one original piece. | Two pieces that can be merged together are highlighted with a gold square around the whole piece. | A picture containing photo, colored, room, colorful  Description automatically generated | Fail |
| When a piece is placed next to the correct piece in the correct position. | The two pieces should “merge” together and be moveable as one piece. |  | Pass |
| When a piece is placed next to an incorrect piece. | The two pieces should not merge. | A picture containing indoor, photo, living, television  Description automatically generated | Pass |
| When a piece is placed next to a correct piece but on the wrong side. | The two pieces should not merge. | A picture containing photo, indoor, living, different  Description automatically generated | Pass |
| When a rotated piece is placed next to another none rotated piece. | The two pieces should not merge. | A picture containing indoor, photo, screen, living  Description automatically generated | Fail |
| When a rotated piece is placed next to another rotated piece. | The two pieces should merge correctly and be moveable as one piece. | A picture containing indoor, photo, different, screen  Description automatically generated | Fail |
| When all pieces are merged correctly. | The jigsaw should end and show the finish page. | A picture containing screenshot  Description automatically generated | Pass |

# **6.0 Critical Appraisal**

In this section I am going to analyse the successfulness of my project based on the aims stated in my introduction. The social, commercial and economic sustainability of my project. And finally, I will discuss my own personal development throughout the creation of my project.

Throughout my project the main aim and the biggest challenge I faced was developing the ability to split up and merge images efficiently, I believe I have reached this goal. This was the part of my project that took the most time, in the end taking almost 4 times the length I initially believed it would take. There was not a straight line taken to achieving this within my project and so I had to adapt the time constraints I gave myself in order to finish what I wanted within my project. I tried many different methods and researched lots of different techniques involved in image manipulation, therefore giving me wider knowledge in both image manipulation and in website development.

Although overall image manipulation went well, I did struggle with getting it to work well within my project. I had many different versions of both image splitting and image merging and could not seem to get them to work together within my project for a very long time. I tried server-side splitting of the images, this worked but it created a lot of unnecessary files as each split of the image would be a new file. I would then have to delete all of the files at the end of the puzzle or upon early close of the puzzle. This I did not see as the efficient solution I wanted and was much happier with my final solution. Although, it does sometimes have a bug where the graphics from the image do not load onto the puzzle pieces. I do not understand this bug and why it sometimes happens. Merging of the pieces was the really complex part of my project as the ability to merge images together, track what pieces are merged together and what pieces can be merged together are all very hard to accomplish. I think my merge is very efficient but the possibility of it being more efficient is there as there are stages in the merge functions that if the piece amount was larger would take a lot longer to complete. There is also a small random bug that when attaching a large piece containing multiple pieces to another large or small piece, the large piece will sometimes split and not fully merge with the other piece. It is unknown to me why this happens and I have not managed to recreate a constant time when this occurs so I cannot find a fix.

If I had more time or was to recreate this project again, I would do more research into the methods I used to try and iron out the bugs I currently have. Along with this I now know a good way to merge elements together and so could make the adjustments I need to take into account the rotation of the pieces when merging can take place as the rotate function is currently not useable in my project without problems occurring.

Another essential aim mentioned in my introduction was that my project will be a fun, competitive and educational learning platform. This is essential to my project as my project is a puzzle game, without it being fun no one will enjoy playing it and people will not come back and play it again and again. My project does this well as for people that love jigsaws, an online jigsaw puzzle where there is 0 clean up, no physical space needed, and you can move around while completing the puzzle are all large benefits to my project against a physical jigsaw puzzle. The only thing that would make my project better in this aspect, if I was to create it again, would be to add other game modes such as a challenge mode where the user has levels they have to complete to gain stars and the quicker they complete the puzzle for that level the more stars they can collect. This would be good as it creates another aspect a user can enjoy, they would also gain satisfaction each time they completed a level making them want to complete more.

The competitive aspect adds to the fun and entertainment allowing you to compete against other people both friends and online to keep people coming back to try and beat their old personal best. My project does this through a timed game mode where the user is timed until they complete the puzzle. Their time is then compared against the leader board to see how well they have done. The competitive aspect was a hard aim to achieve as building a jigsaw is a very single player puzzle unless done with others but then this isn’t competitive, it is teamwork. The timer allows people to complete the puzzle together or separately but in a competitive manner.

I wanted my project to be educational as I wanted it to help young children in school develop problem solving abilities. Rather than a school having to fund a new jigsaw every time a child ruins the old one, they can now use my website which has a variety of puzzles that the children can use. My jigsaw puzzle is educational to children as jigsaw puzzles help to develop many skills such as: hand-eye coordination, fine motor skills, problem solving, shape recognition and memory **[15]**. The puzzle will be very beneficial to children although may add to the time young children currently spend using technology which could causes them to lack social skills and other necessary skills when they are adults.

My final aim of my project was to make a professional, user friendly and high-quality user interface. It was crucial for me to do this as there are a wide variety of online jigsaws on the market and I would like to compete with them to maintain users to my web application. I completed this aim to a certain degree. My website is user friendly as it is very simple to use, there are three pages total with a home button on each page that isn’t the home page. I have attempted to keep navigation as easy to understand as possible by using easy to understand prompt buttons and by keeping the web layout clean. The follow-on effect of this is that the users of all age ranges can efficiently use it.

If I was to redo my project id plan more time catered towards the aesthetics of the website. I could also use a CSS framework such as Bootstrap. Bootstrap would allow me to seamlessly create reactive webpages, perfect to be used on mobile devices. This would in turn draw more users in as I know cater to more platforms. Id also push to have more consistent themes such as a navigation bar and a footer, meaning a user could correctly identify where they want to go next more efficiently. A combination of these improvements would drastically improve how professional my website looks.

A potential impact my project has on both people and businesses is if a care home makes use of my project, it will have a positive effect on future residents because of the positive impact both jigsaws and interactions with technology can have on the elderly. This is shown in a Cochrane review **[16]** that’s findings suggest cognitive stimulation such as what you get from completing jigsaw puzzles has a beneficial effect to the memory and thinking test scores of someone with dementia. This paired with the use of technology which a study by Eurostat **[17]** found that 87 percent of people over the age of 75 have never been online. Introducing my online jigsaw to this group of people along with the help from care workers would be a good way to introduce elderly to technology and the use of the internet. This introduction to technology can also help the elderly stay more in touch with family members that may otherwise be hard to reach.

My project also has environmental impacts, which can be seen through the lack of resources it takes to manufacture my puzzle. With the current environmental crisis, it is essential that people minimise their carbon footprint, my jigsaw improves this due to it not producing a high level of pollution. In comparison to producing a standard cardboard jigsaw which can potentially add to deforestation currently ruining our planet. Another environmental benefit my online jigsaw has is the high level of replay-ability, as a result of the ability to pick your own number of pieces and being able to change the image multiple times for the jigsaw. A high level of replay-ability keeps users engaged and less likely to want to buy a standard physical jigsaw. My project can cater for many people all playing the same or different jigsaws at the same time further reducing the environmental impact as multiple jigsaw are not needed to be made for everyone to play.

I believe my project could be viewed in either a teaching or academic light. As it can be fitted to a wider environment due to its potential to be used in care homes. I could also introduce my jigsaw to be used in primary schools and nurseries to help with keyboard and mouse skills. Although because of the visual standard my website is currently at I do not believe it would be something that could be used to make profit therefore rendering it more relevant to the academic environment. With some adjustments to the aesthetics of my project and if some of the bugs are ironed out it could be used to make a profit as part of an online puzzle website.

A big risk with my project is that it increases the amount of time people spend using technology. This could be bad, especially in young people such as children as they might not develop the same skills as they would if completing a physical jigsaw. They also cannot work on skills such as teamwork as it only accepts one input from a mouse. This causes them to spend a lot of time on their own making them struggle when they have to communicate with others or work in a team as they grow up.

Throughout my project I have been constantly developing my skills. During my time at university my worst module was CO1019 Databases and Web Applications that I took during first year. This module was where I learnt the basics of HTML, CSS and Javascript. I have not done any other module since then that developed my skills in these coding languages. I have done web development modules, but they focused more on the back-end side of the web application rather than the HTML, CSS or Javascript. This made my project a perfect choice to give me the opportunity to develop these skills. I had to create a project from scratch and build it into a final year project. I developed my abilities with HTML elements such as buttons, images, canvas and forms. Especially using different types of input for forms such as file inputs. I developed my CSS both through the CSS file itself and adding style properties to specific elements within my HTML file. My Javascript file was the big development for me as I have never done that much work with the Javascript language before whereas this project relied heavily on it. All of these newfound skills are very relevant as I have developed the basic web application coding languages. There are variations of coding languages for web applications but the majority use HTML, CSS and Javascript. I would feel much more comfortable going into a web development role after university now I have developed these skills further.

Another key skill I developed through this project were my project management skills. I developed these as from the beginning I had to plan what I wanted to do and the time frames in which I wanted to complete them in. Another part of this scheduling was to stick to the Waterfall methodology I had in place from the beginning as this was essential to the success of my project. An extension to this skill was the ability to adapt to new time frames. As this was the first project I have managed and completed from start to finish, some of my timings for how long functions would take were a little off. This caused me to have to adapt my future time frames to take into account this extended period for the current task. This is an extremely useful skill in the workplace as if I wanted a project management role, this project is evidence of experience doing that and even if I did not want a project management role the experience of this project help me to understand the future overall projects I will be working on.

My final major skill I developed was planning and sticking to my selected development methodology. This was new to me as I had only once before created a project using a development methodology and it was a group project for which we used the Agile methodology. This time I would be in charge of all stages of the development, from requirements and planning all the way to testing the final product. This is a very useful skill as I would like to go into a software development role in a company and no matter what project I will be working on they will always use some kind of development methodology to follow as they work well and have high rates of success.

# **7.0 Conclusion**

My project is a well-rounded jigsaw puzzle that anyone can play and enjoy in either a casual or competitive aspect. It was a much more complicated project than I first thought it would be as I developed more and more parts especially as it was a web application, none the less it was enjoyable to create. I completed almost all of my aims and objectives except for the professional aesthetics which I need to work on. Other than that, my project effectively completes all of my aims to a good level which is exactly what I set out to achieve from the start of this project.

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# **Appendix**

## Appendix 1

A close up of a device

Description automatically generated

## Appendix 2

A screenshot of a cell phone

Description automatically generated

## Appendix 3

A close up of a mans face

Description automatically generated

## A screenshot of a social media post Description automatically generatedAppendix 4

## Appendix 5

A screenshot of a cell phone

Description automatically generated

## Appendix 6

A picture containing sitting, cat, photo, window

Description automatically generated