NUI Galway
OÉ Gaillimh

“Fool Me Once”
Bluffing card game

Final year project, Computer science and information technology

Daragh Sweeney | Student ID: 14376656 | Date 17/04/2018

Supervisor: Sam Redfern
Supervisor: Denis O’Hora

Acknowledgements

I would like to offer thanks to my supervisor Sam Redfern for all of his help throughout all aspects of the project from the original concept design to the development of the game.

I would also like to offer a special thanks to Denis O'Hora without whose advice and guidance I would not have been able to complete this project.

Finally I would like to thank anyone who played the game, without them I would not have been able to gather samples for my results.

Table of contents

Table of figures

Background Research

BRIEF

"*This project, in collaboration with Dr. Denis O'Hora (Psychology lecturer, NUIG), will develop a "bluffing" card game and use this to investigate indications of deceit apparent in body language. Background: Body language has been used as a term to describe a variety of non-verbal signals, such as facial expressions, that usually accompany verbal language. One means through which nonverbal information is conveyed is through our movements during choice. Specifically, features of cognitive computations are reflected in the motor execution of decisions. We answer quickly and move directly when making easy decisions requiring little computation, but we pause and vacillate when making difficult decisions. When we attempt to deceive, we move differently from when we respond in line with our true motivations. The current project will assess whether mouse movement can be used to identify true and false responses. An online card game will be developed in which one player attempts to deceive another in order to win a gamble.*"

The use of mouse tracking software in recent years has shown that a person's decision-making process is often reflected in their movements. The project is to create an online card game in which a player has the option to lie or not. Then using the information generated by the game it will determined if there is a relationship between the data collected about a player's move and their decision to lie or tell the truth.

BRIEF ANALYSIS

After analysis of the brief it was concluded that there are three main objectives of this project the first is to design the card game. The second to implement it online to collect data for the investigation. The third is to use the data to investigate if there is a relationship between the movements of a player and their decision to lie or tell the truth.

1. Developing a game – the game is based on a design created by Dr Denis O'Hora, it involves placing a card in a higher or lower section depending on if your card is higher or lower than the center card, it is during this move the player can choose to lie or tell the truth.

2. Creating an online platform for the game - It order to make an online multi player game various components are required, these include a host to hold the code that will run the website, a server to distribute information about the website and a database to store game information. It will also require development of the online version of the game.

3. Testing the relationship between a user's move and decision – Once the data has been gathered it will then be tested to see if there is a relationship between the move and the decision to lie or not.

GAME DESIGN

The original game was designed by Denis O'Hora based on his research into decision making and the psychology of deceit. The aim of the game is to try and fool the other player. I.e. if you lie you want the other player to guess you told the truth and if you tell the truth you want the other player to guess you lied.

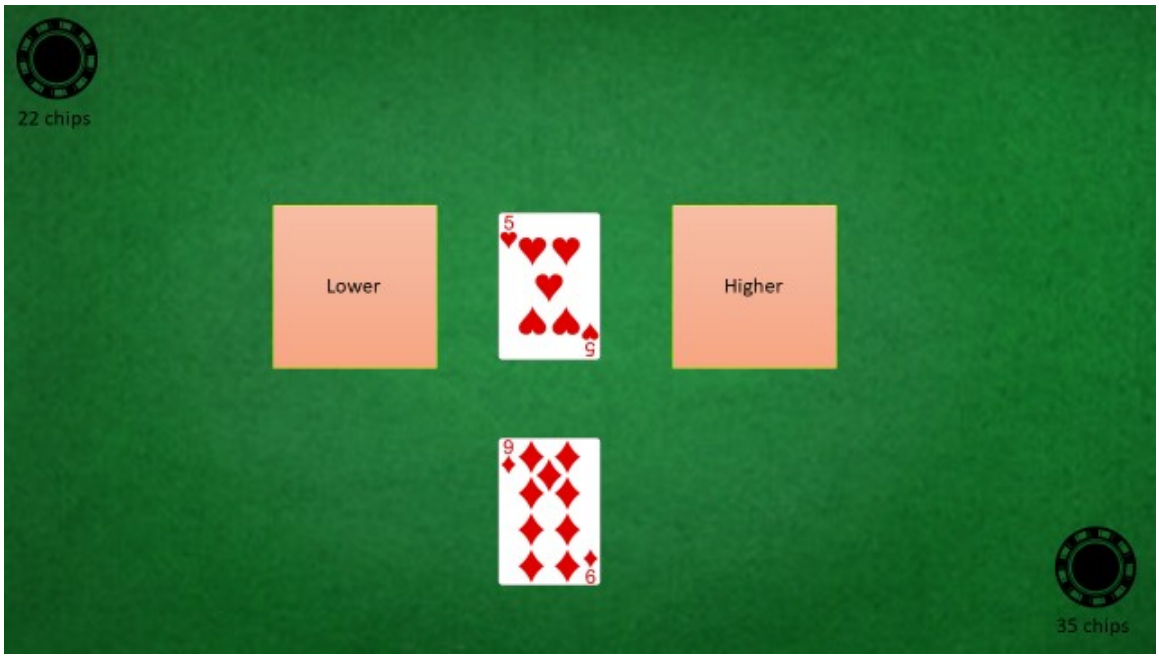

Figure 1 - Mock draw up of game layout

On your turn you will be presented with a card, there will also be a card in the middle of the table. You must decide whether you wish to place the card in the higher or lower section depending on if your card is higher or lower than the card in the middle, i.e. if you want to tell the truth or lie. The opponent must make a guess as to whether you were lying or telling the truth. The following table illustrates how the winner of the round is determined.

	Guess lie	Guess Truth
Player lies	Guesser wins	Player wins
Player is truthful	Player wins	Guesser wins

Figure 2 - description of possible round outcomes

The game then alternates between the players so that the player that was making the move is now the guesser and the guesser is now the player, this process will continue until one of the players has won the game.

LITERATURE REVIEW

This project is based on the idea that as an individual makes a decision it is reflected in their movements. The decision to lie has been shown to take up more cognitive energy than telling the truth and this is reflected in subtle movements of an individual as they lie. It is believed that the mouse movements of a user will indicate when a user is telling the truth or a lie.

The idea of tracking a subject's mouse movements to see if they reflect the cognitive decision-making process has been studied before and the results indicate that as a user makes a decision e.g. whether to lie or not, it is reflected in their mouse movements. In the article "Hand in motion reveals mind in motion" [1], Jonathan B Freeman, Rick Dale and Thomas A. Farmer discuss the cognitive decision-making process and the motor action system and the relationship they share during a decision-making process. They propose that motor responses are not a result of a one-way system, "perception -> cognition -> action" but instead these processes overlap and influence one another. This indicates that even as you are deciding you have already begun to perform an action and that action will constantly change to reflect your decision process.

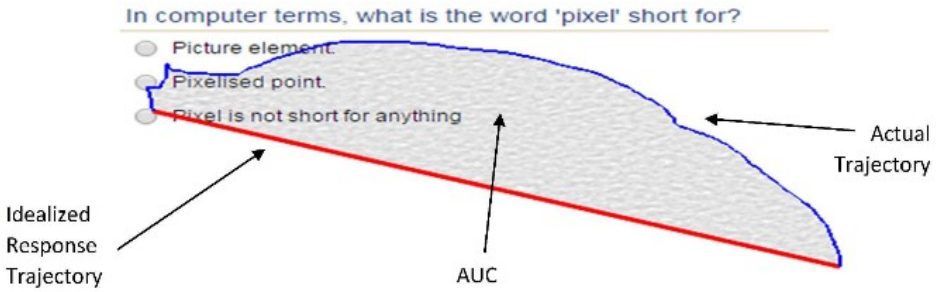

Figure 3 - extract from "A Multi-Experimental Examination of Analyzing Mouse Cursor Trajectories to Gauge Subject Uncertainty"

In this review they note the work illustrated in the paper "A Multi-Experimental Examination of Analyzing Mouse Cursor Trajectories to Gauge Subject Uncertainty" [2] in this paper participants were asked to move their mouse into a box depending on a question they received. As shown above, the paper shows that for questions where the subjects were unsure, there was a greater fluctuation in their mouse movements this is because it takes greater cognitive energy to decide on something you are unsure of rather than something you are more certain of and your movement will be in flux until you decide.

This idea is backed up by Dr. Denis O'Hora's report "Decisions in motion: Decision Dynamics during intertemporal choice reflect subjective Evaluation of Delayed Rewards" [3]

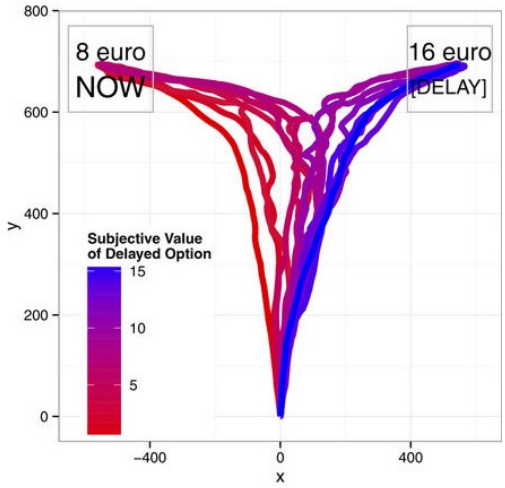

Figure 4– extract from Decisions in Motion

As part of this report, he discusses the use of mouse trajectories of a participant when they were deciding if they would like a reward now or would like an increased reward on a later date, shown above when participants had to decide if they would like an 8-euro reward now or a 16-euro reward on a later time. He displays that the decision for this may not be based on the previously thought idea that the cognitive decision is made before the motor function, and that by using mouse trajectories you can display that certain decisions take a longer time but while this decision is being made the motor function is in flux.

As part of the game two things are expected to affect the cognitive decision of a subject, the first is the difference in value between their card and the card in the middle. The card game is based on the user putting a card in a higher or lower section depending on if their card is higher or lower than the card in the middle. It has been shown that the greater the distance between the numbers the easier it is to identify if a number is higher or lower than another number. The second is that it takes more cognitive energy to lie rather than telling the truth.

Numerical distance effect - In the research of Jao-Hyun Song and Ken Nakayama in their review "Hidden cognitive states revealed in choice reaching tasks" [4], they list research that has been carried out to that display the dynamic internal processes that are involved in perceptual and cognitive processes.

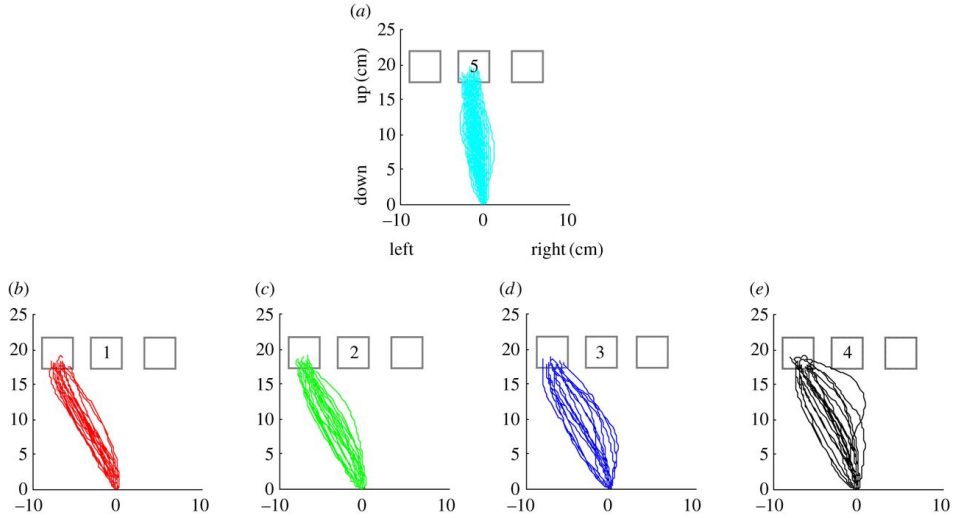

Figure 5 - extract from "Numeric comparison in a visually-guided manual reaching task"

In the journal "Numeric comparison in a visually-guided manual reaching task" [5] an experiment illustrated above shows the "numerical distance effect", this phenomenon is where as the distance between two numbers increase the reaction time to identify which number is higher or lower decrease. For example, in the experiment users were asked to move to the left box if the center number was lower than five, move to the center box if the number was five and move to the right box if the number was greater than five. As you can see the closer the number was to five the less direct paths were to the answer. This indicates that the numeric magnitude of a number is spatially encoded. It is believed that this phenomenon will have an effect on users as they play the game as they will have to make a similar decision to place a card in a higher or lower box depending on if its value is higher or lower than the card in the middle.

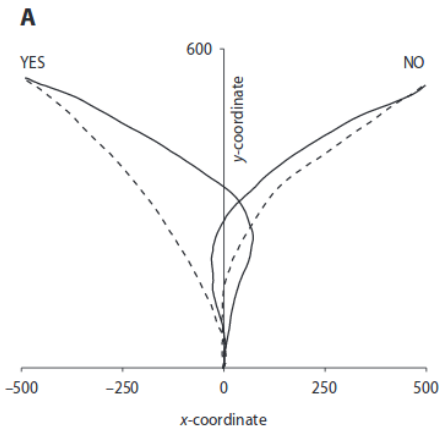

Figure 6 - extract from the action dynamics of overcoming the truth

Decision to lie or tell the truth

– the decision to lie or tell the truth will also have an effect on the cognitive decision-making process. In the paper "The action dynamics of overcoming the truth" [6] by Nicholas D. Duran, Rick Dale and Danielle S. Mc Namara it is shown that it is more difficult to lie than to tell the truth. In an experiment, users were asked to either respond truthfully or falsely to a number of questions. They responded by moving a cursor on a screen using a Wii remote.

To the left is an extract from the paper, the solid lines show lies and the dotted lines show truths. As shown the trajectory of lines where the user is lying are more complex, they appear to tend towards the truth before altering towards the lie value, they tend to cover more distance and tend to be less direct. The effect appears to be more prevalent in false yes answers.

It is believed this effect will have an influence the cognitive decision-making process of users when they play the game as they will have to consciously decide whether they want to lie or not.

Although there has already been research into the numerical distance effect and also research into deceit the research will focus on a combination of the two, it is also notable to add that in all of these studies the participants were asked to lie, whereas in this research the complete decision to lie or not is up to the player and this may increase amount of cognitive energy required to complete the task and this may be reflected in the user's mouse movements.

It is hypothesized that by using the data collected as players play the game it will be possible to generate an algorithm that will be able to identify correctly if a user is telling a lie or telling the truth based on data collected about their move.

MACHINE LEARNING ALGORITHMS

In recent years machine learning has been used for a number of tasks, one task that it has been shown to be good at is classification. In the game to be developed users will have the choice to tell the truth or to lie. As part of this project classification algorithms will be used on the data gathered, to classify if the user was telling the truth or lying. Both the KNN and Naive Bayes algorithms where chosen to classify the data.

K Nearest Neighbor

This is a machine learning algorithm can be used for classification. It works by mapping every sample to a point in a sample space. When you want to query a new sample you simply place it into the sample space and compare it to its neighbors, the estimated value is an average of its K nearest neighbors [7].

The K value in KNN is the number of neighbors the sample is to be compared to. For example, in the diagram to the right a value of 3 is used for k, the center value is compared to its 3 closest neighbors and determined to be a yes value. The optimal value for K is dependent on the data set and can be determined by trial and error.

It is predicted that by using the data set created by the game, an accurate model for estimating if a player was telling the truth or lying can be created.

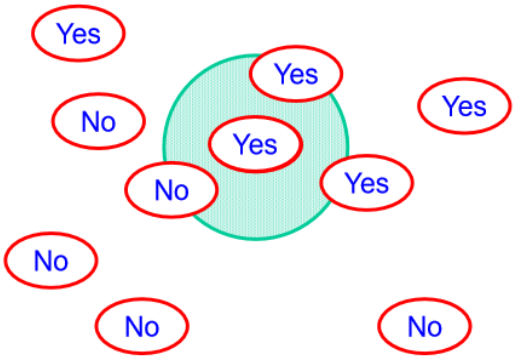

Figure 7 - Visualization of classification using KNN [7]

Naive Bayes

The Naive Bayes algorithm was developed using Bayes theorem. Bayes theorem states [8].

$$P(h|d) = \frac{P(d|h)P(h)}{P(d)}$$

- P (h|d) = the probability of a hypothesis h given the data d
- P (d|h) = the probability of data d given the hypothesis h is true
- P (h) = the probability of h being true
- P (d) = the probability of the data

Each attribute in the classification is calculated independently and a combination of the results is used to test the classification, i.e. pick the value with the highest probability. This may not be accurate as many of the attributes are correlated and not independent, however Naive Bayes has still been shown to produce accurate results.

ROC CURVES

A ROC curve is used to visualize the performance of a binary classifier [9], here the binary classifier is whether the participant told the truth or told a lie. A ROC curve is a plot of the true positive rate against the false positive rate for every possible classification threshold.

When reviewing a graph, we are looking for a high true positive rate and a low false positive rate, ideally as close to the top left-hand corner of the graph as possible, this would mean that the algorithm was able to guess accurately with the fewest cases of false positives or false negatives.

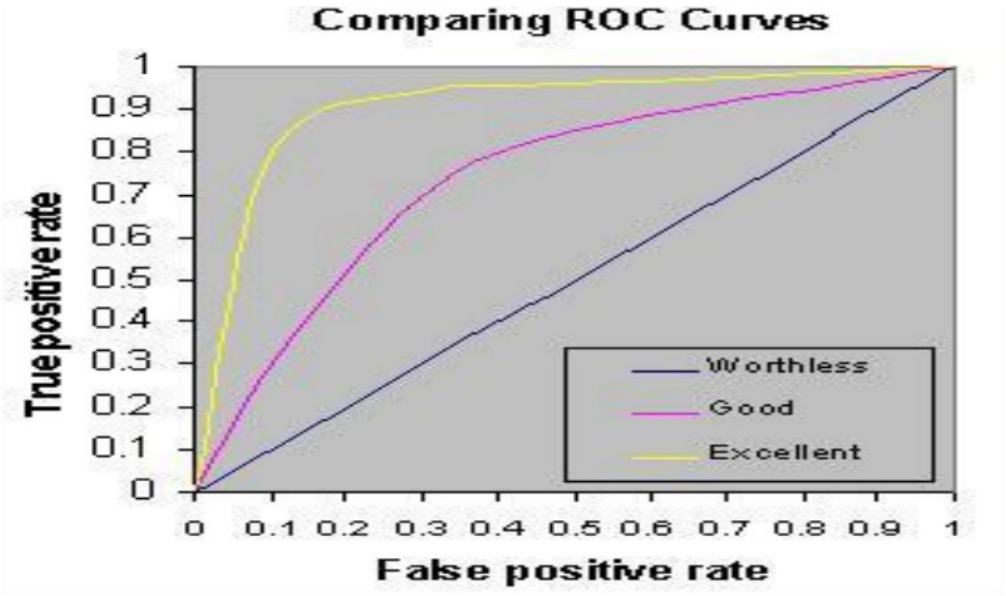

Figure 8 - comparing ROC curves [9]

When reviewing a ROC curve there are a few things that indicate the quality of the algorithm.

1. Area under the curve – The accuracy of the algorithm is measured by the area under the curve. The closer the area is to 1 the more accurate it is, the closer it is to 0.5 the less accurate the algorithm was.

2. Sensitivity of the curve – This is the true positive rate, i.e. the probability of the result being positive when the estimation was positive, it is represented by how close the line is to the left side of the graph. Depending on what is being tested it may be more desirable to have a higher or lower sensitivity for example if the test was for an illness it would be more desirable to have a high false positive rate and a low false negative result as although it would increase the number of subjects being identified with the illness it would be less likely to identify subjects as not having the illness when in fact they do.

3. Shape of the curve – The general shape of the curve can also be used as an indication of the quality of the algorithm. A clear gradual slope is more desirable as it indicates a clear pattern for identifying values.

CROSS VALIDATION

Cross fold validation is a method that can be used if there is only a small number of instances in the dataset. As part of cross validation, the data is split into N folds or sections, usually 10, of equal or almost equal size.

For every fold a hypothesis is created using that fold for testing and the rest of the folds for training, making sure that each fold is used only once for testing. In the example below there are 5 folds, each column represents a hypothesis being created with the yellow fold being used for testing and the green folds being used for testing. After all hypotheses have been created they are combined to build a final hypothesis.

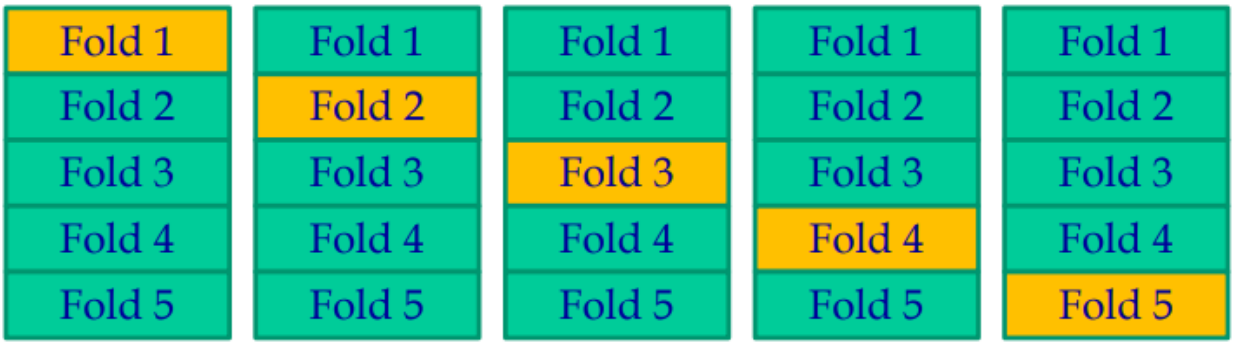

Figure 9 - cross fold validation [9]

Cross fold validation is a good method to use if the data set is small as it uses every value in the set to create an overall hypothesis even though the trained data has always had an independent fold to test on.

Developing the game

To test various components of the game and determine what features worked well several participants played the game using a deck of cards, the middle card would be flipped over and the user whose go it was would get a card and place it in a higher or lower pile, and they would then place a bet on the move. It was then up to the guesser to guess whether they were lying or telling the truth.

Figure 10 - testing the game

This was a great way to prototype and develop the game and allowed for the analysis of game features, for example, how many chips each player should start off with to allow the game time of each game to last on average between 1 and 5 minutes. Also providing real-time feedback.

It also gave a base idea on some of the strategies people were using to win such as betting low on an obvious lie i.e. betting 5 when they told the truth and it was statistically probable they were telling the truth and betting high when it was an ambiguous truth i.e. betting 50 when they were telling the truth, but it was statistically improbable.

GAME RULES

Using the results gathered a final version of the game was developed.

- Both players begin with 100 chips.
- The player who goes first is determined at random.
- That player will be presented with a card, between one and ten, only they can see, a card will also be placed face forward on the center of the table, both cards are chosen randomly and the appearance of one has no influence on the other only that they cannot be the same and that the center card must have at least one value higher and one value lower than it.
- The player slides the card to the higher or lower section, and then places a bet on the move.
- The guesser must call the bet, they then decide if the player was truthful about their move.
- Once the guess is made the round is over, the player who won receives all chips and the rolls of player and guesser are swapped.
- The game continues until one player runs out of chips.

SCORING SYSTEM

This seemingly trivial part of the project proved to be quite a complex and difficult thing to decide on. To begin with I had intended to implement a simple system that if a player won a game they got a point if they lost they received nothing this encouraged people to play more as your score would keep increasing but penalized new players as it would take a long time playing to reach a high score position. Another idea I had was to base the score on the win loss ratio but a huge problem with this was that a user could potentially just play one game, win, and have a 100% win/loss ratio. I decided to implement an Elo Rating system [10].

Elo Rating System

The Elo Rating system is a method of calculating the skill of a player, created by Arpad Elo it was designed to allow chess players to calculate their skill on grounds other than the number of tournaments won. The Elo system is effective at updating the score of a player quickly to match their skill level, it does this by taking into consideration the probability of a player winning against their opponent, this means if you play with high level players you will gain points much quicker than if you play with low level players. The graph below shows two players with a 400 difference in rating, if K is taken to be 32 the brown middle curve, for the expected outcome i.e. the player with a win, there is a very small rating change, 3 in this case. However, for the unexpected outcome i.e. the player with the lower score wins there is a much larger rating change of 29.

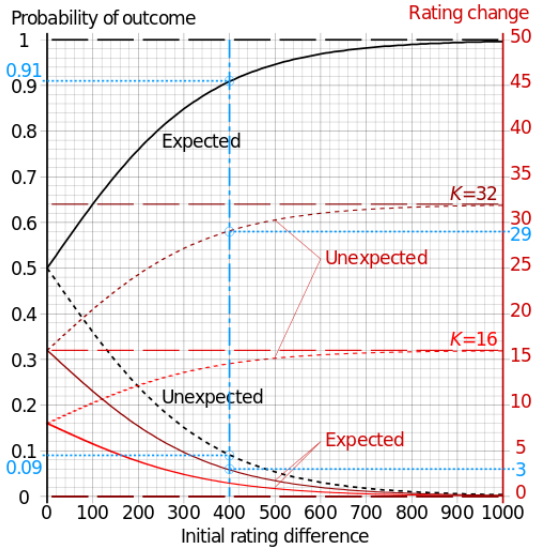

Figure 11 - Distribution of users on an Elo Rating system for chess [15]

Shown below is the version of the Elo Rating system implemented in the game.

1. Transformed rating for each player - Each players original score is altered so that it can be used in calculating the expected score.

$$R(1) = 10^{r(1)/400}$$
$$R(2) = 10^{r(2)/400}$$

2. Calculate their expected score - An expected score for each player is calculated using the transformed rating for each player.

$$E(1) = R\,(1)/\big(R(1) + R(2)\big)$$
$$E(2) = R\,(2)/\big(R(1) + R(2)\big)$$

3. Actual score - An actual score of 1 or 0 is given to the player depending on whether they won the game or not.

$$S(1) = 1(if player1won)$$
$$S(2) = 0(if player2lost)$$

4. Update Elo Rating for each player - Using the expected score the actual score and k a value that determines the sensitivity of the scoring system a new Elo rating is determined for each player

$$r'(1) = r(1) + k * \big(S(1) - E(1)\big)$$
$$r'(2) = r(2) + k * \big(S(2) - E(2)\big)$$

The benefit of using this system is that players who are starting of can climb quickly through the ranks while players who are already on a high rank will find it increasingly more difficult to rise higher. This will create a dynamic competitive environment that will encourage players to continue playing the game.

PARTICIPANTS

Acquiring participants for the game is one of the most difficult tasks, the game requires two players to be available to play at the same time. To get more accurate results we need a large number of participants and to get the information we need from the game we are restrained to a certain number of sources. Here are various sources that were considered.

- The game could be placed on a website that has a range of regular users, such as Io games [11], here it will be more likely to get user participation. Also, using a competitive environment i.e. a scoring board, we hope to encourage more users to play.

- A link to the game could be shared on social media among friends and family members and on online boards. More people are likely to play as they would be interested in using a product developed by someone they know.

- Participants could be requested from the school of psychology. This is the least desirable option as it is too late to request them for this year and so testing would have to be done next year.

- An event could be held with a prize to encourage several players to play the game in a short period of time.

Technical Review

A number of technologies where considered for the development of the "fool me once" game. When deciding on a technology several factors were taken into consideration such as time taken to learn how to use the technology if not already familiar, the amount of work required to set up the technology, the efficiency of the technology and the cost. The following technologies were used.

HOSTING THE GAME

It was decided to use the free server space offered by the IT department. This was an ideal option as the college runs high speed servers in the IT building that can be accessed by IT students for free, with technical support available and easily reached.

SERVER-SIDE PLATFORM

The server is used to process requests and transfer data, a node JS server for the game [12].

The server was built using this technology because using node, it is easy to build fast scalable network applications. Node is lightweight event driven and non-blocking this means that it does not wait for a response before moving on to the next process which makes node extremely fast. Node is single threaded which means it avoids the overhead of switching between threads and so can be quicker in certain circumstances. Another advantage of node is that it has a huge range of documentation online that can be accessed quickly if any problems should arise. Finally, node uses JavaScript on the server, a language I am proficient in and so by choosing node the time required to get accustomed with the technology is drastically reduced.

DATABASE

The database is where information is stored. In the case of this game data would include things such as the user names and passwords of the players, the game data and the data relating to the trajectory of a user's mouse movements when they make a move.

A Mongo Data Base was used for various reasons, MongoDB is a free and open source document database that is extremely scalable and flexible. It is a no-SQL database which means that it does not use the SQL programming language, instead it uses JSON-like documents with schemas [13]. I have gained experience using a mongo DB as part of the software engineering module and found it to be a very useful dynamic database type. It is a good fit for the way data in this project is going to be stored, its flexible structure is more desirable for storing information

of different lengths such as the x, y coordinates and the timestamps used for storing trajectory information.

DATA COLLECTED

All data is to be stored in the Mongo Data Base. This will include the user information, their log in details and score. The game information including the game identification number and the associated players. Also, the round information this will saved included information about each round.

User Collection

- Name: The user's username
- Password: The user's password
- Score: The Elo rating of the player

Games Collection

- Name: The unique name given to the game
- Player1: The first player to join the game
- Player2: The second player to join the game

Moves Collection

- GameID: The unique game id to which this move belongs, the game ID is generated when the game is made and is the exact time and date the game begun.
- PlayerMoved: The player that made the move this round
- PlayerGuessed: The player that made the guess this round
- CentreCard: The value of the center card as an integer
- PlayerCard: The value of the player card as an integer
- Move: If the player placed the card in the "Higher" or "Lower" section
- PlayerMove: The x and y coordinates of the mouse and timestamps for the movement of a player as they made a move
- Bet: How much chips the user decided to bet on the move
- Guess: Did the guesser guess the move was "True" or "False"
- PlayerGuess: The x and y coordinates of the mouse and timestamps for the movement of a player as they made a guess
- Chips: The remaining chips of both players after the move is complete.

CLIENT SIDE DEVELOPMENT

HTML – As the project is web-based HTML, the standard markup language for creating web pages and web applications, was used to create web pages that would be displayed to the users.

JavaScript – is a programming language that can be used to make dynamic web pages, it is implemented by almost all modern websites and is supported by all modern web browsers.

CSS –a combination of inline CSS and Bootstrap was used when designing the web page. CSS is a language used to affect the design of elements on a HTML page.

Bootstrap - is a free open source front end library for designing websites and web applications. It contains HTML and CSS templates as well as JavaScript extensions.

HTML5 canvas – The <canvas> element in HTML is used to draw graphics on a web page, the canvas element acts as a container or "canvas" and JavaScript is used to draw on to the container.

The following diagram shows how all the components will interact with each other

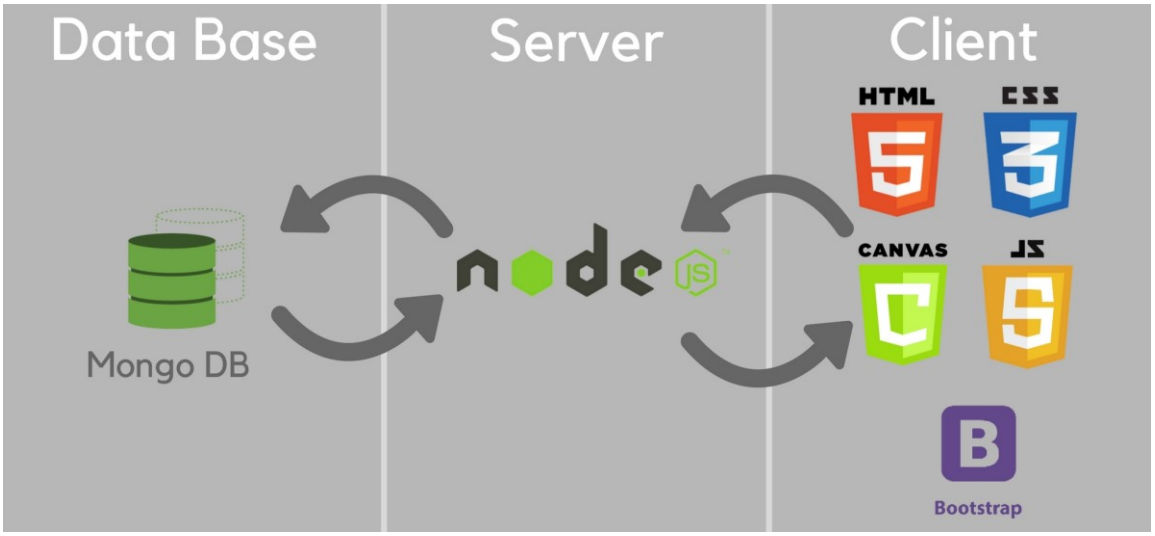

Figure 12 - technology overview

MACHINE LEARNING SOFTWARE

The software chosen to perform machine learning and data mining tasks on the data was Weka [14]. Weka is an open source set of tools developed by the University of Waikato, New Zealand that allows for operations to be carried out directly on a dataset. Weka has been licensed under the general public license this means that users are allowed to run and edit the software as they see fit.

Using Weka, it is possible to compare results across a number of algorithms with variety of major machine learning algorithms pre-built into the software. It is easy to compare results as Weka uses an intuitive easy to understand graphical interface.

KNN and Naive Bayes the algorithms that the data set will be tested with are both part of the Weka software package and so it will be easy and quick to process results.

Development, prototyping and testing

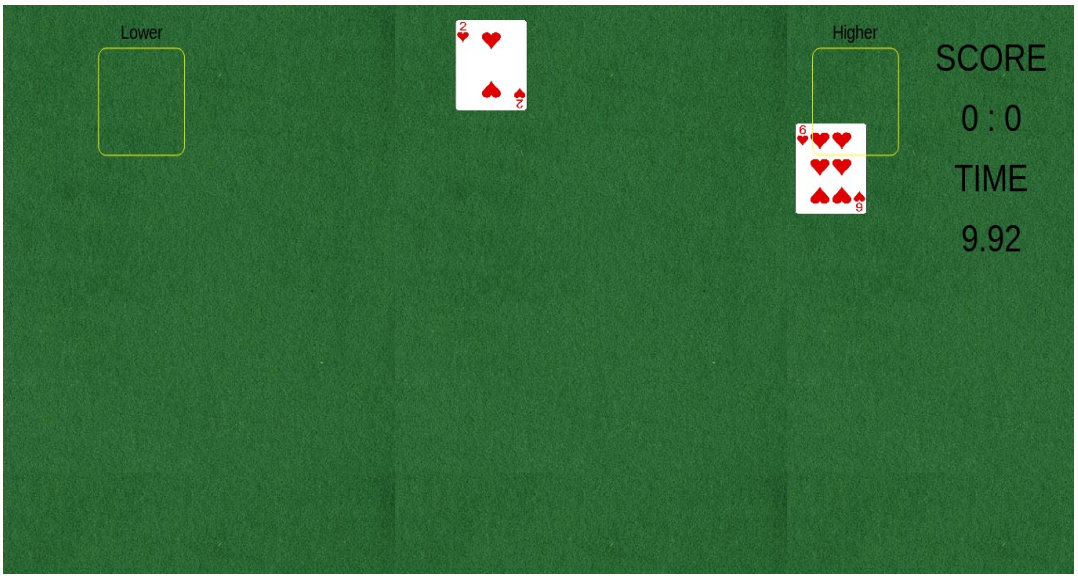

Figure 13 – Early version of the "Fool me once" game

TECHNICAL OVERVIEW

As displayed above the game went through several prototypes before a final design was decided on. During the development stage a number of features were tested to see how they would affect the game, such as displaying the time since starting move shown above. Some of these features were kept and some were removed. As the code was constantly being updated GitHub was used for version control. It was believed that a constant evaluation process would yield a better end product.

A full version of the code is available at https://github.com/DaraghSweeney/Fool_Me_Once.

Website overview

The website has several components that interact to make the game work. The game is hosted on the college server space with access to port number 8703. On the host space a node server is running, this server is the central component to the website and handles all requests.

The central component is the node server. The server is responsible for processing requests and directing users to the correct web page. It handles all quires to the database and also processes all information about the currently running games.

FINAL GAME FEATURES

Log-in/sign-up system

Any users wishing to use the website must enter through the log-in/sign-up page, available at http://danu7.it.nuigalway.ie:8703/index. This log in system is paramount to the project as when users log in they are tracked throughout the game and their data is linked with their username. This allows for the tracking of individual participants.

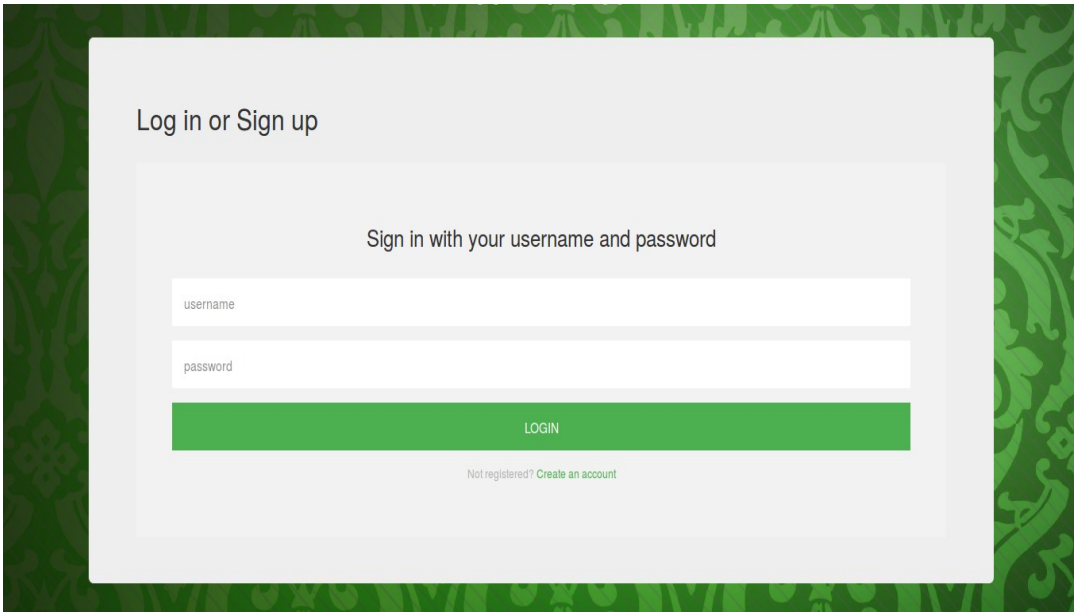

Figure 14 - log in system

A simple method was implemented that when a user logs in the server checks the database to see if there is already a user with that name then the password is sent back if not then the user is redirected back to the log in page. If the password matches the password that was given by the user, then the user is redirected to their user page if the passwords don't match the user is redirected back to the log in page.

```
/*  user log in code    */

app.post('/login', urlencodedParser, function(req, res) {

    dbase.collection("Users").findOne({
        name: req.body.username
    }, function(err, result) {
        if (!result) {
            res.sendFile(__dirname + '/public_html/index.html');
        } else if (result) {

            //user signs in successfully
            if (req.body.username == result.name && req.body.password == result.password) {
                res.render(__dirname + '/public_html/userHangout.html', {
                    name: result.name
                });
            }

            //else user returns to sign in page
            else {
                res.sendFile(__dirname + '/public_html/index.html');
            }
        }
    });
});
```

Figure 15 - user log in code

When creating a profile the user submits a user-name and password, the server checks to see if that user-name is already present in the database, if it is then the profile is not created and the user is redirected to the log-in page, if that user-name has not already been taken then the user's profile is created with an initial score of 1000 and the user is redirected to their user hangout page.

```
/*  user create an account code */

app.post('/signup', urlencodedParser, function(req, res) {

    dbase.collection("Users").findOne({
        name: req.body.username
    }, function(err, result) {
        if (result) {
            res.sendFile(__dirname + '/public_html/index.html');
        } else if (!result) {

            //create new user
            var data = {
                name: req.body.username,
                password: req.body.password,
                score: 1000
            }
            dbase.collection("Users").insertOne(data, function(err, res) {});

            //send user to hangout page
            res.render(__dirname + '/public_html/userHangout.html', {
                name: req.body.username
            });
        }
    });
});
```

Figure 16 - create user account code

User hangout page

The user hangout page was developed as a buffer between games when a user logs in it isn't practical for them to be entered into a game immediately but instead they are placed into the user hangout area of the game, here they can view their world ranking, the points they currently have, enter the tutorial page and they can choose to enter a game. They also can view the leader board, this feature displays the global top five players, and it was designed to create a competitive environment in the game. It was hoped that by introducing this feature it would encourage players to play more of the game.

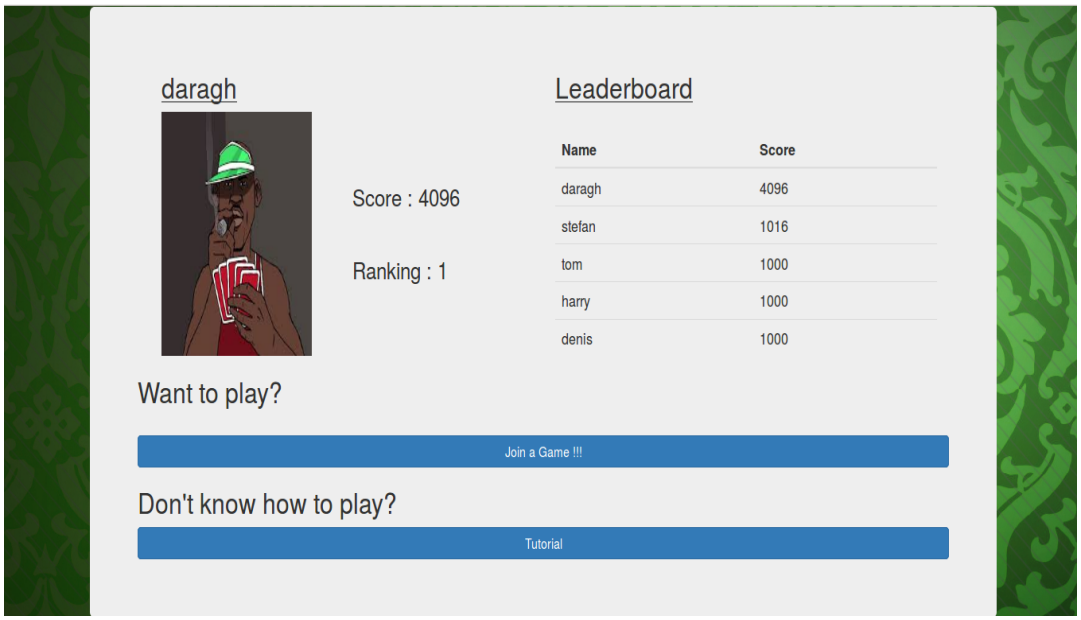

Figure 17 - user hangout page

The code bellow shows how the user hangout page is updated and uses real time data from the database to update values on the page. To get the data Ajax uses a post method to request information from the server.

```
//gets information on players
$.ajax({
    url: ('/users'),
    type: 'GET',
    dataType: 'json',
    success: function(e) {
        userData = e;
        //sort array so that players with top score on top
        userData.sort(compare);

        //update table with the top 5 players
        for (var num = 0; num < 5; num++) {
            $('#table').append('<tr><td>' + userData[num].name + "" + '</td><td>' + userData[num].score + "" + '</td></tr>');
        }

        //finds the players score and ranking by using their name as an identifier
        var ranking = findWithAttr(userData, 'name', "<%= name %>") + 1;
        var score = userData[ranking - 1].score;

        //updates page with users score and ranking
        document.getElementById("score").innerHTML = "Score : " + score;
        document.getElementById("ranking").innerHTML = "Ranking : " + ranking;

    }
});
```

Figure 18 - update user hangout code

Tutorial page

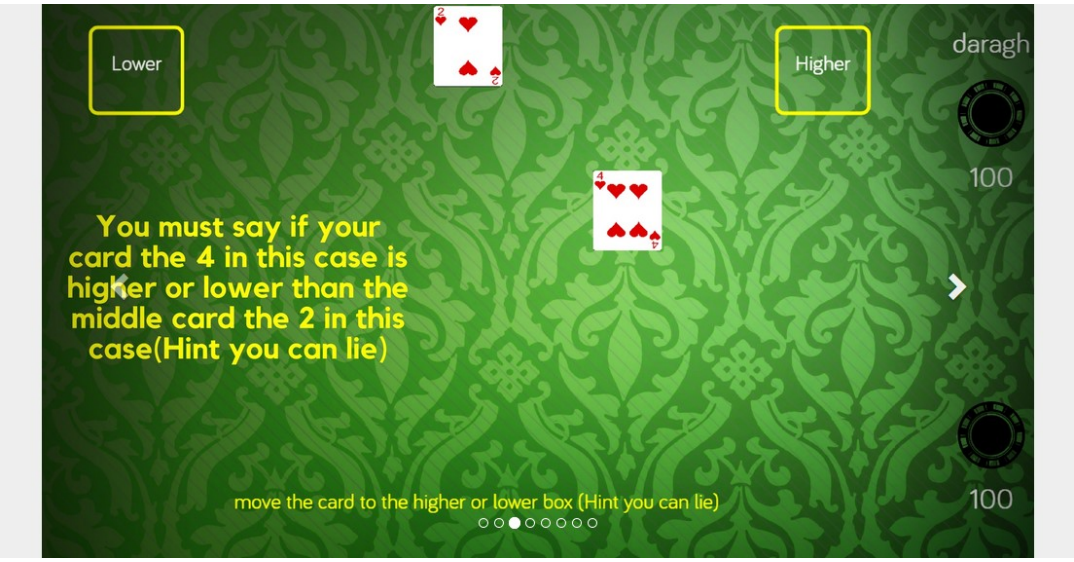

Figure 19 - tutorial page

The Tutorial page was designed to help players understand the rules of the game and to allow users get a feel for the game in a quick space. It consists of a bootstrap carousel that rotates between several images that describe the game in detail.

Game Page

The game has a number of features there are a number of states a user can be in depending on where they are in the game. The following code places them in the mode they are meant to be in.

```
//if game finished display score and give users an option to return to the lobby
if (gameoff) {gameOff();}

else {
    //Game on player can be guessing, betting or its their making a move
    if (gameon == true && yourTurn == true) {

        if (guessing == true) {playerGuessing();}

        else if (betting == true) {PlaceBet();}

        else {playerTurn();}
    }

    //Else you may be waiting for the other player to complete their move
    else if (gameon == true && yourTurn == false) {playerWaitingForMove();}

    //Else you may be waiting for another player to join the game
    else if (gameon == false) {playerWaitingForOpponent();}
}
```

Figure 20 - Game logic code

The figure below displays a number of game states a user could be in depending on what stage of a game they are in. Clockwise beginning in the top left corner, they are waiting for an opponent to join, waiting for opponent to complete move, player guessing, game over, place bet and player move

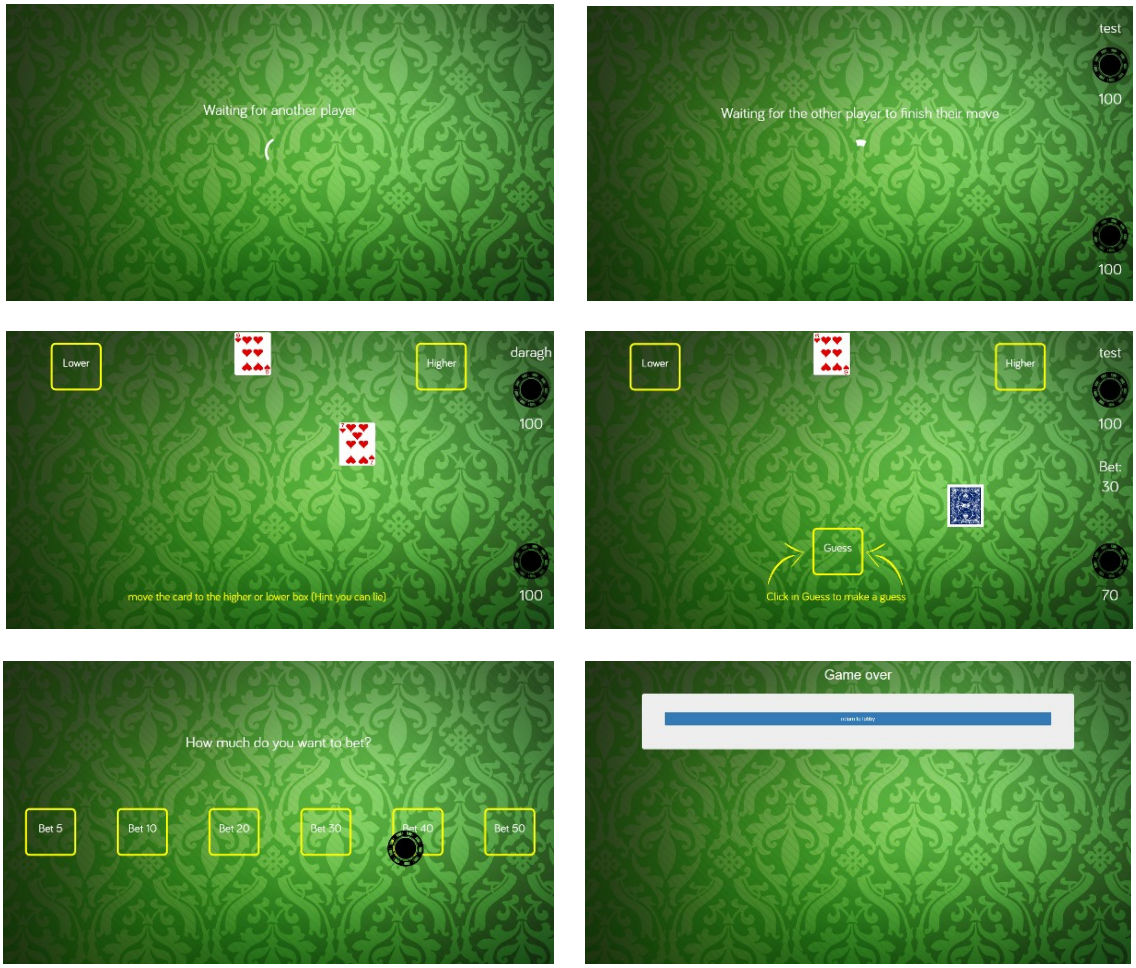

Figure 21 - Game states

There are various features on the game page designed to make the game easy to play and visually appealing, these include arrows in some states to show the user where they need to click, small text boxes with hints, a spinner on pages where the user must wait, this is to indicate that the game is still in progress and finally large chip icons on the side of the screen to show where the score is

Data retrieval page

The data retrieval page was created to extract information about the various games and display them in a simple interactive manor. When a user first enters the page, they have the option of choosing from various game or user values, they also have the option of selecting all data on the database.

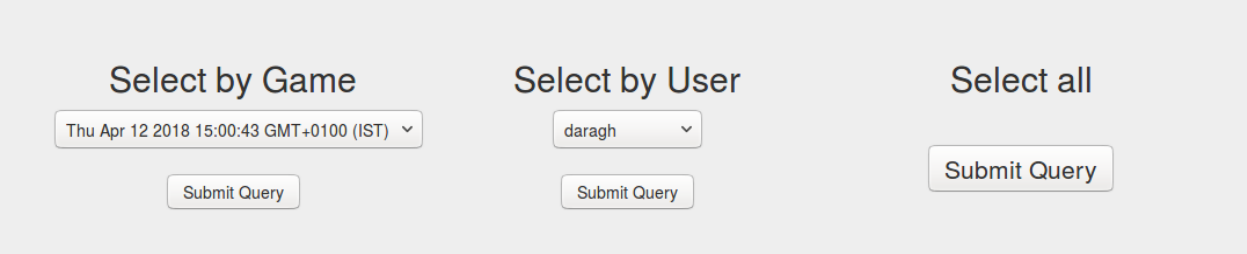

Figure 22 - Data retrieval page, select data

- Select Game – If a game is selected, the moves in a specific game will be displayed.
- Select User – If a user is selected, the moves where that user was a making a move will be displayed.
- select all – If select all is selected, all moves on the data base will be displayed

When a user hits submit on the "select by user", "select by game" or "select all" a request is sent to the server with the information selected. The server searches the database for any entries that match the requirements and redirects the user back to the data retrieval page with the data rendered with the response.

```
app.post('/playerInfo', urlencodedParser, function(req, res) {
    dbase.collection("moves").find({
        playermoved: req.body.request
    }).toArray(function(err, result) {
        var data = {
            data: result,
            type: 'user',
            title: req.body.request
        };
        res.render(__dirname + '/public_html/data.html', {
            data: data
        });
    });
});
```

Figure 233 - data about user retrieved from database on server

Figure 244 - Data retrieval page, display moves

The user can select any of the moves sub sectioned under the moves they selected, and they will be displayed a range of information about that move including a mapped trajectory of both the player move and the guesser move displayed bellow. The black shows the player move and the red shows the guess.

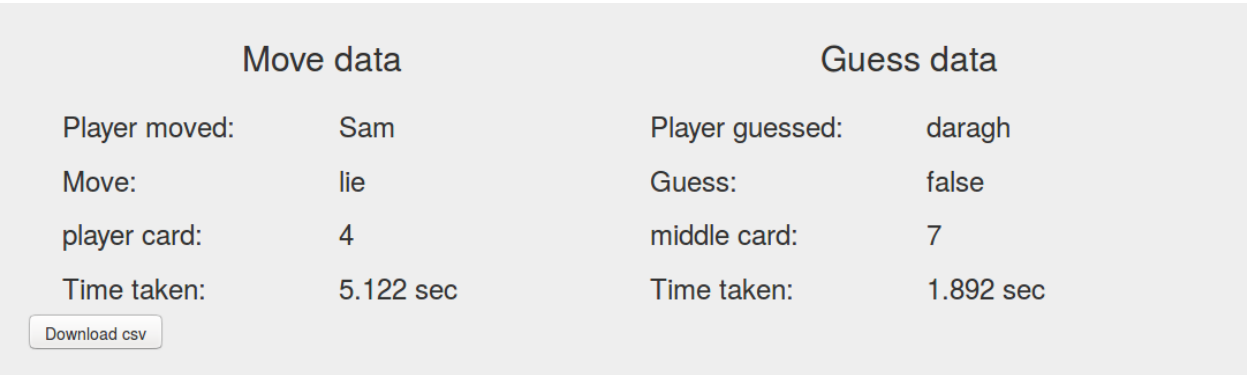

Figure 255 - Data retrieval page, game information

Information about the move will also be displayed including the player usernames the move, if it was the truth or a lie, the guess, if they guessed true or false, the cards on display and both the time taken for the move and the guess.

Images and icons used in projects

Below is a list of images that were used in the project all were taken from open source websites.

Description	Pages used	source	Link
Background image	Log in, user hangout, game, tutorial, data retrieval	Isthmus Montessori Academy	http://isthmusmontessoriacademy.org/green-background-for-website-and-photoshop
Cards	game	Open game art	https://opengameart.org/content/playing-cards-vector-png
Poker chip	game	The noun project	https://thenounproject.com/marcusmichaels/uploads/?i=170698
User image	User Hangout	Free pic	https://www.freepik.com/index.php?goto=74&idfoto=761436&term=avatar
Diamond	Used as favicon	clker	http://www.clker.com/clipart-diamond-cards.html

Development issues

There were several development issues when designing and implementing the online "Fool Me Once" game.

1. One of the issues was development on the node server, node is single threaded, and although this is useful in certain situations it is different to the traditional multi-threaded server. This means that it takes time to develop a system that can handle multiple clients, in the case of this project the game handles all requests in an array sequentially, although it still offers high speed results there were issues with games crashing.

2. After editing code on the danu6 server the npm command no longer worked, this resulted in server downtime for 2 weeks. This issue was solved by migrating the site to danu7.

3. Time was also an issue, there were several features of the website that were not possible to be developed because there was not enough time to complete them.

Results

Machine learning algorithms were used to classify whether someone was lying or not using various data from their move. The information extracted was the name of the player, the time taken for the move, the relative distance covered on screen, the middle card value, the player card value, the absolute distance between the middle card and the player card and the decision to tell the truth (true) or lie (false).

The software tool Weka was used to compile the data collected from the various games played. The csv file generated on the data retrieval page can be directly inputted into Weka using the open file section. From there you can visualize various aspects of the data, as shown below, the blue values represent truths and the red values represent lies.

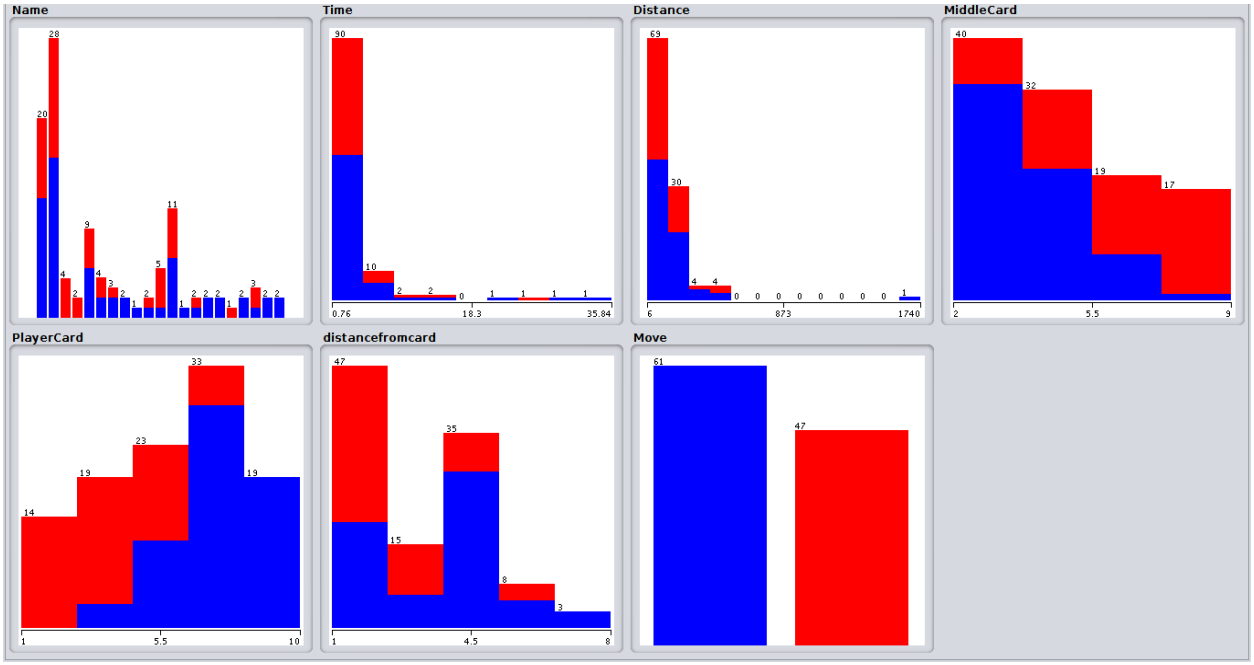

Figure 26 - visualizing data in Weka

Once extracted operations can be carried out on the data. The data was tested using several classifying machine learning algorithms to test how efficient they were at classifying if the user was lying or telling the truth.

The dataset that was extracted included 108 move entries for use for testing. These participants were from a variety of sources several of them came from responses to an online post about the game, there was also an announcement in one on Denis O'Hora's classes asking for participants and there was a competition held in one of the computer science labs.

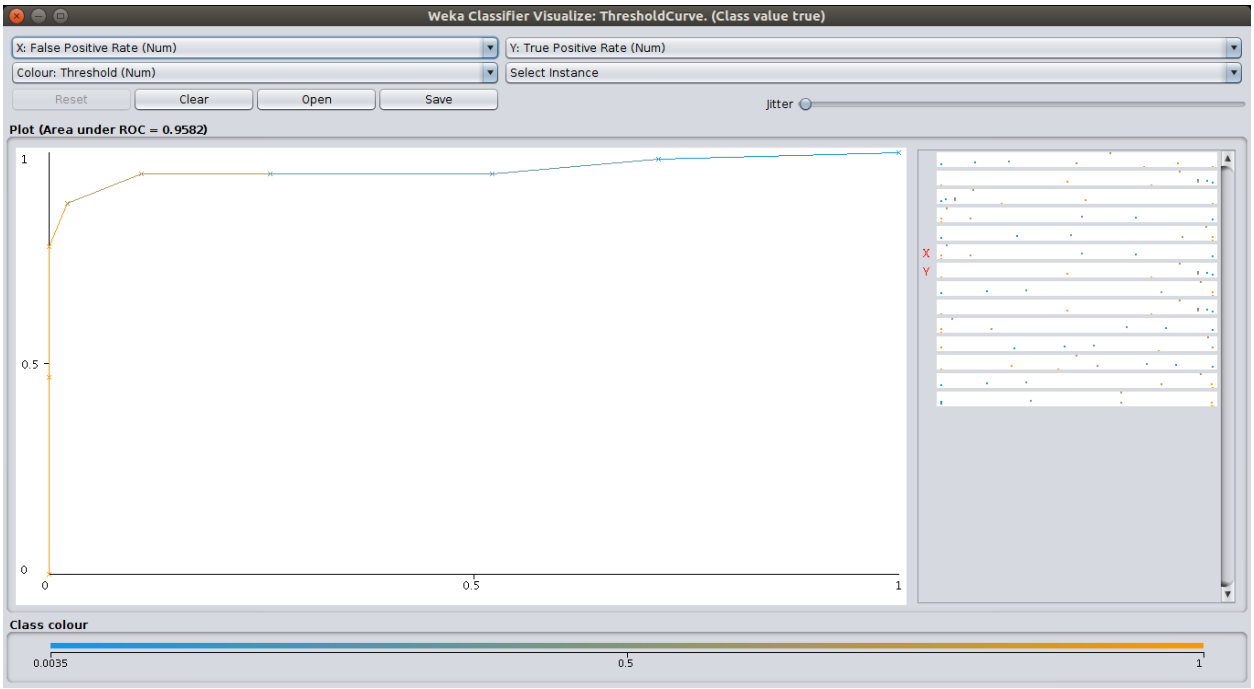

Figure 27 - ROC curve data for KNN

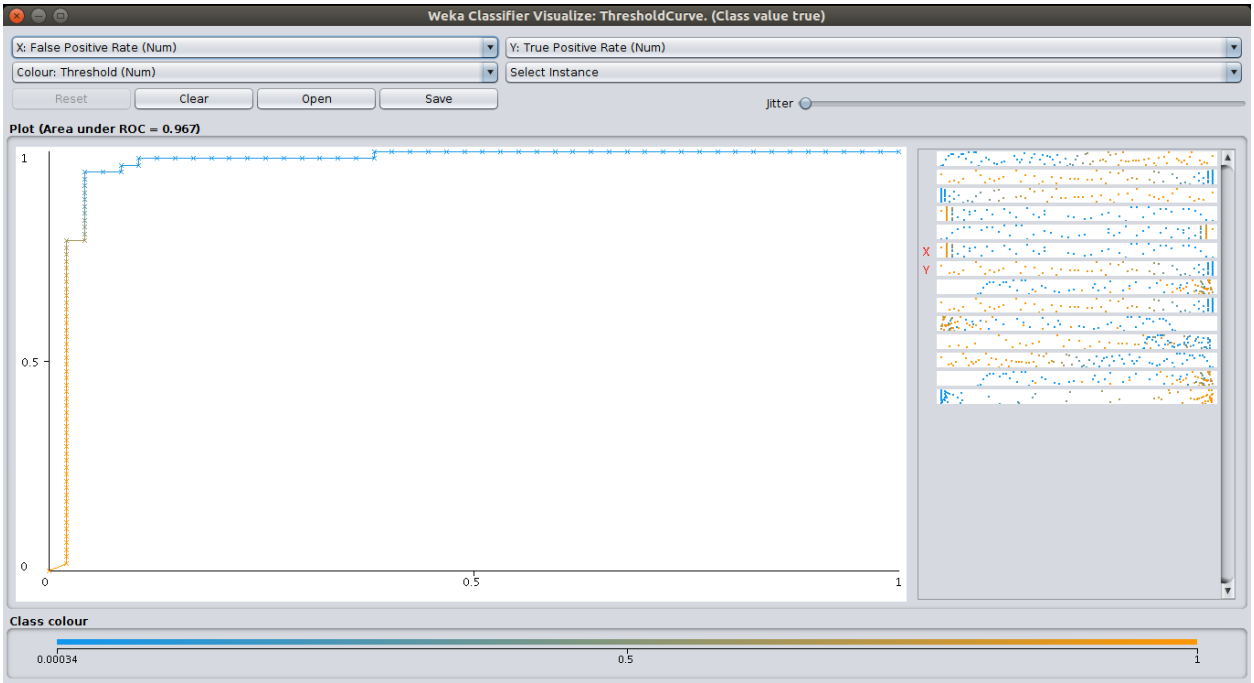

Figure 28 - ROC curve for Naive Bayes

KNN

The KNN algorithm correctly classified 96 of the 108 instances in the data giving it a correct classification percentage of 88.8889%. The value for K was decided using a trial and error method while and it was determined that the optimum value for k was 3. The area under the curve was 0.9582 an extremely high value indicating that KNN was a very effective method at classifying this data set. This method was carried out using 10-fold cross validation.

NAIVE BAYES

The Naive Bayes algorithm correctly classified 93 of the 108 instances in the data giving it a correct classification percentage of 86.1111%. The area under the curve was 0.967 another extremely high value indicating that it was good at classifying the data set. This method was carried out using 10-fold cross validation.

EVALUATION

Both tests yielded a high correct identification percentage with KNN correctly identifying 88.8889% of instances and Naive Bayes correctly identifying 86.1111% of instances on the dataset. These are extremely high results showing a clear connection between the information taken about a move and the outcome of that move. The machine performed drastically better than the participants guessing who identified 61 of the 108 instances or 56.48% of instances.

Although these results show an indication that it is possible to identify a person's decision to lie based on data about their move, the data set is relatively small, and more testing is required to get a more conclusive outcome.

Conclusion

Project outcomes

I am very pleased with the outcome of this project. I believe I have fulfilled the brief and have delivered a product that indicates that there is an identifiable correlation between a user's move and their decision to lie or tell the truth.

Throughout the process of completing this final year project I have gained a vast number of skills in areas including communication, the development process, timekeeping, version control and human computer interaction. I have also gained an insight in how to take an idea based on psychology research and apply it to a computing system.

I believe I have completed all aspects of the brief adequately and am pleased with the results obtained. However, there are many aspects of the project that could be improved.

- Improved timekeeping – I believe that timekeeping was one of the biggest issues I faced regarding this project, I did not manage my time at the beginning of the year and so was under a lot of pressure to complete aspects of the game approaching the end of the project.
- Collect more results - By the time the game was ready there was not enough time to implement some of the methods noted before instead I decided to host two events to get as much data as possible. The first was a meeting with some psychology students that were part of Dennis' class. The second was a session I planned on having with friends and family.
- Learning new technologies – There are several technologies used in the project that could be improved. Canvas was used for graphics, however it was slow and hindered the sampling rate. An alternative machine learning software tool could be considered such as Apache spark or TensorFlow

Future work

There are several avenues I would like to pursue with regards to this project. X

The results could be updated to include a number of extra features including the full list of data points, a higher sampling rate could be taken, individual investigation of good/bad users could be done and a larger sample, this would increase confidence in the results and possibly increase accuracy.

Research could also be carried out on the guesser to determine if there is a relationship between the guessers move and their ability to guess a move correctly.

References

[1] J. Freeman, R. Dale and T. Farmer, "Hand in Motion Reveals Mind in Motion", Frontiers in Psychology, vol. 2, 2011.

[2] J. L. Jenkins,R. Larsen, R. Bodily, D. Sandberg,P. Williams, S. Stokes, S. Harris and J S. Valacich "A Multi-Experimental Examination of Analyzing Mouse Cursor Trajectories to Gauge Subject Uncertainty ", Twenty-first Americas Conference on Information Systems, Puerto Rico, 2015

[3] D. O'Hora, R. Carey, A. Kervick, D. Crowley and M. Dabrowski, "Decisions in Motion: Decision Dynamics during Intertemporal Choice reflect Subjective Evaluation of Delayed Rewards", Scientific Reports, vol. 6, no. 1, 2016.

[4] Song, J. and Nakayama, K. (2009). Hidden cognitive states revealed in choice reaching tasks. *Trends in Cognitive Sciences*, 13(8), pp.360-366.

[5] Numeric comparison in a visually-guided manual reaching task. (2008). *Cognition*, 106(2), pp.994-1003.

[6] D. Duran, N., Dale, R. and S. Mc Namara, D. (2010). The action dynamics of overcoming the truth. *Psychonomic Bulletin & Review*, 17(4), pp.486-491.

[7] Madden, M. (2018). Instance-Based Learning. [online] Blackboard. Available at: https://nuigalway.blackboard.com/bbcswebdav/pid-1346148-dt-content-rid-6811410_1/courses/1718-CT475/CT475_03_IBL.pdf [Accessed 16 Apr. 2018].

[8] Scikit-learn.org. (2018). 1.9. Naive Bayes — scikit-learn 0.19.1 documentation. [online] Available at: http://scikit-learn.org/stable/modules/naive_bayes.html [Accessed 16 Apr. 2018].

[9] Madden, M. (2018). Evaluating Classifier Performance; Practical Advice; Some Data Mining Tools. [online] Blackboard. Available at: https://nuigalway.blackboard.com/bbcswebdav/pid-1360797-dt-content-rid-6875555_1/courses/1718-CT475/CT475_04_Evaluation%2BAdvice%2BTools%281%29.pdf [Accessed 16 Apr. 2018].

[10] Thechessworld.com. (2018). Deeper look at ELO: chess rating system. [online] Available at: https://thechessworld.com/articles/general-information/deeper-look-at-elo-chess-rating-system/ [Accessed 16 Apr. 2018].

[11] Iogames.space. (2018). .io Games | The BEST io Games List at iogames.space. [online] Available at: http://iogames.space/ [Accessed 16 Apr. 2018].

[12] Foundation, N. (2018). Node.js. [online] Node.js. Available at: https://nodejs.org/en/ [Accessed 16 Apr. 2018].

[13] MongoDB. (2018). MongoDB for GIANT Ideas. [online] Available at: https://www.mongodb.com/ [Accessed 16 Apr. 2018].

[14] Cs.waikato.ac.nz. (2018). Weka 3 - Data Mining with Open Source Machine Learning Software in Java. [online] Available at: https://www.cs.waikato.ac.nz/ml/weka/ [Accessed 16 Apr. 2018].

[15] En.wikipedia.org. (2018). Elo rating system. [online] Available at: https://en.wikipedia.org/wiki/Elo_rating_system [Accessed 16 Apr. 2018].