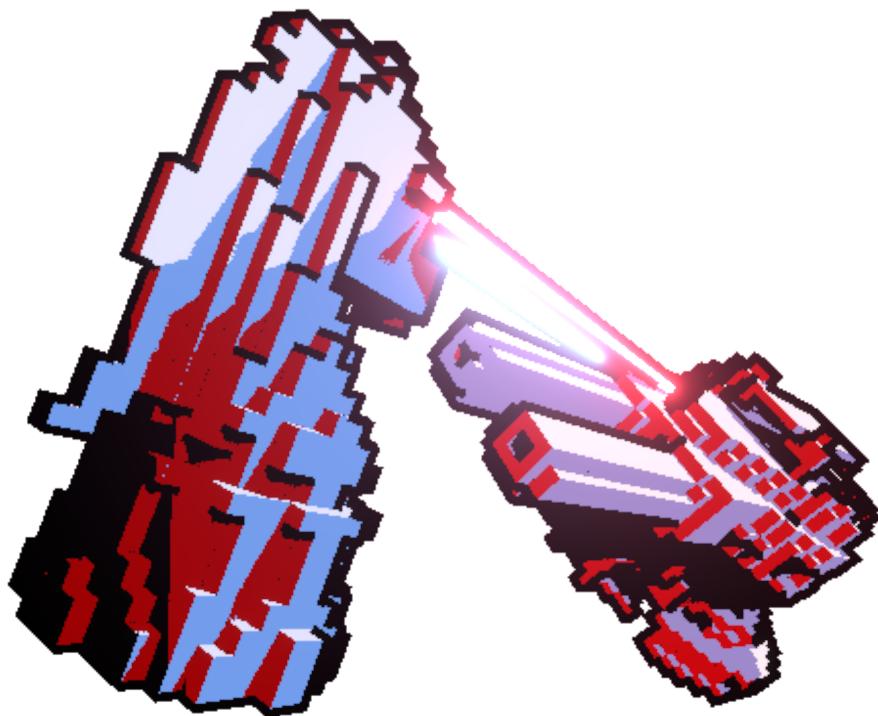


NEA Report

# Laser Chess



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# Chapter 1

## Analysis

### 1.1 Background

Mr Myslov is a teacher at Tonbridge School, and currently runs the school chess club. Seldomly, a field day event will be held, in which the club convenes together, playing a chess, or another variant, tournament. This year, Mr Myslov has decided to instead, hold a tournament around another board game, namely laser chess, providing a deviation yet retaining the same familiarity of chess. However, multiple physical sets of laser chess have to be purchased for the entire club to play simultaneously, which is difficult due to it no longer being manufactured. Thus, I have proposed a solution by creating a digital version of the game.

#### 1.1.1 Game Description

Laser Chess is an abstract strategy game played between two opponents. The game differs from regular chess, involving a 10x8 playing board arranged in a predefined condition. The aim of the game is to position your pieces such that your laser beam strikes the opponent's pharaoh (the equivalent of a king). Pieces include:

1. Pharaoh
  - Equivalent to the king in chess
2. Scarab
  - 2 for each colour
  - Contains dual-sided mirrors, capable of reflecting a laser from any direction
  - Can move into an occupied adjacent square, by swapping positions with the piece on it (even with an opponent's piece)
3. Pyramid
  - 7 for each colour
  - Contains a diagonal mirror used to direct the laser
  - The other 3 out of 4 sides are vulnerable to being hit
4. Anubis

- 2 for each colour
- Large pillar with one mirrored side, vulnerable to the other sides

### 5. Sphinx

- 1 for each colour
- Piece from which the laser is shot from
- Cannot be moved

On each turn, a player may move a piece one square in any direction (similar to the king in regular chess), or rotate a piece clockwise or anticlockwise by 90 degrees. After their move, the laser will automatically be fired. It should be noted that a player's own pieces can also be hit by their own laser. As in chess, a three-fold repetition results in a draw. Players may also choose to forfeit or offer a draw.

#### 1.1.2 Current Solutions

Current free implementations of laser chess that are playable online are limited, seemingly only available on <https://laser-chess.com/>.

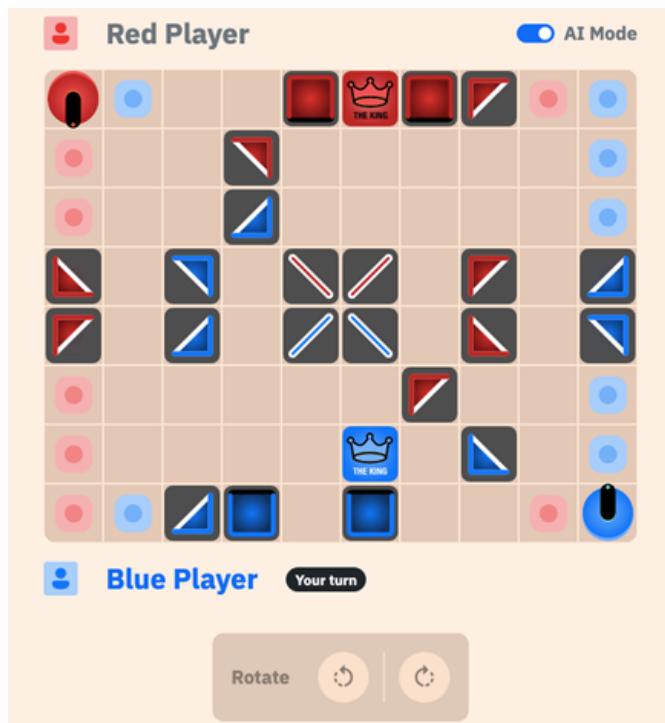


Figure 1.1: Online implementation on laser-chess.com

The game is hosted online and is responsive and visually appealing, with pieces easy to differentiate and displaying their functionality clearly. It also contains a two-player mode for playing between friends, or an option to play against a functional CPU bot. However, the game lacks the following basic functionalities that make it unsuitable for my client's requests:

- No replay options (going through past moves)
  - A feature to look through previous moves is common in digital board game implementations
  - My client requires this feature as it is an essential tool for learning from past games and to aid in analysing past games
- No option to save and load previous games
  - This QOL feature allows games to be continued on if they cannot be finished in one sitting, and to keep an archive of past games
- Internet connection required
  - My client has specifically requested an offline version as the game will predominantly be played in settings where a connection might not be available (i.e. on a plane or the maths dungeons)
- Unable to change board configuration
  - Most versions of laser chess (i.e. Khet) contain different starting board configurations, each offering a different style of play

Our design will aim to append the missing feature from this website while learning from their commendable UI design.

### 1.1.3 Client Interview

**Q:** Why have you chosen Laser Chess as your request?

**A:** Everyone is familiar with chess, so choosing a game that feels similar, and requires the same thinking process and calculations was important to me. Laser chess fit the requirements, but also provides a different experience in that the new way pieces behave have to be learnt and adapted to. It hopefully will be more fun and a better fit for the boys than other variants such as Othello, as the laser aspects and visuals will keep it stimulating.

*Objectives 1 & 7*

Implementing laser chess in a style similar to normal chess will be important. The client also requests for it to be stimulating, requiring both proper gameplay and custom visuals.

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**Q:** Have you explored any alternatives?

**A:** I remember Laser Chess was pretty popular years ago, but now it's harder to find a good implementation I can use, since I don't plan on buying multiple physical copies or paid online copies for every student. I have seen a few free websites offering a decent option, but I'm worried that with the terrible connection in the basement will prove unreliable if everybody tries to connect at once. However, I did find the ease-of-use and simple visuals of some websites pleasing, and something that I wish for in the final product as well.

*Objective 2 & 6*

The client's limitations call for a digital implementation that plays offline. Taking inspiration from alternatives, a user-friendly GUI is also expected.

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**Q:** What features are you looking for in the final product?

**A:** I'm looking for most features chess websites like Chess.com or Lichess offer, a smooth playing experience with no noticeable bugs. I'm also expecting other features such as having a functional timer, being able to draw and resign, as these are important considerations in our everyday chess games too. Since this will be a digital game, I think having handy features such as indicators for moves and audio cues will also make it more user-friendly and enjoyable. If not for myself, having the option to play against a computer bot will be appreciated as well, since I'll be able to play during lesson time, or in the case of odd numbers in the tournament. All in all, I'd be happy with a final product that plays Laser Chess, but emulates the playing experience of any chess website well.

*Objectives 1 & 4 & 6*

Gameplay similar to that of popular chess websites is important to our client, introducing the requirement of subtle features such as move highlighting. A CPU bot is also important to our client, who enjoys thinking deeply and analysing chess games, and so will prove important both as a learning tool and as an opponent.

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**Q:** Are there any additional features that might be helpful for your tournament use-cases?

**A:** Being able to configure the gameplay will be useful for setting custom time-controls for everybody. I also would like to archive games and share everybody's matches with the team, so having the functionality to save games, and to go through previous ones, will be highly requested too. Being able to quickly set up board starting positions or share them will also be useful, as this will allow more variety into the tournament and give the stronger players some more interesting options.

*Objectives 3 & 5*

Saving games and customising them is a big logistical priority for a tournament, as this will provide the means to record games and for opponents to all agree on the starting conditions, depending on the circumstances of the tournament.

## 1.2 Objectives

### 1.2.1 Client Objectives

The following objectives should be met to satisfy my clients' requirements:

1. All laser chess game logic should be properly implemented
  - (a) Pieces should be destroyed when laser hits their vulnerable side
  - (b) Pyramid should rotate laser by 90° from one side
  - (c) Scarab should rotate laser by 90° from both sides
  - (d) Anubis should absorb laser from one side
  - (e) Active colour should alternate every move
  - (f) Laser should automatically fire from the sphinx after a player move
  - (g) Travel path of laser should be correctly implemented
  - (h) Game should end when a player's pharaoh is destroyed
  - (i) Game should end in a draw if three-fold repetition is automatically detected
2. Game should process user input correctly

- (a) Clicking on a piece of the active colour selects it
  - (b) Clicking on an invalid square deselects the piece
  - (c) Clicking on a piece and an available square should move the piece
  - (d) Grabbing a piece and releasing it on an available square should move the piece
  - (e) Clicking on the clockwise or anticlockwise button should rotate the selected piece accordingly the piece
3. Save or load game options should be implemented
    - (a) Games should be encoded into FEN string format
    - (b) Games can be saved locally into external files
    - (c) Entering the browser screen should display all previous games
    - (d) Previous games should be sorted according to specific criteria (i.e. winner)
    - (e) Previous games should be paginated
    - (f) User should be able to delete previous games
    - (g) User should be able to review previous games
    - (h) The review screen should display information relevant for each game
    - (i) Clicking on the previous or next buttons should scroll through moves
  4. Other board game requirements should be implemented
    - (a) Draws should be made an option
    - (b) Resigning should be made an option
    - (c) Timer displaying time left for each player should be displayed
    - (d) Time logic should be implemented, pausing when it is the opponent's turn, forfeiting players who run out of time
  5. Game settings and config should be customisable
    - (a) User should be able to play against another player or CPU
    - (b) User should be able to customise timer and duration
    - (c) User should be able to select starting colours
    - (d) User should be able to enter custom FEN string in the config screen
    - (e) Config screen should be able to detect invalid FEN strings
    - (f) Users should be able to place any pieces in editor screen
    - (g) Users should be able to rotate pieces in editor screen
    - (h) Clicking on empty or reset buttons should update the board accordingly
    - (i) User should be able to change board colours
    - (j) User should be able to change program settings (e.g. fullscreen or volume)
  6. Game UI should improve player experience
    - (a) Selected pieces should be clearly marked with a visual indicator
    - (b) Indicator showing available squares to move to when clicking on a piece

- (c) Destroying a piece should display a visual and audio cue
  - (d) Captured pieces should be displayed for each player
  - (e) Status message should display current status of the game (whose turn it is, move a piece, game won etc.)
  - (f) Move list should display played moves in string notation
  - (g) Mouse cursor icon should change depending on context
7. GUI design should be functional and display concise information
- (a) GUI should always remain responsive throughout the running of the program
  - (b) Program should be divided into separate sections with their own menus and functionality (e.g. title page, settings)
  - (c) Navigation buttons (e.g. return to menu) should concisely display their functionality
  - (d) UI should contain exit and help buttons
  - (e) UI should be designed for clarity in mind and visually pleasing
  - (f) Application window should be draggable and resizable

### 1.2.2 Other User Considerations

Although my current primary client is Mr Myslov, I aim to make my program shareable and accessible, so other parties who would like to try laser chess can access a comprehensive implementation of the game, which currently is not readily available online. Additionally, the code should be concise and well commented, complemented by proper documentation, so other parties can edit and implement additional features such as multiplayer to their own liking.

## 1.3 Research

Before proceeding with the actual implementation of the game, I will have to conduct research to plan out the fundamental architecture of the game. Reading on available information online, prior research will prevent me from committing unnecessary time to potentially inadequate ideas or code. I will consider the following areas: board representation, CPU techniques and GUI framework.

### 1.3.1 Board Representation

Board representation is the use of a data structure to represent the state of all pieces on the chessboard, and the state of the game itself, at any moment. It is the foundation on which other aspects such as move generation and the evaluation function are built upon, with different methods of implementation having their own advantages and disadvantages on simplicity, execution efficiency and memory footprint. Every board representation can be classified into two categories: piece-centric or square-centric. Piece-centric representations involve keeping track of all pieces on the board and their associated position. Conversely, square-centric representations track every available square, and if it is empty or occupied by a piece. The following are descriptions of various board representations with their respective pros and cons.

**Square list**

Square list, a square-centric representation, involves the encoding of each square residing in a separately addressable memory element, usually in the form of an 8x8 two-dimensional array. Each array element would identify which piece, if any, occupies the given square. A common piece encoding could involve using the integers 1 for a pawn, 2 for knight, 3 for bishop, and + and - for white and black respectively (e.g. a white knight would be +2). This representation is easy to understand and implement, and has easy support for multiple chess variants with different board sizes. However, it is computationally inefficient as nested loop commands must be used in frequently called functions, such as finding a piece location. Move generation is also problematic, as each move must be checked to ensure that it does not wrap around the edge of the board.

**0x88**

0x88, another square-centric representation, is an 128-byte one-dimensional array, equal to the size of two adjacent chessboards. Each square is represented by an integer, with two nibbles used to represent the rank and file of the respective square. For example, the 8-integer 0x42 (0100 0010) would represent the square (4, 2) in zero-based numbering. The advantage of 0x88 is that faster bitwise operations are used for computing piece transformations. For example, add 16 to the current square number to move to the square on the row above, or add 1 to move to the next column. Moreover, 0x88 allows for efficient off-the-board detection. Every valid square number is under 0x88 in hex (0111 0111), and by performing a bitwise AND operation between the square number and 0x88 (1000 1000), the destination square can be shown to be invalid if the result is non-zero (i.e. contains 1 on 4th or 8th bit).

**Bitboards**

Bitboards, a piece-centric representation, are finite sets of 64 elements, one bit per square. To represent the game, one bitboard is needed for each piece-type and colour, stored as an array of bitboards as part of a position object. For example, a player could have a bitboard for white pawns, where a positive bit indicates the presence of the pawn. Bitboards are fast to incrementally update, such as flipping bits at the source and destination positions for a moved piece. Moreover, bitmaps representing static information, such as spaces attacked by each piece type, can be pre-calculated, and retrieved with a single memory fetch at a later time. Additionally, bitboards can operate on all squares in parallel using bitwise operations, notably, a 64-bit CPU can perform all operations on a 64-bit bitboard in one cycle. Bitboards are therefore far more execution efficient than other board representations. However, bitboards are memory-intensive and may be sparse, sometimes only containing a single bit in 64. They require more source code, and are problematic for devices with a limited number of process registers or processor instruction cache.

**1.3.2 CPU techniques****Minimax**

Minimax is a backtracking algorithm that evaluates the best move given a certain depth, assuming optimal play by both players. A game tree of possible moves is formulated, until the leaf node reaches a specified depth. Using a heuristic evaluation function, minimax recursively assigns each node an evaluation based on the following rules:

- If the node represents a white move, the node's evaluation is the *maximum* of the evaluation of its children
- If the node represents a black move, the node's evaluation is the *minimum* of the evaluation of its children

Thus, the algorithm *minimizes* the loss involved when the opponent chooses the move that gives *maximum* loss.

Several additional techniques can be implemented to improve upon minimax. For example, transposition tables are large hash tables storing information about previously reached positions and their evaluation. If the same position is reached via a different sequence of moves, the cached evaluation can be retrieved from the table instead of evaluating each child node, greatly reducing the search space of the game tree. Another, such as alpha-beta pruning can be stacked and applied, which eliminates the need to search large portions of the game tree, thereby significantly reducing the computational time.

### Monte-Carlo Tree Search

Monte-Carlo Tree Search (MCTS) involves playouts, where games are played to its end by selecting random moves. The result of each playout is then backpropagated up the game tree, updating the weight of nodes visited during the playout, meaning the algorithm successively improves at accurately estimating the values of the most promising moves. MCTS periodically evaluates alternatives to the currently perceived optimal move, and could thereby discover a better, otherwise overlooked, path. Another benefit is that it does not require an explicit evaluation function, as it relies on statistical sampling as opposed to developed theory on the game state. Additionally, MCTS is scalable and may be parallelized, making it suitable for distributed computing or multicore architectures. However, the rate of tree growth is exponential, requiring huge amounts of memory. In addition, MCTS requires many iterations to be able to reliably decide the most efficient path.

### 1.3.3 GUI framework

#### Pygame

Pygame is an open-source Python module geared for game development. It offers abundant yet simple APIs for drawing sprites and game objects on a screen-canvas, managing user input, audio et cetera. It also has good documentation, an extensive community, and receives regular updates through its community edition. Although it has greater customizability in drawing custom bitmap graphics and control over the main loop, it lacks built-in support for UI elements such as buttons and sliders, requiring custom implementation. Moreover, it is less efficient, using 2D pixel arrays and the RAM instead of utilising the GPU for batch rendering, being single-threaded, and running on an interpreted language.

#### PyQt

PyQt is the Python binding for Qt, a cross-platform C++ GUI framework. PyQt contains an extensive set of documentation online, complemented by the documentation and forums for its C++ counterpart. Unlike Pygame, PyQt contains many widgets for common UI elements, and support for concurrency within the framework. Another advantage in using PyQt is its development ecosystem, with peripheral applications such as Qt Designer for layouts, QML for user interfaces, and QSS for styling. Although it is not open-source, containing a commercial

licensing plan, I have no plans to commercialize the program, and can therefore utilise the open-source licence.

### **OpenGL**

Python contains multiple bindings for OpenGL, such as PyOpenGL and ModernGL. Being a widely used standard, OpenGL has the best documentation and support. It also boasts the highest efficiency, designed to be implemented using hardware acceleration through the GPU. However, its main disadvantage is the required complexity compared to the previous frameworks, being primarily a graphical API and not for developing full programs.

## **1.4 Proposed Solution**

### **1.4.1 Language**

The two main options regarding programming language choice, and their pros and cons, are as listed:

		Python
Pros	Cons	
<ul style="list-style-type: none"> <li>• Versatile and intuitive, uses simple syntax and dynamic typing</li> <li>• Supports both object-oriented and procedural programming</li> <li>• Rich ecosystem of third-party modules and libraries</li> <li>• Interpreted language, good for portability and easy debugging</li> </ul>	<ul style="list-style-type: none"> <li>• Slow at runtime</li> <li>• High memory consumption</li> </ul>	

		JavaScript
Pros	Cons	

- Simple, dynamically typed and automatic memory management
  - Versatile, easy integration with both server-side and front-end
  - Extensive third-party modules
  - Also supports object-oriented programming
  - Mainly focused for web development
  - Comprehensive knowledge of external frameworks (i.e. Electron) needed for developing desktop applications
- 

I have chosen Python as the programming language for this project. This is mainly due to its extensive third-party modules and libraries available. Python also provides many different GUI frameworks for desktop applications, whereas options are limited for JavaScript due to its focus on web applications. Moreover, the amount of resources and documentation online will prove invaluable for the development process.

Although Python generally has worse performance than JavaScript, speed and memory efficiency are not primary objectives in my project, and should not affect the final program. Therefore, I have prioritised Python's simpler syntax over JavaScript's speed. Being familiar with Python will also allow me to divert more time for development instead of researching new concepts or fixing unfamiliar bugs.

### 1.4.2 Development Environment

A good development environment improves developer experiences, with features such as auto-indentation and auto-bracket completion for quicker coding. The main development environments under consideration are: Visual Studio Code (VS Code), PyCharm and Sublime Text. I have decided to use VS Code due to its greater library of extensions over Sublime, and its more user-friendly implementation of features such as version control and GitHub integration. Moreover, VS Code contains many handy features that will speed up the development process, such as its built-in debugging features. Although PyCharm is an extensive IDE, its default features can be supplemented by VS Code extensions. Additionally, VS Code is more lightweight and customisable, and contains vast documentation online.

### 1.4.3 Source Control

A Source Control Tool automates the process of tracking and managing changes in source code. A good source control tool will be essential for my project. It provides the benefits of: protecting the code from human errors (i.e. accidental deletion), enabling easy code experimentation on a clone created through branching from the main project, and by tracking changes through the code history, enabling easier debugging and rollbacks. For my project, I have chosen Git as my version control tool, as it is open-source and provides a more user-friendly interface and documentation over alternatives such as Azure DevOps, and contains sufficient functionality for a small project like mine.

#### 1.4.4 Techniques

I have decided on employing the following techniques, based on the pros and cons outlined in the research section above.

##### Board representation

I have chosen to use a bitboard representation for my game. The main consideration was computational efficiency, as a smooth playing experience should be ensured regardless of device used. Bitboards allow for parallel bitwise operations, especially as most modern devices nowadays run on 64-bit architecture CPUs. With bitboards being the mainstream implementation, documentation should also be plentiful.

##### CPU techniques

I have chosen minimax as my searching algorithm. This is due to its relatively simplistic implementation and evaluation accuracy. Additionally, Monte-Carlo Tree Search is computationally intensive, with a high memory requirement and time needed to run with a sufficient number of simulations, which I do not have.

##### GUI framework

I have chosen Pygame as my main GUI framework. This is due to its increased flexibility, in creating custom art and widgets compared to PyQt's defined toolset, which is tailored towards building commercial office applications. Although Pygame contains more overhead and boilerplate code to create standard functionality, I believe that the increased control is worth it for a custom game such as laser chess, which requires dynamic rendering of elements such as the laser beam.

I will also integrate Pygame together with ModernGL, using the convenient APIs in for handling user input and sprite drawing, together with the speed of OpenGL to draw shaders and any other effect overlays.

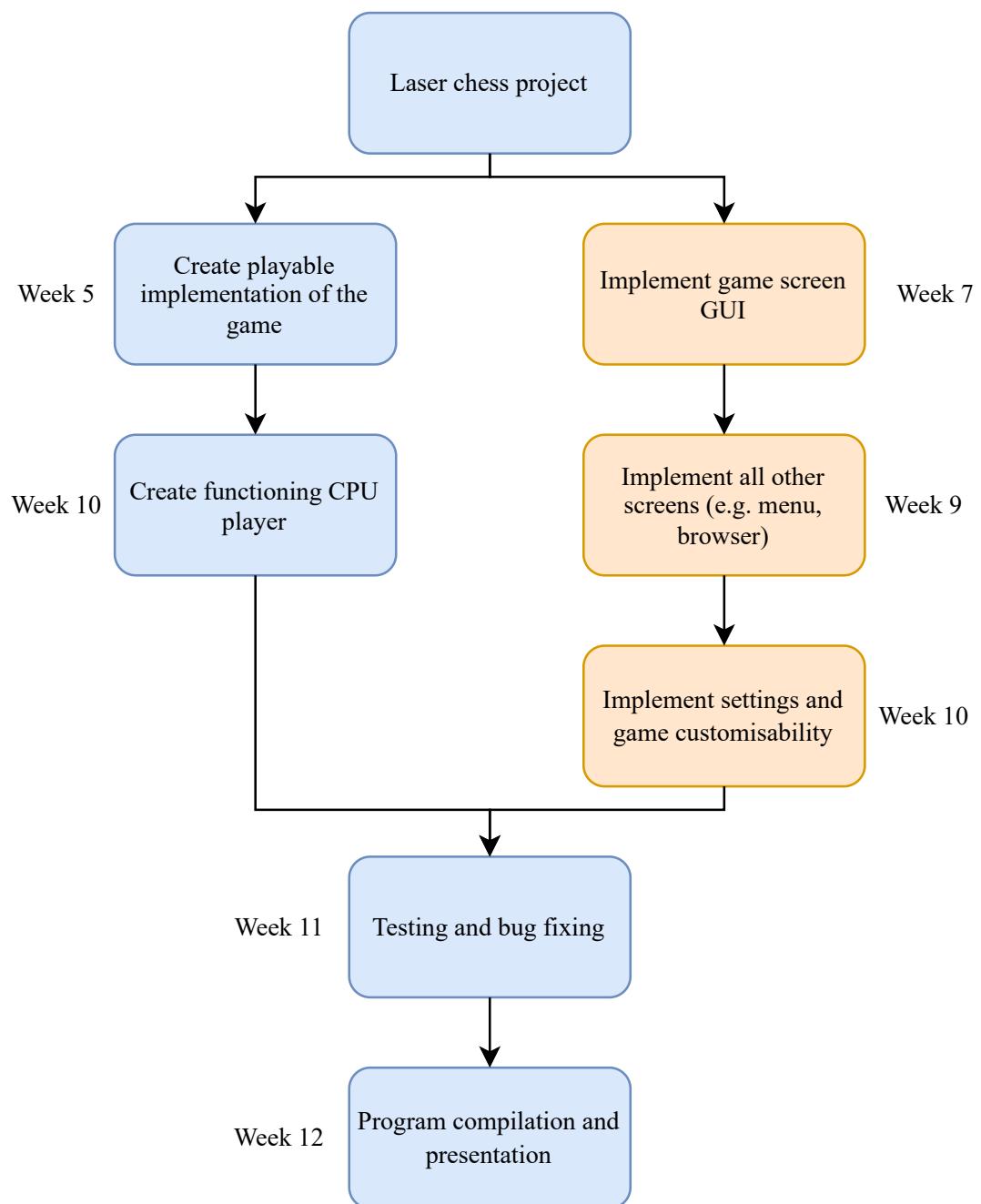
## 1.5 Limitations

I have agreed with my client that due to the multiple versions of Laser Chess that exist online, together with a lack of regulation, an implementation that adheres to the general rules of Laser Chess, and not strictly to a specific version, is acceptable.

Moreover, due to the time constraints on both my schedules for exams and for the date of the tournament, the game only has to be presented in a functional state, and not polished for release, with extra work such as porting to a wide range of OS systems.

## 1.6 Critical Path Design

In order to meet my client's requirement of releasing the game before the next field day, I have given myself a time limit of 12 weeks to develop my game, and have created the following critical path diagram to help me adhere to completing every milestone within the time limit.



# Chapter 2

## Design

### 2.1 System Architecture

In this section, I will lay out the overall logic, and an overview of the steps involved in running my program. By decomposing the program into individual abstracted stages, I can focus on the workings and functionality of each section individually, which makes documenting and coding each section easier. I have also included a flowchart to illustrate the logic of each screen of the program.

I will also create an abstracted GUI prototype in order to showcase the general functionality of the user experience, while acting as a reference for further stages of graphical development. It will consist of individually drawn screens for each stage of the program, as shown in the top-level overview. The elements and layout of each screen are also documented below.

The following is a top-level overview of the logic of the program:

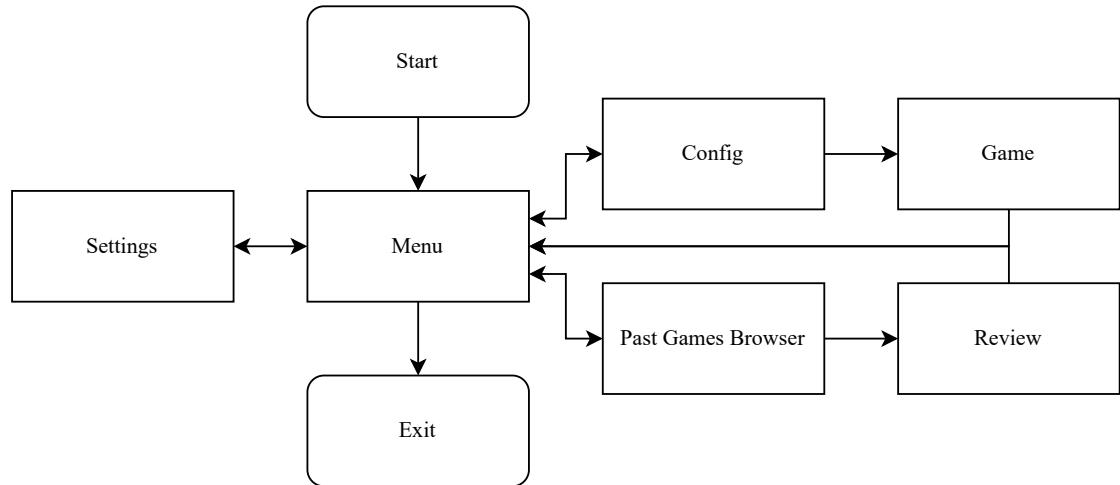


Figure 2.1: Flowchart for Program Overview

### 2.1.1 Main Menu



Figure 2.2: Main Menu screen prototype

The main menu will be the first screen to be displayed, providing access to different stages of the game. The GUI should be simple yet effective, containing clearly-labelled buttons for the user to navigate to different parts of the game.

### 2.1.2 Settings

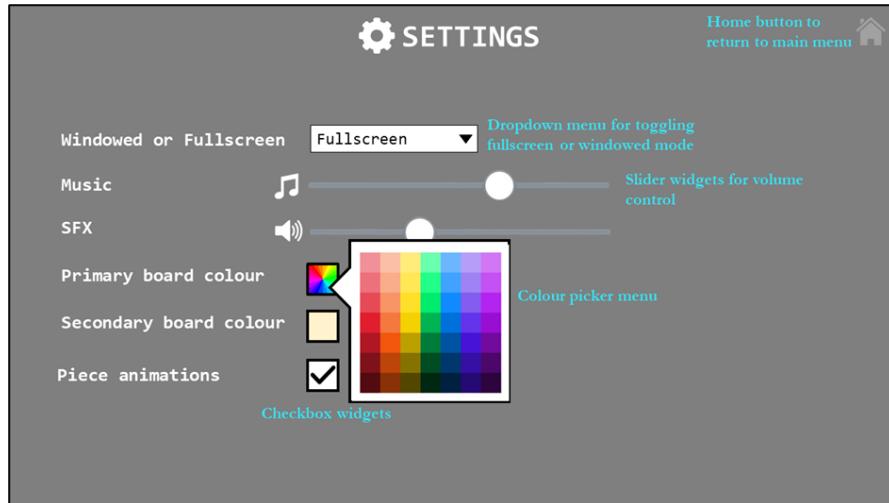


Figure 2.3: Settings screen prototype

The settings menu allows for the user to customise settings related to the program as a whole. The settings will be changed via GUI elements such as buttons and sliders, offering the ability

to customise display mode, volume, board colour etc. Changes to settings will be stored in an intermediate code class, then stored externally into a JSON file. Game settings will instead be changed in the Config screen.

The setting screen should provide a user-friendly interface for changing the program settings intuitively; I have therefore selected appropriate GUI widgets for each setting:

- Windowed or Fullscreen - Drop-down list for selecting between pre-defined options
- Music and SFX - Slider for selecting audio volume, a continuous value
- Board colour - Colour grid for the provision of multiple pre-selected colours
- Piece animation - Checkbox for toggling between on or off

Additionally, each screen is provided with a home button icon on the top right (except the main menu), as a shortcut to return to the main menu.

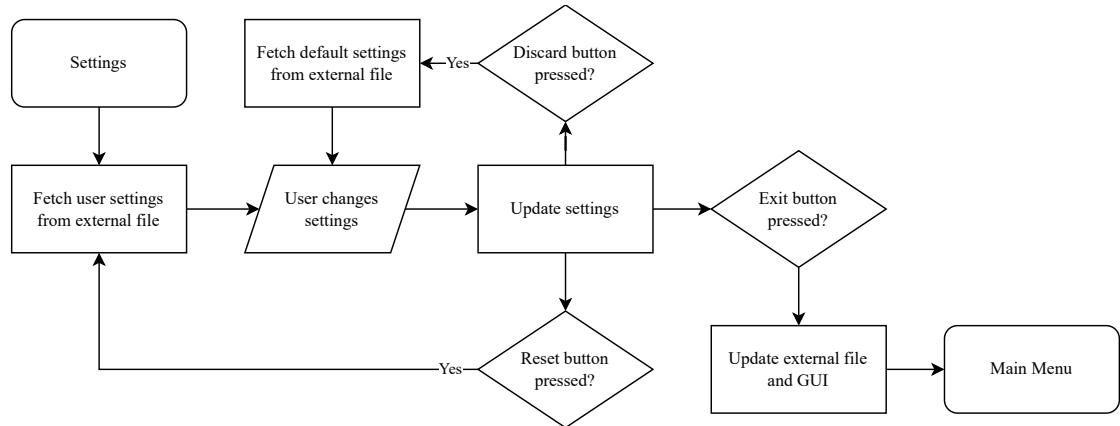


Figure 2.4: Flowchart for Settings

### 2.1.3 Past Games Browser



Figure 2.5: Browser screen prototype

The Past Games Browser menu displays a list of previously played games to be replayed. When selecting a game, the replay will render out the saved FEN string into a board position identical to the one played previously, except the user is limited to replaying back and forth between recorded moves. The menu also offers the functionality of sorting games in terms of time, game length etc.

For the GUI, previous games will be displayed on a strip, scrolled through by a horizontal slider. Information about the game will be displayed for each instance, along with the option to copy the FEN string to be stored locally or to be entered into the Review screen. When choosing a past game, a green border will appear to show the current selection, and double-clicking enters the user into the full replay mode. While replaying the game, the GUI will appear identical to an actual game. However, the user will be limited to scrolling throughout the moves via the left and right arrow keys.

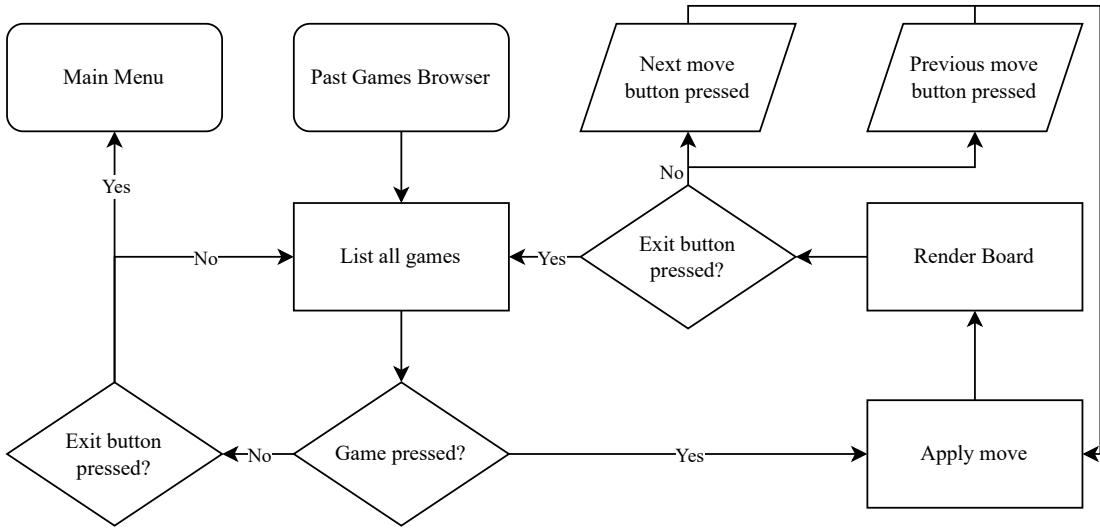


Figure 2.6: Flowchart for Browser

#### 2.1.4 Config



Figure 2.7: Config screen prototype

The config screen comes prior to the actual gameplay screen. Here, the player will be able to change game settings such as toggling the CPU player, time duration, playing as white or black etc.

The config menu is loaded with the default starting position. However, players may enter their own FEN string as an initial position, with the central board updating responsively to give a visual representation of the layout. Players are presented with the additional options to play against a friend, or against a CPU, which displays a drop-down list when pressed to select the CPU difficulty.

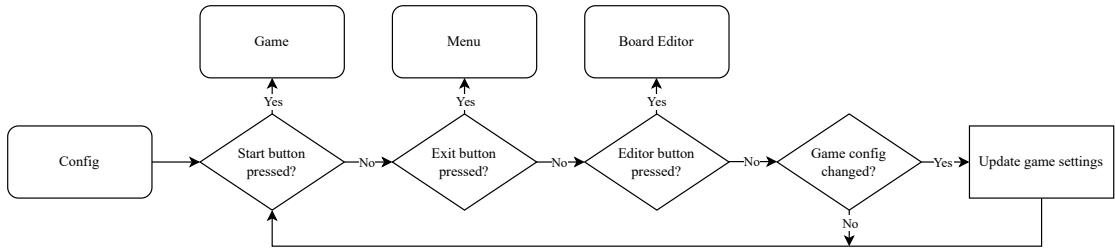


Figure 2.8: Flowchart for Config

### 2.1.5 Game



Figure 2.9: Game screen prototype

During the game, handling of the game logic, such as calculating player turn, calculating CPU moves or laser trajectory, will be computed by the program internally, rendering the updated GUI accordingly in a responsive manner to provide a seamless user experience.

In the game screen, the board is positioned centrally on the screen, surrounded by accompanying widgets displaying information on the current state of the game. The main elements include:

- Status text - displays information on the game state and prompts for each player move
- Rotation buttons - allows each player to rotate the selected piece by 90° for their move
- Timer - displays available time left for each player
- Draw and forfeit buttons - for the named functionalities, confirmed by pressing twice
- Piece display - displays material captured from the opponent for each player

Additionally, the current selected piece will be highlighted, and the available squares to move to will also contain a circular visual cue. Pieces will either be moved by clicking the

target square, or via a drag-and-drop mechanism, accompanied by responsive audio cues. These implementations aim to improve user-friendliness and intuitiveness of the program.

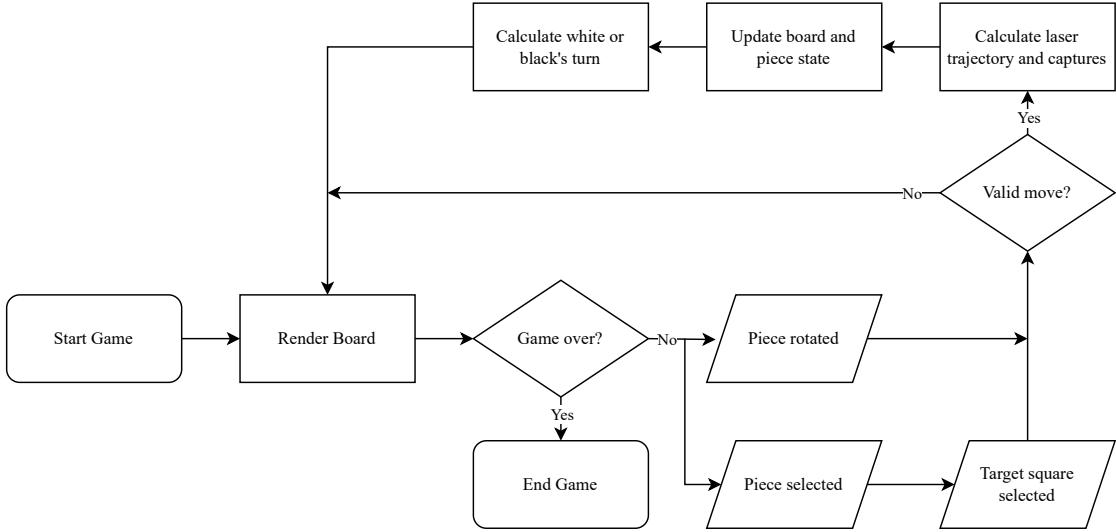


Figure 2.10: Flowchart for Game

### 2.1.6 Board Editor



Figure 2.11: Editor screen prototype

The editor screen is used to configure the starting position of the board. Controls should include the ability to place all piece types of either colour, to erase pieces, and easy board manipulation shortcuts such as dragging pieces or emptying the board.

For the GUI, the buttons should clearly represent their functionality, through the use of icons and appropriate colouring (e.g. red for delete).

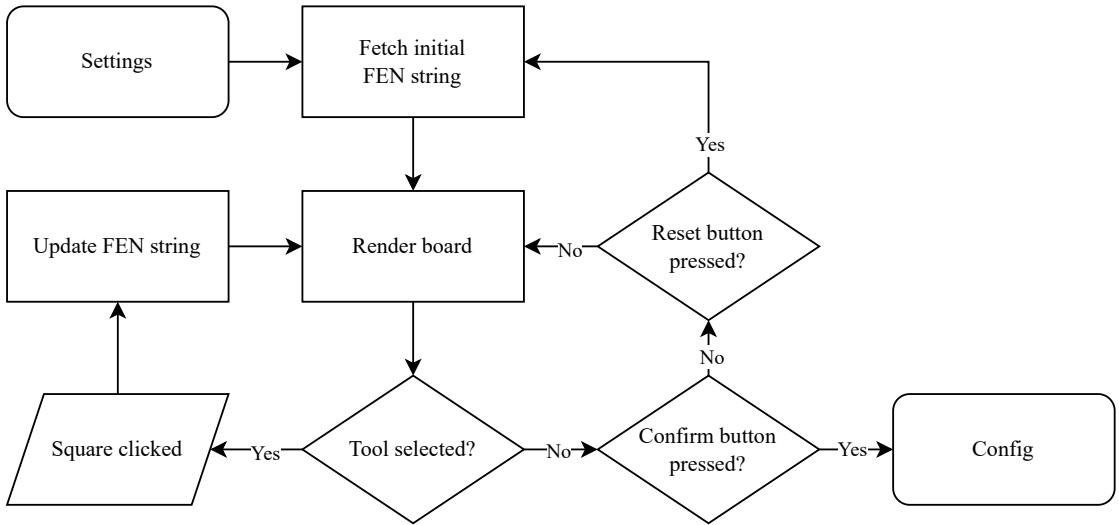


Figure 2.12: Flowchart for board editor

## 2.2 Algorithms and Techniques

### 2.2.1 Minimax

Minimax is a backtracking algorithm commonly used in zero-sum games used to determine the score according to an evaluation function, after a certain number of perfect moves. Minimax aims to minimize the maximum advantage possible for the opponent, thereby minimizing a player's possible loss in a worst-case scenario. It is implemented using a recursive depth-first search, alternating between minimizing and maximizing the player's advantage in each recursive call.

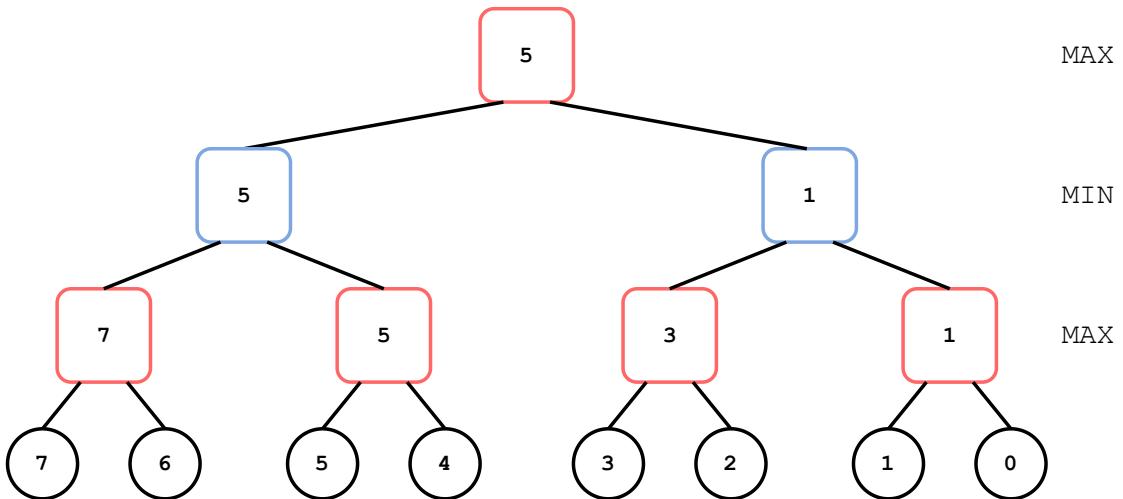


Figure 2.13: Example minimax tree

For the example minimax tree show in Figure 2.13, starting from the bottom leaf node

evaluations, the maximising player would choose the highest values (7, 5, 3, 1). From those values, the minimizing player would choose the lowest values (5, 1). The final value chosen by the maximum player would therefore be the highest of the two, 5.

Implementation in the form of pseudocode is shown below:

---

**Algorithm 1** Minimax pseudocode

---

```

function MINIMAX(node, depth, maximisingPlayer)
    if depth = 0 OR node equals game over then
        return EVALUATE
    end if

    if maximisingPlayer then
        value  $\leftarrow -\infty$ 
        for child of node do
            value  $\leftarrow \text{MAX}(value, \text{MINIMAX}(child, depth - 1, false))$ 
        end for
        return value
    else
        value  $\leftarrow +\infty$ 
        for child of node do
            value  $\leftarrow \text{MIN}(value, \text{MINIMAX}(child, depth - 1, true))$ 
        end for
        return value
    end if
end function

```

---

## 2.2.2 Minimax improvements

### Alpha-beta pruning

Alpha-beta pruning is a search algorithm that aims to decrease the number of nodes evaluated by the minimax algorithm. Alpha-beta pruning stops evaluating a move in the game tree when one refutation is found in its child nodes, proving the node to be worse than previously-examined alternatives. It does this without any potential of pruning away a better move. The algorithm maintains two values: alpha and beta. Alpha ( $\alpha$ ), the upper bound, is the highest value that the maximising player is guaranteed of; Beta ( $\beta$ ), the lower bound, is the lowest value that the minimizing player is guaranteed of. If the condition  $\alpha \geq \beta$  for a node being evaluated, the evaluation process halts and its remaining children nodes are ‘pruned’.

This is shown in the following maximising example:

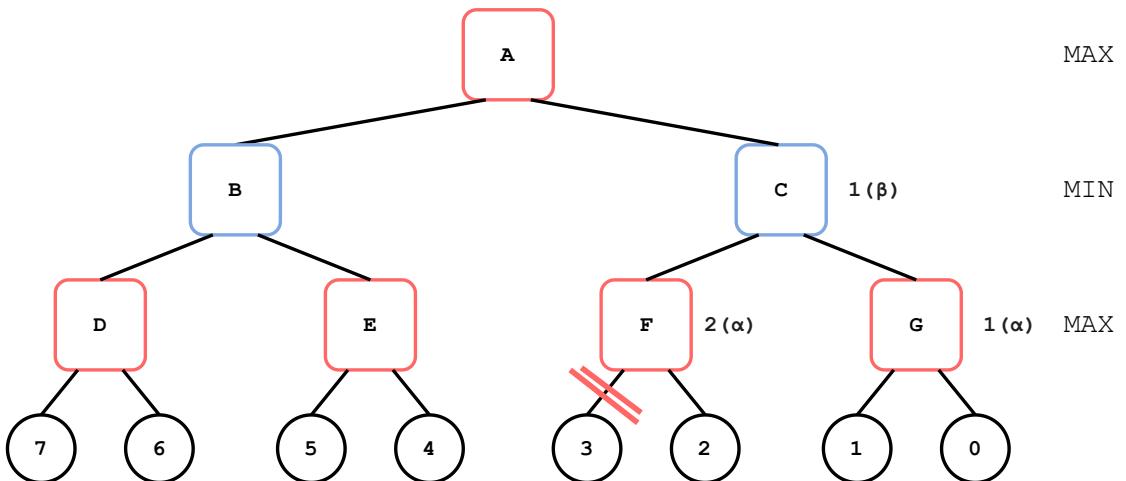


Figure 2.14: Example minimax tree with alpha-beta pruning

Since minimax is a depth-first search algorithm, nodes  $C$  and  $G$  and their  $\alpha$  and  $\beta$  have already been searched. Next, at node  $F$ , the current  $\alpha$  and  $\beta$  are  $-\infty$  and 1 respectively, since the  $\beta$  is passed down from node  $C$ . Searching the first leaf node, the  $\alpha$  subsequently becomes  $\alpha = \max(-\infty, 2)$ . This means that the maximising player at this depth is already guaranteed an evaluation of 2 or greater. Since we know that the minimising player at the depth above is guaranteed a value of 1, there is no point in continuing to search node  $F$ , a node that returns a value of 2 or greater. Hence at node  $F$ , where  $\alpha \geq \beta$ , the branches are pruned.

Alpha-beta pruning therefore prunes insignificant nodes by maintain an upper bound  $\alpha$  and lower bound  $\beta$ . This is an essential optimization as a simple minimax tree increases exponentially in size with each depth ( $O(b^d)$ , with branching factor  $b$  and  $d$  ply depth), and alpha-beta reduces this and the associated computational time considerably.

The pseudocode implementation is shown below:

**Algorithm 2** Minimax with alpha-beta pruning pseudocode

---

```

function MINIMAX(node, depth,  $\alpha$ ,  $\beta$ , maximisingPlayer)
    if depth = 0 OR node equals game over then
        return EVALUATE
    end if

    if maximisingPlayer then
        value  $\leftarrow -\infty$ 
        for child of node do
            value  $\leftarrow \text{MAX}(\text{value}, \text{MINIMAX}(\text{child}, \text{depth} - 1, \alpha, \beta, \text{false}))$ 
            if value >  $\beta$  then break
            end if
             $\alpha \leftarrow \text{MAX}(\alpha, \text{value})$ 
        end for
        return value
    else
        value  $\leftarrow +\infty$ 
        for child of node do
            value  $\leftarrow \text{MIN}(\text{value}, \text{MINIMAX}(\text{child}, \text{depth} - 1, \alpha, \beta, \text{true}))$ 
            if value <  $\alpha$  then break
            end if
             $\beta \leftarrow \text{MIN}(\beta, \text{value})$ 
        end for
        return value
    end if
end function

```

---

**Transposition Tables & Zobrist Hashing**

Transition tables, a memoisation technique, again greatly reduces the number of moves searched. During a brute-force minimax search with a depth greater than 1, the same positions may be searched multiple times, as the same position can be reached from different sequences of moves. A transposition table caches these same positions (transpositions), along with their associated evaluations, meaning commonly reached positions are not unnecessarily re-searched.

Flags and depth are also stored alongside the evaluation. Depth is required as if the current search comes across a cached position with an evaluation calculated at a lower depth than the current search, the evaluation may be inaccurate. Flags are required for dealing with the uncertainty involved with alpha-beta pruning, and can be any of the following three.

**Exact** flag is used when a node is fully searched without pruning, and the stored and fetched evaluation is accurate.

**Lower** flag is stored when a node receives an evaluation greater than the  $\beta$ , and is subsequently pruned, meaning that the true evaluation could be higher than the value stored. We are thus storing the  $\alpha$  and not an exact value. Thus, when we fetch the cached value, we have to recheck if this value is greater than  $\beta$ . If so, we return the value and this branch is pruned (fail high); If not, nothing is returned, and the exact evaluation is calculated.

**Upper** flag is stored when a node receives an evaluation smaller than the  $\alpha$ , and is subsequently pruned, meaning that the true evaluation could be lower than the value stored. Similarly, when we fetch the cached value, we have to recheck if this value is lower than  $\alpha$ . Again, the current branch is pruned if so (fail low), and an exact evaluation is calculated if not.

The pseudocode implementation for transposition tables is shown below:

---

**Algorithm 3** Minimax with transposition table pseudocode

---

```

function MINIMAX(node, depth,  $\alpha$ ,  $\beta$ , maximisingPlayer)
    hash_key  $\leftarrow$  HASH(node)
    entry  $\leftarrow$  GETENTRY(hash_key)

    if entry.hash_key = hash_key AND entry.hash_key  $\geq$  depth then
        if entry.hash_key = EXACT then
            return entry.value
        else if entry.hash_key = LOWER then
             $\alpha \leftarrow \text{MAX}(\alpha, \text{entry.value})$ 
        else if entry.hash_key = UPPER then
             $\beta \leftarrow \text{MIN}(\beta, \text{entry.value})$ 
        end if
        if  $\alpha \geq \beta$  then
            return entry.value
        end if
    end if

    ...normal minimax...

    entry.value  $\leftarrow$  value
    entry.depth  $\leftarrow$  depth
    if value  $\leq \alpha$  then
        entry.flag  $\leftarrow$  UPPER
    else if value  $\geq \beta$  then
        entry.flag  $\leftarrow$  LOWER
    else
        entry.flag  $\leftarrow$  EXACT
    end if

    return value
end function

```

---

The current board position will be used as the index for a transposition table entry. To convert our board state and bitboards into a valid index, Zobrist hashing may be used. For every square on the chessboard, a random integer is assigned to every piece type (12 in our case, 6 piece type, times 2 for both colours). To initialise a hash, the random integer associated with the piece on a specific square undergoes an XOR operation with the existing hash. The hash is incrementally updated with XOR operations every move, instead of being recalculated from scratch improving computational efficiency. Using XOR operations also allows moves to be reversed, proving useful for the functionality to scroll through previous moves. A Zobrist hash is also a better candidate than FEN strings in checking for threefold-repetition, as they are less

intensive to calculate for every move.

The pseudocode implementation for Zobrist hashing is shown below:

---

**Algorithm 4** Zobrist hashing pseudocode

---

*RANDOMINTS represents a pre-initialised array of random integers for each piece type for each square*

```

function HASH _ BOARD(board)
    hash  $\leftarrow$  0
    for each square on board do
        if square is not empty then
            hash  $\oplus$  RANDOMINTS[square][piece on square]
        end if
    end for
    return hash
end function

function UPDATEHASH(hash, move)
    hash  $\oplus$  RANDOMINTS[source square][piece]
    hash  $\oplus$  RANDOMINTS[destination square][piece]
    if red to move then
        hash  $\oplus$  hash for red to move  $\triangleright$  Hash needed for move colour, as two identical positions
        are different if the colour to move is different
    end if
    return hash
end function

```

---

### Iterative Deepening

Iterative deepening builds upon the previous alpha-beta and caching improvements. A search is initiated at a depth of one ply, which upon finishing, another starts at depth two, three, and increases until the max depth is reached or time allocated is up. Although this means that more nodes are searched, the improvements come from the fact that the best move (PV-Move) found by a lower depth search, can be used as the first move searched on the next higher depth search. This increases the chance of pruning, reducing the net number of nodes searched, and also provides a 'fallback' move if a higher depth search is interrupted.

#### 2.2.3 Board Representation

##### FEN string

Forsyth-Edwards Notation (FEN) notation provides all information on a particular position in a chess game. I intend to implement methods parsing and generating FEN strings in my program, in order to load desired starting positions and save games for later play. Deviating from the classic 6-part format, a custom FEN string format will be required for our laser chess game, accommodating its different rules from normal chess.

Our custom format implementation is show by the example below:

sc3ncfancpb2/2pc7/3Pd7/pa1Pc1rbra1pb1Pd/pb1Pd1RaRb1pa1Pc/6pb3/7Pa2/2PdNaFaNa3Sa

r

Our FEN string format contains two parts, denoted by the space between them:

- Part 1: Describes the location of each piece. The construction of this part is defined by the following rules:
  - The board is read from top-left to bottom-right, row by row
  - A number represents the number of empty squares before the next piece
  - A capital letter represents a blue piece, and a lowercase letter represents a red piece
  - The letters *F*, *R*, *P*, *N*, *S* stand for the pieces Pharaoh, Scarab, Pyramid, Anubis and Sphinx respectively
  - Each piece letter is followed by the lowercase letters *a*, *b*, *c* or *d*, representing a 0°, 90°, 180° and 270° degree rotation respectively
- Part 2: States the active colour, *b* means blue to move, *r* means red to move

Having inputted the desired FEN string board configuration in the config menu, the bitboards for each piece will be initialised with the following functions:

---

**Algorithm 5** FEN string pseudocode
 

---

```

function PARSE_FEN_STRING(fen_string, board)
  part_1, part_2 ← SPLIT(fen_string)
  rank ← 8
  file ← 0

  for character in part_1 do
    square ← rank × 8 + file
    if character is alphabetic then
      if character is lower then
        board.bitboards[red][character] | 1 << character
      else
        board.bitboards[blue][character] | 1 << character
      end if
    else if character is numeric then
      file ← file + character
    else if character is / then
      rank ← rank - 1
      file ← file + 1
    else
      file ← file + 1
    end if

    if part_2 is b then
      board.active_colour ← b
    else
      board.active_colour ← r
    end if
  end for
end function
  
```

---

The function first processes every piece and corresponding square in the FEN string, modifying each piece bitboard using a bitwise OR operator, with a 1 shifted over to the correctly occupied square using a Left-Shift operator. For the second part, the active colour property of the board class is initialised to the correct player.

### Bitboards

Bitboards are an array of bits representing a position or state of a board game. Multiple bitboards are used with each representing a different property of the game (e.g. scarab position and scarab rotation), and can be masked together or transformed to answer queries about positions. Bitboards offer an efficient board representation, its performance primarily arising from the speed of parallel bitwise operations used to transform bitboards. To map each board square to a bit in each number, we will assign each square from left to right, with the least significant bit (LSB) assigned to the bottom-left square (A1), and the most significant bit (MSB) to the top-right square (J8).

<b>8</b>	70	71	72	73	74	75	76	77	78	79
<b>7</b>	60	61	62	63	64	65	66	67	68	69
<b>6</b>	50	51	52	53	54	55	56	57	58	59
<b>5</b>	40	41	42	43	44	45	46	47	48	49
<b>4</b>	30	31	32	33	34	35	36	37	38	39
<b>3</b>	20	21	22	23	24	25	26	27	28	29
<b>2</b>	10	11	12	13	14	15	16	17	18	19
<b>1</b>	0	1	2	3	4	5	6	7	8	9
	<b>a</b>	<b>b</b>	<b>c</b>	<b>d</b>	<b>e</b>	<b>f</b>	<b>g</b>	<b>h</b>	<b>j</b>	<b>k</b>

Figure 2.15: Square to bit position mapping

Firstly, we need to initialise each bitboard and place 1s in the correct squares occupied by pieces. This is achieved whilst parsing the FEN-string, as shown in Algorithm 5. Secondly, we should implement an approach to calculate possible moves using our computed bitboards. We can begin by producing a bitboard containing the locations of all pieces, achieved through combining every piece bitboard with bitwise OR operations:

```
all_pieces_bitboard = white_pharaoh_bitboard | black_pharaoh_bitboard |
                     white_scarab_bitboard ...
```

Now, we can utilize this aggregated bitboard to calculate possible positional moves for each piece. For each piece, we can shift the entire bitboard to an adjacent target square (since every piece can only move one adjacent square per turn), and perform a bitwise AND operator with the bitboard containing all pieces, to determine if the target square is already occupied by an existing piece. For example, if we want to compute if the square to the left of our selected piece

is available to move to, we will first shift every bit right (as the lowest square index is the LSB on the right, see diagram above), as demonstrated in the following 5x5 example:

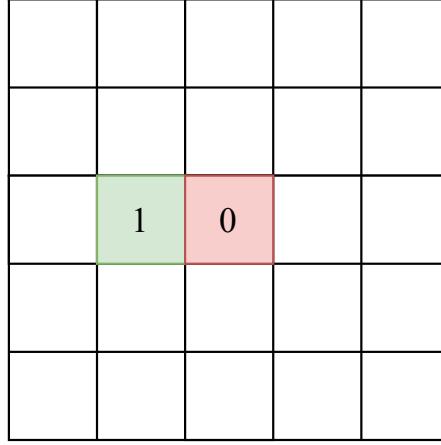


Figure 2.16: `shifted_bitboard = piece_bitboard >> 1`

Where green represents the target square shifted into, and orange where the piece used to be. We can then perform a bitwise AND operation with the complement of the all pieces bitboard, where a square with a result of 1 represents an available target square to move to.

```
available_squares_right = (piece_bitboard >> 1) & ~all_pieces_bitboard
```

However, if the piece is on the leftmost A file, and is shifted to the right, it will be teleported onto the J file on the rank below, which is not a valid move. To prevent these erroneous moves for pieces on the edge of the board, we can utilise an A file mask to mask away any valid moves, as demonstrated below:

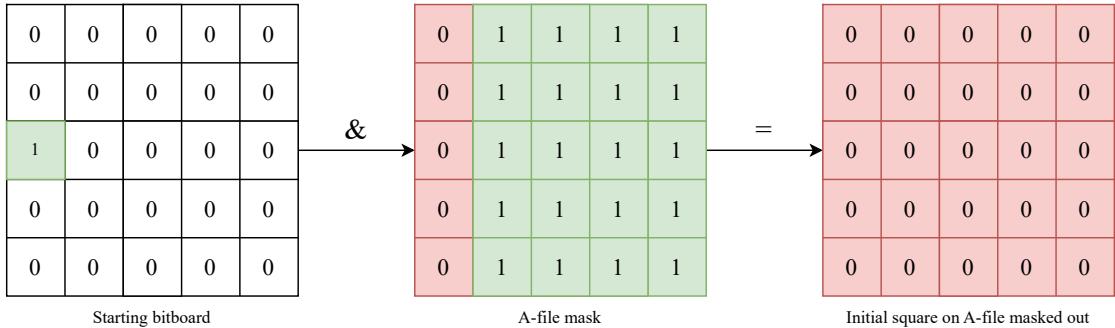


Figure 2.17: A-file mask example

This approach uses the logic that a piece on the A file can never move to a square on the left. Therefore, when calculating if a piece can move to a square on the left, we apply a bitwise AND operator with a mask where every square on the A file is 0; If a piece was on the A file, it will become 0, leaving no possible target squares to move to. The same approach can be mirrored for the far-right J file.

In theory, we do not need to implement the same solution for clipping in regard to ranks, as they are removed automatically by overflow or underflow when shifting bits too far. Our final function to calculate valid moves combines all the logic above: Shifting the selected piece in all 9 adjacent directions by their corresponding bits, masking away pieces trying to move into the edge of the board, combining them with a bitwise OR operator, and finally masking it with the all pieces bitboard to detect which squares are not currently occupied:

---

**Algorithm 6** Finding valid moves pseudocode

---

```

function FIND_VALID_MOVES(selected_square)
    masked_a_square ← selected_square & A_FILE_MASK
    masked_j_square ← selected_square & J_FILE_MASK

    top_left ← masked_a_square << 9
    top_left ← masked_a_square << 9
    top_middle ← selected_square << 10
    top_right ← masked_ << 11
    middle_right ← masked_ << 1
    bottom_right ← masked_ >> 9
    bottom_middle ← selected_square >> 10
    bottom_left ← masked_a_square >> 11
    middle_left ← masked_a_square >> 1

    possible_moves = top_left | top_middle | top_right | middle_right | bottom_right |
    bottom_middle | bottom_left | middle_left
    valid_moves = possible_moves & ~ ALL_PIECES_BITBOARD

    return valid_moves
end function

```

---

#### 2.2.4 Evaluation Function

The evaluation function is a heuristic algorithm to determine the relative value of a position. It outputs a real number corresponding to the advantage given to a player if reaching the analysed position, usually at a leaf node in the minimax tree. The evaluation function therefore provides the values on which minimax works on to compute an optimal move.

In the majority of evaluation functions, the most significant factor determining the evaluation is the material balance, or summation of values of the pieces. The hand-crafted evaluation function is then optimised by tuning various other positional weighted terms, such as board control and king safety.

##### Material Value

Since laser chess is not widely documented, I have assigned relative strength values to each piece according to my experience playing the game:

- Pharaoh -  $\infty$
- Scarab - 200
- Anubis - 110

- Pyramid - 100

To find the number of pieces, we can iterate through the piece bitboard with the following popcount function:

---

**Algorithm 7** Popcount pseudocode

---

```
function POPCOUNT(bitboard)
    count ← 0
    while bitboard do
        count ← count + 1
        bitboard ← bitboard&(bitboard − 1)
    end while
    return count
end function
```

---

Algorithm 7 continually resets the left-most 1 bit, incrementing a counter for each loop. Once the number of pieces has been established, we multiply this number by the piece value. Repeating this for every piece type, we can thus obtain a value for the total piece value on the board.

### Piece-Square Tables

A piece in normal chess can differ in strength based on what square it is occupying. For example, a knight near the centre of the board, controlling many squares, is stronger than a knight on the rim. Similarly, we can implement positional value for Laser Chess through Piece-Square Tables. PSQTs are one-dimensional arrays, with each item representing a value for a piece type on that specific square, encoding both material value and positional simultaneously. Each array will consist of 80 base values representing the piece's material value, with a bonus or penalty added on top for the location of the piece on each square. For example, the following PSQT is for the pharaoh piece type on an example 5x5 board:

0	0	0	0	0
0	0	1	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0

Piece index

-10	-10	-10	-10	-10
-10	-10	-10	-10	-10
-5	-5	-5	-5	-5
0	0	0	0	0
5	5	5	5	5

Used to reference positional value in PSQT

Figure 2.18: PSQT showing the bonus position value gained for the square occupied by a pharaoh

For asymmetrical PSQTs, we would ideally like to label the board identically from both player's point of views. Although the PSQTs are displayed from the blue player's perspective (blue pharaoh at the bottom of the board), it uses indexes from the red player's perspective, as

arrays and lists are defined with index 0 being at the top left of the board. We would like to flip the PSQTs to be reused with blue indexes, so that a generic algorithm can be used to sum up and calculate the total positional values for both players.

To utilise a PSQT for blue pieces, a special ‘FLIP’ table can be implemented:

<b>8</b>	70	71	72	73	74	75	76	77	78	79
<b>7</b>	60	61	62	63	64	65	66	67	68	69
<b>6</b>	50	51	52	53	54	55	56	57	58	59
<b>5</b>	40	41	42	43	44	45	46	47	48	49
<b>4</b>	30	31	32	33	34	35	36	37	38	39
<b>3</b>	20	21	22	23	24	25	26	27	28	29
<b>2</b>	10	11	12	13	14	15	16	17	18	19
<b>1</b>	0	1	2	3	4	5	6	7	8	9

**a    b    c    d    e    f    g    h    j    k**

Figure 2.19: FLIP table used to map a blue piece index to the red player’s perspective

The FLIP table is just an array of indexes, mapping every blue player’s index onto the corresponding red index. The following expression utilises the FLIP table to retrieve a blue player’s value from the red player’s PSQT:

```
blue_psqt_value = PHARAOH_PSQT[FLIP[square]]
```

The following function retrieves an array of bitboards representing piece positions from the board class, then sums up all the values of these pieces for both players, referencing the corresponding PSQT:

**Algorithm 8** Calculating positional value pseudocode

---

```

function CALCULATE_POSITIONAL_VALUE(bitboards, colour)
    positional_score  $\leftarrow$  0
    for all pieces do
        for square in bitboards[piece] do
            if square = 1 then
                if colour is blue then
                    positional_score  $\leftarrow$  positional_score + PSQT[piece][square]
                else
                    positional_score  $\leftarrow$  positional_score + PSQT[piece][FLIP[square]]
                end if
            end if
        end for
    end for
    return positional_score
end function

```

---

**Using valid squares**

Using Algorithm 6 for finding valid moves, we can implement two more improvements for our evaluation function: Mobility and King Safety.

**Mobility** is the number of legal moves a player has for a given position. This is advantageous in most cases, with a positive correlation between mobility and the strength of a position. To implement this, we simply loop over all pieces of the active colour, and sum up the number of valid moves obtained from the previous algorithm.

**King safety** (Pharaoh safety) describes the level of protection of the pharaoh, being the piece that determines a win or loss. In normal chess, this would usually be achieved by castling, or protection via position or with other pieces. Similarly, since the only way to lose in Laser Chess is via a laser, having pieces surrounding the pharaoh, either to reflect the laser or to be sacrificed, is a sensible tactic and improves king safety. Thus, a value for king safety can be achieved by finding the number of valid moves a pharaoh can make, and subtracting them from the maximum possible of moves (8) to find the number of surrounding pieces.

**2.2.5 Shadow Mapping**

Following the client's requirement for engaging visuals, I have decided to implement shadow mapping for my program, especially as lasers are the main focus of the game. Shadow mapping is a technique used to create graphical hard shadows, with the use of a depth buffer map. I have chosen to implement shadow mapping, instead of alternative lighting techniques such as ray casting and ray marching, as its efficiency is more suitable for real-time usage, and results are visually decent enough for my purposes.

For typical 3D shadow mapping, the standard approach is as follows:

1. Render the scene from the light's point of view
2. Extract a depth buffer texture from the render
3. Compare the distance of a pixel from the light to the value stored in the depth texture

4. If greater, there must be an obstacle in the way reducing the depth map value, therefore that pixel must be in shadow

To implement shadow casting for my 2D game, I have modified some steps and arrived at the final following workflow:

1. Render the scene with only occluding objects shown
2. Crop texture to align the centre to the light position
3. To create a 1D depth map, transform Cartesian to polar coordinates, and increase the distance from the origin until a collision with an occluding object
4. Using polar coordinates for the real texture, compare the z-depth to the corresponding value from the depth map
5. Additively blend the light colour if z-depth is less than the depth map value

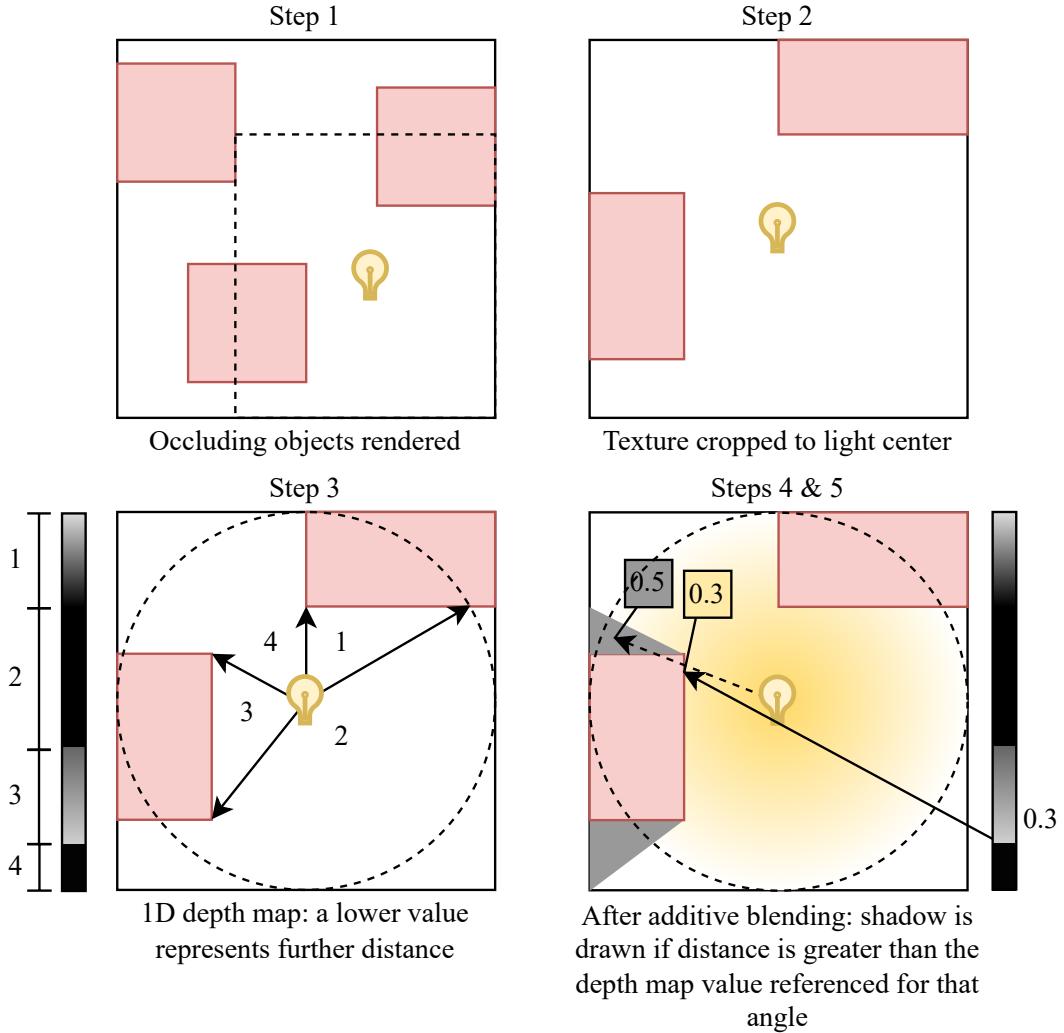


Figure 2.20: Workflow for 2D shadow mapping

Our method requires a coordinate transformation from Cartesian to polar, and vice versa. Polar to Cartesian transformation can be achieved with trigonometry, forming a right-angled triangle in the centre and using the following two equations:

$$x = r \cos(\theta)$$

$$y = r \sin(\theta)$$

Cartesian to polar can also similarly be achieved with the right-angled triangle, finding the radius with the Pythagorean theorem, and the angle with arctan. However, since the range of the arctan function is only a half-circle ( $\frac{\pi}{2} < \theta < \frac{3\pi}{2}$ ), we will have to use the atan2 function, which accounts for the negative quadrants, or the following:

$$\theta = 2 \arctan \left( \frac{r - x}{y} \right)$$

There are several disadvantages to shadow mapping. The relevant ones for us are Aliasing and Shadow Acne:

**Aliasing** occurs when the texture size for the depth map is smaller than the light map, causing shadows to be scaled up and rendered with jagged edges.

**Shadow Acne** occurs when the depth from the depth map is so close to the light map value, that precision errors cause unnecessary shadows to be rendered.

These problems can be mitigated by increasing the size of the shadow map size. However, due to memory and hardware constraints, I will have to find a compromised resolution to balance both artifacting and acuity.

### Soft Shadows

The approach above is used only for calculating hard shadows. However, in real-life scenarios, lights are not modelled as a single particle, but instead emitted from a wide light source. This creates an umbra and penumbra, resulting in soft shadows.

To emulate this in our game, we could calculate penumbra values with various methods, however, due to hardware constraints and simplicity again, I have chosen to use the following simpler method:

1. Sample the depth map multiple times, from various differing angles
2. Sum the results using a normal distribution
3. Blur the final result proportional to the length from the centre

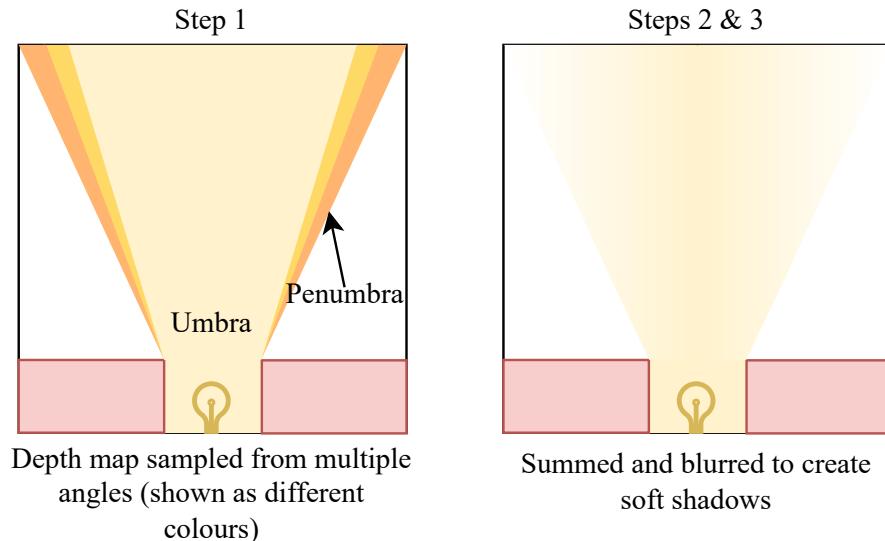


Figure 2.21: Workflow for 2D soft shadows

This method progressively blurs the shadow as the distance from the main shadow (umbra) increases, which results in a convincing estimation while being less computationally intensive.

### 2.2.6 Multithreading

In order to fulfil Objective 7a of a responsive GUI, I will have to employ multi-threading. Since python runs on a single thread natively, code is executed serially, meaning that a time-consuming function such as minimax will prevent the running of another GUI-drawing function until it is finished, hence freezing the program. To overcome this, multi-threading can execute both functions in parallel on different threads, meaning the GUI-drawing thread can run while minimax is being computed, and stay responsive. To pass data between threads, since memory is shared between threads, arrays and queues can be used to store results from threads. The following flowchart shows my chosen approach to keep the GUI responsive while minimax is being computed:

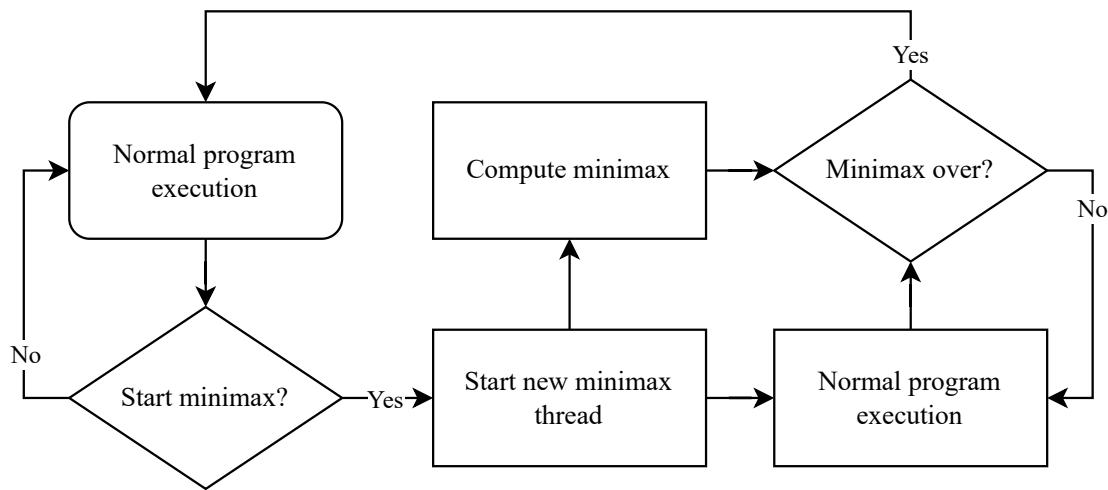


Figure 2.22: Multi-threading for minimax

## 2.3 Data Structures

### 2.3.1 Database

To achieve Objective 3 and stores previous games, I have opted to use a relational database. Choosing between different relational database, I have decided to use SQLite, since it does not require additional server software, has good performance with low memory requirements, and adequate for my use cases, with others such as Postgres being overkill.

#### DDL

Only a single entity will be required for my program, a table to store games. The table schema will be defined as follows:

Table: games			
Field	Key	Data Type	Validation
game_id	Primary	INT	NOT NULL
winner		INT	
cpu_depth		INT	

number_of_moves	INT	NOT NULL
cpu_enabled	BOOL	NOT NULL
moves	TEXT	NOT NULL
initial_board_configuration	TEXT	NOT NULL
time	FLOAT	
created_dt	TIMESTAMP	NOT NULL

Table 2.1: Data table scheme for *games* table

All fields are either generated or retrieved from the board class, except the moves attribute, which will need to be encoded into a suitable data type such as a string. All attributes are also independent of each other<sup>1</sup>, and so the table therefore adheres to the third normal form.

To create the entity, a `CREATE` statement like the following can be used:

---

```

1   CREATE TABLE games(
2       id INTEGER PRIMARY KEY,
3       winner INTEGER,
4       cpu_depth INTEGER,
5       time real NOT NULL,
6       moves TEXT NOT NULL,
7       cpu_enabled INTEGER NOT NULL,
8       created_dt TIMESTAMP NOT NULL,
9       number_of_moves INTEGER NOT NULL,
10      initial_fen_string TEXT NOT NULL,
11  )

```

---

Removing an entity can also be done similarly:

---

```

1   DROP TABLE games

```

---

Migrations are a version control system to track incremental changes to the schema of a database. Since there is no popular SQL Python-binding libraries that support migrations, I will just be using a manual solution of creating python files that represent a change in my schema, defining functions that make use of SQL `ALTER` statements. This allows me to keep track of any changes, and rollback to a previous schema.

## DML

To insert a new game entry into the table, an `INSERT` statement can be used with the provided array, where the appropriate arguments are bound to the correct attribute via ? placeholders when run.

---

```

1   INSERT INTO games (
2       cpu_enabled,
3       cpu_depth,
4       winner,
5       time,
6       number_of_moves,
7       moves,
8       initial_fen_string,
9       created_dt
10      )

```

---

<sup>1</sup>There is a case to be made for *moves* and *number\_of\_moves*, however I have included *number\_of\_moves* to save the computational effort of parsing the moves for every game just to display it on the browser preview section.

```
11     VALUES (?, ?, ?, ?, ?, ?, ?, ?)
```

Moreover, we will need to fetch the number of total game entries in the table to be displayed to the user. To do this, the aggregate function `COUNT` can be used, which is supported by all SQL databases.

```
1   SELECT COUNT(*) FROM games
```

## Pagination

When there are a large number of entries in the table, it would be appropriate to display all the games to the user in a paginated form, where they can scroll between different pages and groups of games. There are multiple methods to paginate data, such as using `LIMIT` and `OFFSET` clauses, or cursor-based pagination, but I have opted to use the `ROW_NUMBER()` function.

`ROW_NUMBER()` is a window function that assigns a sequential integer to a query's result set. If I were to query the entire table, each row would be assigned an integer that could be used to check if the row is in the bounds for the current page, and therefore be displayed. Moreover, the use of an `ORDER BY` clause enables sorting of the output rows, allowing the user to choose what order the games are presented in based on an attribute such as number of moves. A `PARTITION BY` clause will also be used to group the results base on an attribute such as winner prior to sorting, if the user wants to search for games based on multiple criteria with greater ease.

The start row and end row will be passed as parameters to the placeholders in the SQL statement, calculated by multiplying the page number by the number of games per page.

```
1   SELECT * FROM
2       (SELECT ROW_NUMBER() OVER (
3           PARTITION BY attribute1
4           ORDER BY attribute2 ASC
5       ) AS row_num, * FROM games)
6   WHERE row_num >= ? AND row_num <= ?
```

## Security

Security measures such as database file permissions and encryption are common for a SQL database. However, since SQLite is a serverless database, and my program runs without any need for an internet connection, the risk of vulnerabilities is greatly reduced. Additionally, the game data stored on my database is frankly inconsequential, so going to great lengths to protect it wouldn't be to best use of my time. Nevertheless, my SQL Python-binding does support the user of placeholders for parameters, thereby addressing the risk of SQL injection attacks.

### 2.3.2 Linked Lists

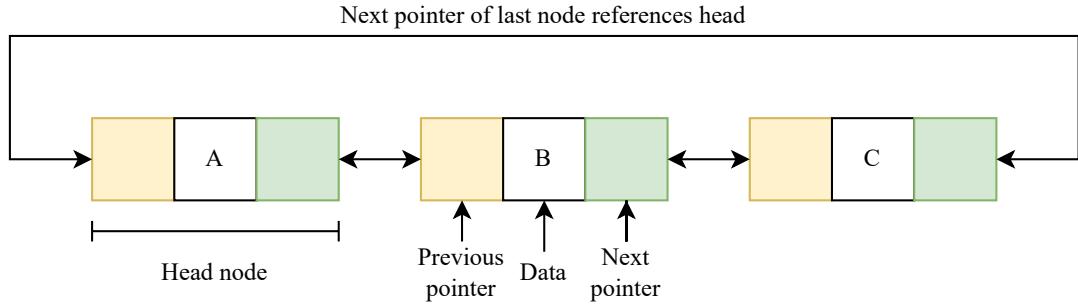


Figure 2.23: Structure of a circular doubly-linked list

Another data structure I intend to implement is linked lists. This will be integrated into widgets such as the carousel or multiple icon button widget, since these will contain a variable number of items, and where  $O(1)$  random access is not a priority. Since moving back and forth between nodes is a must for a carousel widget, the linked list will be doubly-linked, with each node containing to its previous and next node. The list will also need to loop, with the next pointer of the last node pointing back to the first node, making it a circular linked list, as demonstrated in Figure 2.23.

The following pseudocode outlines the basic functionality of the linked list:

**Algorithm 9** Circular doubly linked list pseudocode

```
function INSERT_AT_FRONT(node)
    if head is none then
        head  $\leftarrow$  node
        node.next  $\leftarrow$  node.previous  $\leftarrow$  head
    else
        node.next  $\leftarrow$  head
        node.previous  $\leftarrow$  head.previous
        head.previous.next  $\leftarrow$  node
        head.previous  $\leftarrow$  node

        head  $\leftarrow$  node
    end if
end function
```

**Require:**  $\text{LEN}(list) > 0$ 

```
function DATA_IN_LIST(data)
    current_node  $\leftarrow$  head.next
    while current_node  $\neq$  head do
        if current_node.data = data then
            return True
        end if
        current_node  $\leftarrow$  current_node.next
    end while
    return False
end function
```

**Require:** Data in list

```
function REMOVE(data)
    current_node  $\leftarrow$  head
    while current_node.data  $\neq$  data do
        current_node  $\leftarrow$  current_node.next
    end while

    current_node.previous.next  $\leftarrow$  current_node.next
    current_node.next.previous  $\leftarrow$  current_node.previous

    delete current_node
end function
```

---

### 2.3.3 Stack

Being a data structure with LIFO ordering, a stack is used for handling moves in the review screen. Starting with full stack of moves, every move undone pops an element off the stack to be processed. This move is then pushed onto a second stack. Therefore, cycling between moves requires pushing and popping between the two stacks, as shown in Figure 2.24. The same functionality can be achieved using a queue, but I have chosen to use two stacks as it is simpler

to implement, as being able to quickly check the number of items in each will come in handy.

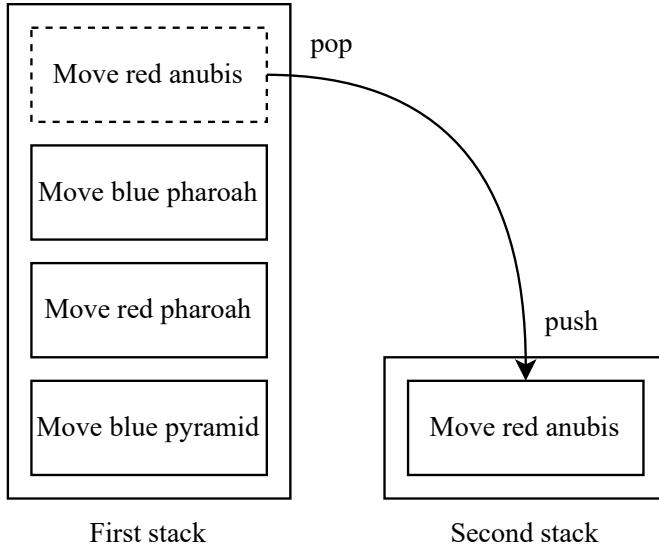


Figure 2.24: *Move red anubis* is undone and pushed onto the second stack

## 2.4 Classes

I will be using an Object-Oriented Programming (OOP) paradigm for my program. OOP reduces repetition of code, as inheritance can be used to abstract repetitive code into a base class, as shown in my widgets implementation. Testing and debugging classes will make my workflow more efficient. This section documents the base classes I am going to implement in my program.

### State

Since there will be multiple screens in my program as demonstrated in Figure 2.1, the State base class will be used to handle the logic for each screen. For each screen, void functions will be inherited and overwritten, each containing their own logic for that specific screen. For example, all screens will call the startup function in Table 2.2 to initialise variables needed for that screen. This polymorphism approach allows me to use another Control class to enable easy switching between screens, without worrying about the internal logic of that screen. Virtual methods also allow methods such as `draw` to be abstracted to the State superclass, reducing code in the inherited subclasses, while allowing them to override the methods and add their own logic.

Method Name	Description
<code>startup</code>	Initialise variables and functions when state set as displayed screen
<code>cleanup</code>	Cleanup any variables and functions when state removed from screen
<code>draw</code>	Draw to display
<code>update</code>	Update any variables for every game tick
<code>handle_resize</code>	Scale GUI when window resized
<code>get_event</code>	Receive pygame events as argument and process them

Table 2.2: Methods for State class

### Widget

I will be implementing my own widget system for creating the game GUI. This allows me to fully customise all graphical elements on the screen, and also create a resizing system that adheres to Objective 7a. The default Pygame rescaling options also simply resize elements without accounting for aspect ratios or resolution, and I could not find a library that suits my needs. Having a bespoke GUI implementation also justifies my use of Pygame over other Python frameworks.

I will be utilising the Pygame sprite system for my GUI. All GUI widgets will be subclasses inheriting from the base Widget class, which itself is a subclass of the Pygame sprite class. Since Pygame sprites are drawn via a `spriteGroup` class, I will also have to create a custom subclass inheriting that as well. As with the State class, polymorphism will allow the `spriteGroup` class to render all widgets regardless of their functionality. Each widget will override their base methods, especially the draw (set\_image) method, for their own needs. Additionally, I will use getter and setter methods, used with the `@property` decorator in python, to compute attributes mainly used for resizing widgets. This allows me to expose common variables, and to reduce code repetition.

Method Name	Description
<code>set_image</code>	Render widget to internal image attribute for Pygame sprite class
<code>set_geometry</code>	Set position and size of image
<code>set_screen_size</code>	Set screen size for resizing purposes
<code>get_event</code>	Receives Pygame events and processes them
<code>screen_size*</code>	Returns screen size in pixels
<code>position*</code>	Returns topleft of widget rect
<code>size*</code>	Returns size of widget in pixels
<code>margin*</code>	Returns distance between border and actual widget image
<code>border_width*</code>	Returns border width
<code>border_radius*</code>	Returns border radius for rounded corners
<code>font_size*</code>	Returns font size for text-based widgets

\* represents getter method / property

Table 2.3: Methods for Widget class

I will also employ multiple inheritance to combine different base class functionalities together. For example, I will create a pressable base class, designed to be subclassed along with the widget class. This will provide attributes and methods for widgets that support clicking and dragging. Following Python's Method Resolution Order (MRO), additional base classes should be referenced first, having priority over the base Widget class.

Method Name	Description
<code>get_event</code>	Receives Pygame events and sets current state accordingly
<code>set_state</code>	Sets current Pressable state, called by <code>get_event</code>
<code>set_colours</code>	Set fill colour according to widget Pressable state

Method Name	Description
current_state*	Returns current Pressable state (e.g. hovered, pressed etc.)
* represents getter method / property	

Table 2.4: Methods for example Pressable class

## Game

For my game screen, I will be utilising the Model-View-Controller architectural pattern (MVC). MVC defines three interconnected parts, the model processing information, the view showing the information, and the controlling receiving user inputs and connecting the two. This will allow me to decompose the development process into individual parts for the game logic, graphics and user input, speeding up the development process and making testing easier. It also allows me to implement multiple views, for the pause and win screens as well. For MVC, I will have to implement a game model class, a game controller class, and three classes for each view (game, pause, win). Using aggregation, these will be initially connected and handled by the game state class. For the following methods, I have only showed those pertinent to the MVC pattern:

Method Name	Description
get_event	Receives Pygame events and passes them onto the correct part's event handler
handle_game_event	Receives events and notifies the game model and game view
handle_pause_event	Receives events and notifies the pause view
handle_win_event	Receives events and notifies the win view
...	...

Table 2.5: Methods for Controller class

Method Name	Description
process_model_event	Receives events from the model and calls the relevant method to display that information
convert_mouse_pos	Sends controller class information of widget under mouse
draw	Draw information to display
handle_resize	Scale GUI when window resized
...	...

Table 2.6: Methods for View class

Method Name	Description
register_listener	Subscribes method on view instance to an event type, so that the method receives and processes that event every time <code>alert_listener</code> is called
alert_listener	Sends event to all subscribed instances
toggle_win	Sends event for win view
toggle_pause	Sends event for pause view

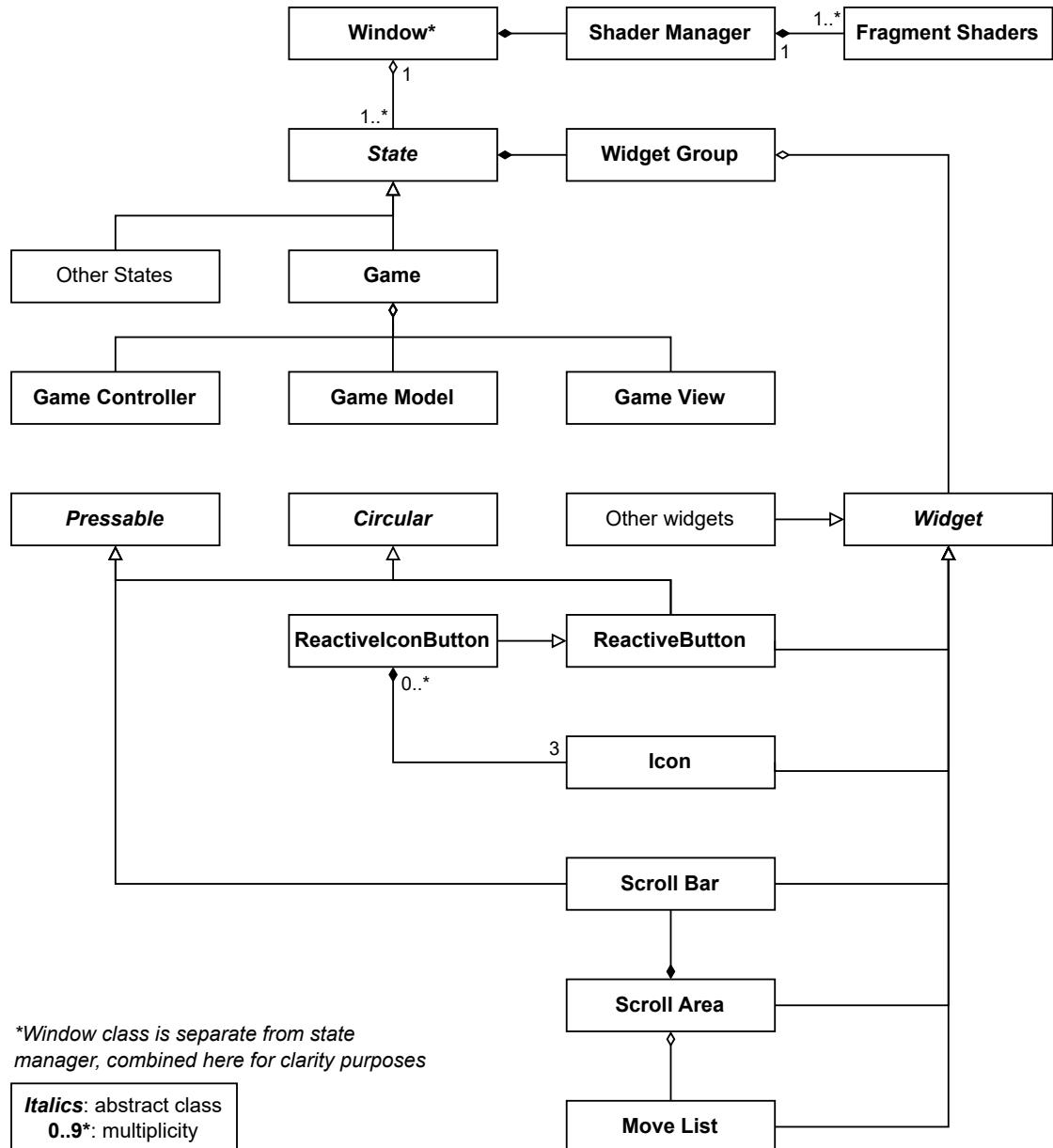
Method Name	Description
...	...

Table 2.7: Methods for Model class

### Shaders

To use ModernGL with Pygame, I have created classes for each fragment shader, controlled by a main shader manager class. The fragment shader classes will rely on composition: The shader manager creates the fragment shader class; Every fragment shader class takes their shader manager parent instance as an argument, and runs methods on it to produce the final output.

### 2.4.1 Class Diagram



View complete class diagram for all widgets.

View complete class diagram for entire program.

View alternate class diagram for entire program.

(Generated with Pyreverse)

# Chapter 3

## Technical Solution

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### 3.1 File Tree Diagram

To help navigate through the source code, I have included the following directory tree diagram, along with comments to explain the general purpose of code contained within specific directories and Python files.

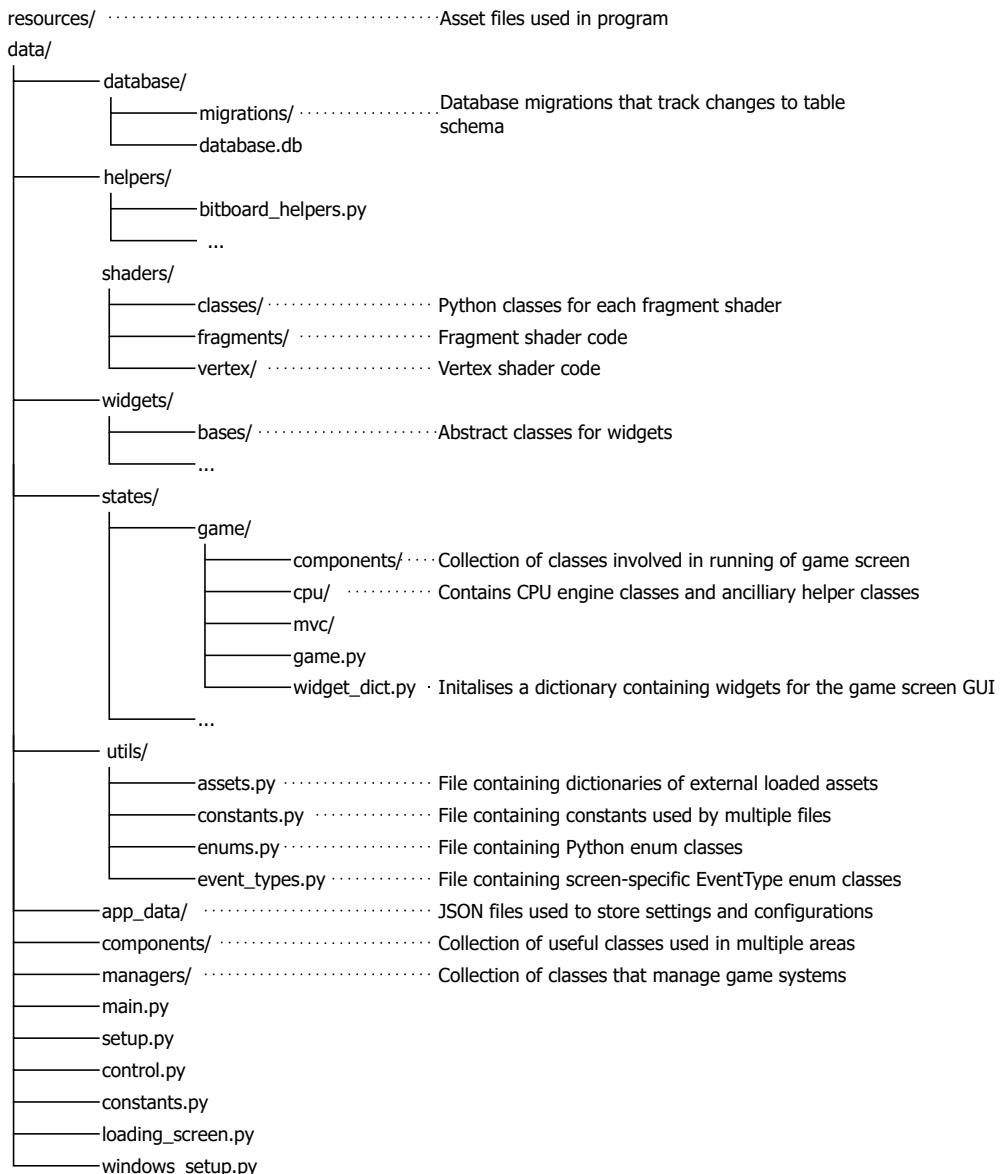


Figure 3.1: File tree diagram

## 3.2 Summary of Complexity

- Minimax improvements (3.6.2 and 3.6.3 and 3.6.4)
- Shadow mapping and coordinate transformations (3.9.3)
- Recursive Depth-First Search tree traversal (3.3.4 and 3.6.1)
- Circular doubly-linked list and stack (3.4.3 and 3.7.1)
- Multipass shaders and Gaussian blur (3.9.2)
- Aggregate and Window SQL functions (3.8.2)
- OOP techniques (3.4.3 and 3.4.4)
- Multithreading (3.3.2 and 3.6.6)
- Bitboards (3.5.5)
- Zobrist hashing (3.6.7)
- (File handling and JSON parsing) (3.3.3)
- (Dictionary recursion) (3.3.4)
- (Dot product) (3.3.3 and 3.9.2)

## 3.3 Overview

### 3.3.1 Main

The file `main.py` is run by the root file `run.py`. Here resources-intensive classes such as the state and asset files are initialised, while the program displays a loading screen to hide the loading process. The main game loop is then executed.

`main.py`

```

1 from sys import platform
2 # Initialises Pygame
3 import data.setup
4
5 # Windows OS requires some configuration for Pygame to scale GUI continuously
6 # while window is being resized
6 if platform == 'win32':
7     import data.windows_setup as win_setup
8
9 from data.loading_screen import LoadingScreen
10
11 states = [None, None]
12
13 def load_states():
14     """
15         Initialises instances of all screens, executed on another thread with results
16         being stored to the main thread by modifying a mutable such as the states list
17     """
18     from data.control import Control
19     from data.states.game.game import Game
      from data.states.menu.menu import Menu

```

```

20     from data.states.settings.settings import Settings
21     from data.states.config.config import Config
22     from data.states.browser.browser import Browser
23     from data.states.review.review import Review
24     from data.states.editor.editor import Editor
25
26     # Initialise dictionary containing each screen in the game, referenced in
27     # Control class by the current state's 'next' and 'previous' attributes,
28     # corresponding to a key in this dictionary
29     state_dict = {
30         'menu': Menu(),
31         'game': Game(),
32         'settings': Settings(),
33         'config': Config(),
34         'browser': Browser(),
35         'review': Review(),
36         'editor': Editor()
37     }
38
39     app = Control()
40
41     states[0] = app
42     states[1] = state_dict
43
44     def main():
45         """
46             Executed by run.py, starts main game loop
47         """
48         app, state_dict = states
49
50         if platform == 'win32':
51             win_setup.set_win_resize_func(app.update_window)
52
53         app.setup_states(state_dict, 'menu')
54         app.main_game_loop()

```

### 3.3.2 Loading Screen

Multithreading is used to separate the loading screen GUI from the resources intensive actions in `main.py`, to keep the GUI responsive. The easing function `easeOutBack` is also used to animate the logo.

`loading_screen.py`

```

1  import pygame
2  import threading
3  import sys
4  from pathlib import Path
5  from data.helpers.load_helpers import load_gfx, load_sfx
6  from data.managers.window import window
7  from data.managers.audio import audio
8
9  FPS = 30
10 start_ticks = pygame.time.get_ticks()
11 logo_gfx_path = (Path(__file__).parent / '../resources/graphics/gui/icons/logo/
12 logo.png').resolve()
12 sfx_path_1 = (Path(__file__).parent / '../resources/sfx/loading_screen/
13 loading_screen_1.wav').resolve()

```

```

13 sfx_path_2 = (Path(__file__).parent / '../resources/sfx/loading_screen/
14     loading_screen_2.wav').resolve()
15
16 def easeOutBack(progress):
17     """
18         Represents a cubic function for easing the logo position.
19         Starts quickly and has small overshoot, then ends slowly.
20
21     Args:
22         progress (float): x-value for cubic function ranging from 0-1.
23
24     Returns:
25         float:  $2.70x^3 + 1.70x^2 + 0x + 1$ , where x is time elapsed.
26     """
27     c2 = 1.70158
28     c3 = 2.70158
29
30     return c3 * ((progress - 1) ** 3) + c2 * ((progress - 1) ** 2) + 1
31
32 class LoadingScreen:
33     def __init__(self, target_func):
34         """
35             Creates new thread, and sets the load_state() function as its target.
36             Then starts draw loop for the loading screen.
37
38         Args:
39             target_func (Callable): function to be run on thread.
40         """
41         self._clock = pygame.time.Clock()
42         self._thread = threading.Thread(target=target_func)
43         self._thread.start()
44
45         self._logo_surface = load_gfx(logo_gfx_path)
46         self._logo_surface = pygame.transform.scale(self._logo_surface, (96, 96))
47         audio.play_sfx(load_sfx(sfx_path_1))
48         audio.play_sfx(load_sfx(sfx_path_2))
49
50         self.run()
51
52     @property
53     def logo_position(self):
54         duration = 1000
55         displacement = 50
56         elapsed_ticks = pygame.time.get_ticks() - start_ticks
57         progress = min(1, elapsed_ticks / duration)
58         center_pos = ((window.screen.size[0] - self._logo_surface.size[0]) / 2, (
59             window.screen.size[1] - self._logo_surface.size[1]) / 2)
60
61         return (center_pos[0], center_pos[1] + displacement - displacement *
62             easeOutBack(progress))
63
64     @property
65     def logo_opacity(self):
66         return min(255, (pygame.time.get_ticks() - start_ticks) / 5)
67
68     @property
69     def duration_not_over(self):
70         return (pygame.time.get_ticks() - start_ticks) < 1500
71
72     def event_loop(self):
73         """
74             Handles events for the loading screen, no user input is taken except to

```

```

    quit the game.
    """
72     for event in pygame.event.get():
73         if event.type == pygame.QUIT:
74             pygame.quit()
75             sys.exit()
76
77     def draw(self):
78         """
79             Draws logo to screen.
80         """
81         window.screen.fill((0, 0, 0))
82
83         self._logo_surface.set_alpha(self.logo_opacity)
84         window.screen.blit(self._logo_surface, self.logo_position)
85
86         window.update()
87
88     def run(self):
89         """
90             Runs while the thread is still setting up our screens, or the minimum
91             loading screen duration is not reached yet.
92         """
93         while self._thread.is_alive() or self.duration_not_over:
94             self.event_loop()
95             self.draw()
96             self._clock.tick(FPS)

```

### 3.3.3 Helper functions

These files provide useful functions for different classes.

`asset_helpers.py` (Functions used for assets and pygame Surfaces)

```

1 import pygame
2 from PIL import Image
3 from functools import cache
4 from random import randint
5 import math
6
7 @cache
8 def scale_and_cache(image, target_size):
9     """
10        Caches image when resized repeatedly.
11
12    Args:
13        image (pygame.Surface): Image surface to be resized.
14        target_size (tuple[float, float]): New image size.
15
16    Returns:
17        pygame.Surface: Resized image surface.
18    """
19    return pygame.transform.scale(image, target_size)
20
21 @cache
22 def smoothscale_and_cache(image, target_size):
23     """
24        Same as scale_and_cache, but with the Pygame smoothscale function.
25
26    Args:
27        image (pygame.Surface): Image surface to be resized.
28        target_size (tuple[float, float]): New image size.

```

```

29
30     Returns:
31         pygame.Surface: Resized image surface.
32     """
33     return pygame.transform.smoothscale(image, target_size)
34
35 def gif_to_frames(path):
36     """
37     Uses the PIL library to break down GIFs into individual frames.
38
39     Args:
40         path (str): Directory path to GIF file.
41
42     Yields:
43         PIL.Image: Single frame.
44     """
45     try:
46         image = Image.open(path)
47
48         first_frame = image.copy().convert('RGBA')
49         yield first_frame
50         image.seek(1)
51
52         while True:
53             current_frame = image.copy()
54             yield current_frame
55             image.seek(image.tell() + 1)
56     except EOFError:
57         pass
58
59 def get_perimeter_sample(image_size, number):
60     """
61     Used for particle drawing class, generates roughly equally distributed points
62     around a rectangular image surface's perimeter.
63
64     Args:
65         image_size (tuple[float, float]): Image surface size.
66         number (int): Number of points to be generated.
67
68     Returns:
69         list[tuple[int, int], ...]: List of random points on perimeter of image
70         surface.
71     """
72     perimeter = 2 * (image_size[0] + image_size[1])
73     # Flatten perimeter to a single number representing the distance from the top-
74     # middle of the surface going clockwise, and create a list of equally spaced
75     # points
76     perimeter_offsets = [(image_size[0] / 2) + (i * perimeter / number) for i in
77     range(0, number)]
78     pos_list = []
79
80     for perimeter_offset in perimeter_offsets:
81         # For every point, add a random offset
82         max_displacement = int(perimeter / (number * 4))
83         perimeter_offset += randint(-max_displacement, max_displacement)
84
85         if perimeter_offset > perimeter:
86             perimeter_offset -= perimeter
87
88         # Convert 1D distance back into 2D points on image surface perimeter
89         if perimeter_offset < image_size[0]:
90             pos_list.append((perimeter_offset, 0))

```

```

86         elif perimeter_offset < image_size[0] + image_size[1]:
87             pos_list.append((image_size[0], perimeter_offset - image_size[0]))
88         elif perimeter_offset < image_size[0] + image_size[1] + image_size[0]:
89             pos_list.append((perimeter_offset - image_size[0] - image_size[1],
90                             image_size[1]))
91         else:
92             pos_list.append((0, perimeter - perimeter_offset))
93     return pos_list
94
95 def get_angle_between_vectors(u, v, deg=True):
96     """
97     Uses the dot product formula to find the angle between two vectors.
98
99     Args:
100        u (list[int, int]): Vector 1.
101        v (list[int, int]): Vector 2.
102        deg (bool, optional): Return results in degrees. Defaults to True.
103
104    Returns:
105        float: Angle between vectors.
106    """
107     dot_product = sum(i * j for (i, j) in zip(u, v))
108     u_magnitude = math.sqrt(u[0]**2 + u[1]**2)
109     v_magnitude = math.sqrt(v[0]**2 + v[1]**2)
110
111     cos_angle = dot_product / (u_magnitude * v_magnitude)
112     radians = math.acos(min(max(cos_angle, -1), 1))
113
114     if deg:
115         return math.degrees(radians)
116     else:
117         return radians
118
119 def get_rotational_angle(u, v, deg=True):
120     """
121     Get bearing angle relative to positive x-axis centered on second vector.
122
123     Args:
124        u (list[int, int]): Vector 1.
125        v (list[int, int]): Vector 2, set as center of axes.
126        deg (bool, optional): Return results in degrees. Defaults to True.
127
128    Returns:
129        float: Bearing angle between vectors.
130    """
131     radians = math.atan2(u[1] - v[1], u[0] - v[0])
132
133     if deg:
134         return math.degrees(radians)
135     else:
136         return radians
137
138 def get_vector(src_vertex, dest_vertex):
139     """
140     Get vector describing translation between two points.
141
142     Args:
143        src_vertex (list[int, int]): Source vertex.
144        dest_vertex (list[int, int]): Destination vertex.
145
146    Returns:
147        tuple[int, int]: Vector between the two points.

```

```

147     """
148     return (dest_vertex[0] - src_vertex[0], dest_vertex[1] - src_vertex[1])
149
150 def get_next_corner(vertex, image_size):
151     """
152     Used in particle drawing system, finds coordinates of the next corner going
153     clockwise, given a point on the perimeter.
154
155     Args:
156         vertex (list[int, int]): Point on perimeter.
157         image_size (list[int, int]): Image size.
158
159     Returns:
160         list[int, int]: Coordinates of corner on perimeter.
161     """
162     corners = [(0, 0), (image_size[0], 0), (image_size[0], image_size[1]), (0,
163     image_size[1])]
164
165     if vertex in corners:
166         return corners[(corners.index(vertex) + 1) % len(corners)]
167
168     if vertex[1] == 0:
169         return (image_size[0], 0)
170     elif vertex[0] == image_size[0]:
171         return image_size
172     elif vertex[1] == image_size[1]:
173         return (0, image_size[1])
174     elif vertex[0] == 0:
175         return (0, 0)
176
177 def pil_image_to_surface(pil_image):
178     """
179     Args:
180         pil_image (PIL.Image): Image to be converted.
181
182     Returns:
183         pygame.Surface: Converted image surface.
184     """
185     return pygame.image.frombytes(pil_image.tobytes(), pil_image.size, pil_image.
186     mode).convert()
187
188 def calculate_frame_index(elapsed_milliseconds, start_index, end_index, fps):
189     """
190     Determine frame of animated GIF to be displayed.
191
192     Args:
193         elapsed_milliseconds (int): Milliseconds since GIF started playing.
194         start_index (int): Start frame of GIF.
195         end_index (int): End frame of GIF.
196         fps (int): Number of frames to be played per second.
197
198     Returns:
199         int: Displayed frame index of GIF.
200     """
201     ms_per_frame = int(1000 / fps)
202     return start_index + ((elapsed_milliseconds // ms_per_frame) % (end_index -
203     start_index))
204
205 def draw_background(screen, background, current_time=0):
206     """
207     Draws background to screen

```

```
205     Args:
206         screen (pygame.Surface): Screen to be drawn to
207         background (list[pygame.Surface, ...] | pygame.Surface): Background to be
208             drawn, if GIF, list of surfaces indexed to select frame to be drawn
209             current_time (int, optional): Used to calculate frame index for GIF.
210             Defaults to 0.
211             """
212         if isinstance(background, list):
213             # Animated background passed in as list of surfaces, calculate_frame_index
214             () used to get index of frame to be drawn
215             frame_index = calculate_frame_index(current_time, 0, len(background), fps
216             =8)
217             scaled_background = scale_and_cache(background[frame_index], screen.size)
218             screen.blit(scaled_background, (0, 0))
219         else:
220             scaled_background = scale_and_cache(background, screen.size)
221             screen.blit(scaled_background, (0, 0))
222
223     def get_highlighted_icon(icon):
224         """
225             Used for pressable icons, draws overlay on icon to show as pressed.
226
227             Args:
228                 icon (pygame.Surface): Icon surface.
229
230             Returns:
231                 pygame.Surface: Icon with overlay drawn on top.
232             """
233             icon_copy = icon.copy()
234             overlay = pygame.Surface((icon.get_width(), icon.get_height()), pygame.
235             SRCALPHA)
236             overlay.fill((0, 0, 0, 128))
237             icon_copy.blit(overlay, (0, 0))
238             return icon_copy
239
240
241     data_helpers.py (Functions used for file handling and JSON parsing)
242
243     1 import json
244     2 from pathlib import Path
245
246     4 module_path = Path(__file__).parent
247     5 default_file_path = (module_path / '../app_data/default_settings.json').resolve()
248     6 user_file_path = (module_path / '../app_data/user_settings.json').resolve()
249     7 themes_file_path = (module_path / '../app_data/themes.json').resolve()
250
251     9 def load_json(path):
252         """
253             Args:
254                 path (str): Path to JSON file.
255
256             Raises:
257                 Exception: Invalid file.
258
259             Returns:
260                 dict: Parsed JSON file.
261             """
262             try:
263                 with open(path, 'r') as f:
264                     file = json.load(f)
265
266             return file
```

```

25     except:
26         raise Exception('Invalid JSON file (data_helpers.py)')
27
28     def get_user_settings():
29         return load_json(user_file_path)
30
31     def get_default_settings():
32         return load_json(default_file_path)
33
34     def get_themes():
35         return load_json(themes_file_path)
36
37     def update_user_settings(data):
38         """
39             Rewrites JSON file for user settings with new data.
40
41         Args:
42             data (dict): Dictionary storing updated user settings.
43
44         Raises:
45             Exception: Invalid file.
46         """
47         try:
48             with open(user_file_path, 'w') as f:
49                 json.dump(data, f, indent=4)
50         except:
51             raise Exception('Invalid JSON file (data_helpers.py)')

```

#### widget\_helpers.py (Files used for creating widgets)

```

1  import pygame
2  from math import sqrt
3
4  def create_slider(size, fill_colour, border_width, border_colour):
5      """
6          Creates surface for sliders.
7
8      Args:
9          size (list[int, int]): Image size.
10         fill_colour (pygame.Color): Fill (inner) colour.
11         border_width (float): Border width.
12         border_colour (pygame.Color): Border colour.
13
14     Returns:
15         pygame.Surface: Slider image surface.
16     """
17     gradient_surface = pygame.Surface(size, pygame.SRCALPHA)
18     border_rect = pygame.FRect((0, 0, gradient_surface.width, gradient_surface.height))
19
20     # Draws rectangle with a border radius half of image height, to draw an
21     # rectangle with semicircular cap (obround)
22     pygame.draw.rect(gradient_surface, fill_colour, border_rect, border_radius=int(
23         (size[1] / 2)))
24     pygame.draw.rect(gradient_surface, border_colour, border_rect, width=int(
25         border_width), border_radius=int(size[1] / 2))
26
27     return gradient_surface
28
29     def create_slider_gradient(size, border_width, border_colour):
30         """

```

```

28     Draws surface for colour slider, with a full colour gradient as fill colour.
29
30     Args:
31         size (list[int, int]): Image size.
32         border_width (float): Border width.
33         border_colour (pygame.Color): Border colour.
34
35     Returns:
36         pygame.Surface: Slider image surface.
37     """
38     gradient_surface = pygame.Surface(size, pygame.SRCALPHA)
39
40     first_round_end = gradient_surface.height / 2
41     second_round_end = gradient_surface.width - first_round_end
42     gradient_y_mid = gradient_surface.height / 2
43
44     # Iterate through length of slider
45     for i in range(gradient_surface.width):
46         draw_height = gradient_surface.height
47
48         if i < first_round_end or i > second_round_end:
49             # Draw semicircular caps if x-distance less than or greater than
50             # radius of cap (half of image height)
51             distance_from_cutoff = min(abs(first_round_end - i), abs(i - second_round_end))
52             draw_height = calculate_gradient_slice_height(distance_from_cutoff,
53                 gradient_surface.height / 2)
54
55             # Get colour from distance from left side of slider
56             color = pygame.Color(0)
57             color.hsva = (int(360 * i / gradient_surface.width), 100, 100, 100)
58
59             draw_rect = pygame.FRect((0, 0, 1, draw_height - 2 * border_width))
60             draw_rect.center = (i, gradient_y_mid)
61
62             pygame.draw.rect(gradient_surface, color, draw_rect)
63
64     border_rect = pygame.FRect((0, 0, gradient_surface.width, gradient_surface.height))
65     pygame.draw.rect(gradient_surface, border_colour, border_rect, width=int(border_width),
66                      border_radius=int(size[1] / 2))
67
68     return gradient_surface
69
70 def calculate_gradient_slice_height(distance, radius):
71     """
72     Calculate height of vertical slice of semicircular slider cap.
73
74     Args:
75         distance (float): x-distance from center of circle.
76         radius (float): Radius of semicircle.
77
78     Returns:
79         float: Height of vertical slice.
80     """
81
82     return sqrt(radius ** 2 - distance ** 2) * 2 + 2
83
84 def create_slider_thumb(radius, colour, border_colour, border_width):
85     """
86     Creates surface with bordered circle.
87
88     Args:
89

```

```

85         radius (float): Radius of circle.
86         colour (pygame.Color): Fill colour.
87         border_colour (pygame.Color): Border colour.
88         border_width (float): Border width.
89
90     Returns:
91         pygame.Surface: Circle surface.
92     """
93     thumb_surface = pygame.Surface((radius * 2, radius * 2), pygame.SRCALPHA)
94     pygame.draw.circle(thumb_surface, border_colour, (radius, radius), radius,
95                        width=int(border_width))
96     pygame.draw.circle(thumb_surface, colour, (radius, radius), (radius -
97                        border_width))
98
99    return thumb_surface
100
101
102 def create_square_gradient(side_length, colour):
103     """
104     Creates a square gradient for the colour picker widget, gradient transitioning
105     between saturation and value.
106     Uses smoothscale to blend between colour values for individual pixels.
107
108     Args:
109         side_length (float): Length of a square side.
110         colour (pygame.Color): Colour with desired hue value.
111
112     Returns:
113         pygame.Surface: Square gradient surface.
114     """
115     square_surface = pygame.Surface((side_length, side_length))
116
117     mix_1 = pygame.Surface((1, 2))
118     mix_1.fill((255, 255, 255))
119     mix_1.set_at((0, 1), (0, 0, 0))
120     mix_1 = pygame.transform.smoothscale(mix_1, (side_length, side_length))
121
122     hue = colour.hsva[0]
123     saturated_rgb = pygame.Color(0)
124     saturated_rgb.hsva = (hue, 100, 100)
125
126     mix_2 = pygame.Surface((2, 1))
127     mix_2.fill((255, 255, 255))
128     mix_2.set_at((1, 0), saturated_rgb)
129     mix_2 = pygame.transform.smoothscale(mix_2, (side_length, side_length))
130
131     mix_1.blit(mix_2, (0, 0), special_flags=pygame.BLEND_MULT)
132
133     square_surface.blit(mix_1, (0, 0))
134
135    return square_surface
136
137 def create_switch(size, colour):
138     """
139     Creates surface for switch toggle widget.
140
141     Args:
142         size (list[int, int]): Image size.
143         colour (pygame.Color): Fill colour.
144
145     Returns:
146         pygame.Surface: Switch surface.
147     """

```

```

144     switch_surface = pygame.Surface((size[0], size[1]), pygame.SRCALPHA)
145     pygame.draw.rect(switch_surface, colour, (0, 0, size[0], size[1]),
146                      border_radius=int(size[1] / 2))
147
148     return switch_surface
149
150
151 def create_text_box(size, border_width, colours):
152     """
153     Creates bordered textbox with shadow, flat, and highlighted vertical regions.
154
155     Args:
156         size (list[int, int]): Image size.
157         border_width (float): Border width.
158         colours (list[pygame.Color, ...]): List of 4 colours, representing border
159         colour, shadow colour, flat colour and highlighted colour.
160
161     Returns:
162         pygame.Surface: Textbox surface.
163     """
164
165     surface = pygame.Surface(size, pygame.SRCALPHA)
166
167     pygame.draw.rect(surface, colours[0], (0, 0, *size))
168     pygame.draw.rect(surface, colours[2], (border_width, border_width, size[0] - 2
169                                         * border_width, size[1] - 2 * border_width))
170     pygame.draw.rect(surface, colours[3], (border_width, border_width, size[0] - 2
171                                         * border_width, border_width))
172     pygame.draw.rect(surface, colours[1], (border_width, size[1] - 2 *
173                                         border_width, size[0] - 2 * border_width, border_width))
174
175     return surface

```

### 3.3.4 Theme

The theme manager file is responsible for providing an instance where the colour palette and dimensions for the GUI can be accessed. Values read from a JSON file are **recursively** flattened, with keys created from the dictionary hierarchy, and stored into the internal dictionary of a `ThemeManager` object.

`theme.py`

```

1 from data.helpers.data_helpers import get_themes, get_user_settings
2
3 themes = get_themes()
4 user_settings = get_user_settings()
5
6 def flatten_dictionary_generator(dictionary, parent_key=None):
6     """
6     Recursive depth-first search to yield all items in a dictionary.
6
6     Args:
6         dictionary (dict): Dictionary to be iterated through.
6         parent_key (str, optional): Prefix added to every key. Defaults to None.
6
6     Yields:
6         dict | tuple[str, str]: Another dictionary or key, value pair.
6     """
6
6     for key, value in dictionary.items():
6         if parent_key:
6             new_key = parent_key + key.capitalize()
6         else:
6             new_key = key

```

```

22         if isinstance(value, dict):
23             yield from flatten_dictionary(value, new_key).items()
24         else:
25             yield new_key, value
26
27     def flatten_dictionary(dictionary, parent_key=''):
28         return dict(flatten_dictionary_generator(dictionary, parent_key))
29
30     class ThemeManager:
31         def __init__(self):
32             self.__dict__.update(flatten_dictionary(themes['colours']))
33             self.__dict__.update(flatten_dictionary(themes['dimensions']))
34
35         def __getitem__(self, arg):
36             """
37                 Override default class's __getitem__ dunder method, to make retrieving an
38                 instance attribute nicer with [] notation.
39
40             Args:
41                 arg (str): Attribute name.
42
43             Raises:
44                 KeyError: Instance does not have requested attribute.
45
46             Returns:
47                 str | int: Instance attribute.
48             """
49             item = self.__dict__.get(arg)
50
51             if item is None:
52                 raise KeyError('({}) Requested theme item not found: {}'.format(self.__class__.__name__, arg))
53
54             return item
55
56 theme = ThemeManager()

```

## 3.4 GUI

### 3.4.1 Laser

The `LaserDraw` class draws the laser in both the game and review screens.

`laser_draw.py`

```

1 import pygame
2 from data.helpers.board_helpers import coords_to_screen_pos
3 from data.utils.enums import LaserType, Colour, ShaderType
4 from data.managers.animation import animation
5 from data.utils.assets import GRAPHICS, SFX
6 from data.utils.constants import EMPTY_BB
7 from data.managers.window import window
8 from data.managers.audio import audio
9
10 type_to_image = {
11     LaserType.END: ['laser_end_1', 'laser_end_2'],
12     LaserType.STRAIGHT: ['laser_straight_1', 'laser_straight_2'],
13     LaserType.CORNER: ['laser_corner_1', 'laser_corner_2']
14 }
15

```

```

16 GLOW_SCALE_FACTOR = 1.5
17
18 class LaserDraw:
19     def __init__(self, board_position, board_size):
20         self._board_position = board_position
21         self._square_size = board_size[0] / 10
22         self._laser_lists = []
23
24     @property
25     def firing(self):
26         return len(self._laser_lists) > 0
27
28     def add_laser(self, laser_result, laser_colour):
29         """
30             Adds a laser to the board.
31
32             Args:
33                 laser_result (Laser): Laser class instance containing laser trajectory
34                 info.
35                 laser_colour (Colour.RED | Colour.BLUE): Active colour of laser.
36
37         laser_path = laser_result.laser_path.copy()
38         laser_types = [LaserType.END]
39         # List of angles in degree to rotate the laser image surface when drawn
40         laser_rotation = [laser_path[0][1]]
41         laser_lights = []
42
43         # Iterates through every square laser passes through
44         for i in range(1, len(laser_path)):
45             previous_direction = laser_path[i-1][1]
46             current_coords, current_direction = laser_path[i]
47
48             if current_direction == previous_direction:
49                 laser_types.append(LaserType.STRAIGHT)
50                 laser_rotation.append(current_direction)
51             elif current_direction == previous_direction.get_clockwise():
52                 laser_types.append(LaserType.CORNER)
53                 laser_rotation.append(current_direction)
54             elif current_direction == previous_direction.get_anticlockwise():
55                 laser_types.append(LaserType.CORNER)
56                 laser_rotation.append(current_direction.get_anticlockwise())
57
58             # Adds a shader ray effect on the first and last square of the laser
59             # trajectory
60             if i in [1, len(laser_path) - 1]:
61                 abs_position = coords_to_screen_pos(current_coords, self.
62                 _board_position, self._square_size)
63                 laser_lights.append([
64                     (abs_position[0] / window.size[0], abs_position[1] / window.
65                     size[1]),
66                     0.35,
67                     (0, 0, 255) if laser_colour == Colour.BLUE else (255, 0, 0),
68                     ])
69
70             # Sets end laser draw type if laser hits a piece or piece is anubis
71             if laser_result.end_cap:
72                 laser_types[-1] = LaserType.END
73                 laser_path[-1] = (laser_path[-1][0], laser_path[-2][1].get_opposite())
74                 laser_rotation[-1] = laser_path[-2][1].get_opposite()
75
76             # Played audio cue if piece is destroyed
77             if laser_result.hit_square_bitboard != EMPTY_BB:

```

```

74         audio.play_sfx(SFX['piece_destroy'])
75
76     laser_path = [(coords, rotation, type) for (coords, dir), rotation, type
77     in zip(laser_path, laser_rotation, laser_types)]
78     self._laser_lists.append((laser_path, laser_colour))
79
80     window.clear_effect(ShaderType.RAYS)
81     window.set_effect(ShaderType.RAYS, lights=laser_lights)
82     animation.set_timer(1000, self.remove_laser)
83
84     audio.play_sfx(SFX['laser_1'])
85     audio.play_sfx(SFX['laser_2'])
86
87     def remove_laser(self):
88         """
89             Removes a laser from the board.
90         """
91         self._laser_lists.pop(0)
92
93         if len(self._laser_lists) == 0:
94             window.clear_effect(ShaderType.RAYS)
95
96     def draw_laser(self, screen, laser_list, glow=True):
97         """
98             Draws every laser on the screen.
99
100            Args:
101                screen (pygame.Surface): The screen to draw on.
102                laser_list (list): The list of laser segments to draw.
103                glow (bool, optional): Whether to draw a glow effect. Defaults to True
104
105            """
106
107        laser_path, laser_colour = laser_list
108        laser_list = []
109        glow_list = []
110
111        for coords, rotation, type in laser_path:
112            square_x, square_y = coords_to_screen_pos(coords, self._board_position
113            , self._square_size)
114            image = GRAPHICS[type_to_image[type][laser_colour]]
115            rotated_image = pygame.transform.rotate(image, rotation.to_angle())
116            scaled_image = pygame.transform.scale(rotated_image, (self.
117            _square_size + 1, self._square_size + 1)) # +1 to prevent rounding creating
118            black lines
119            laser_list.append((scaled_image, (square_x, square_y)))
120
121            # Scales up the laser image surface as a glow surface
122            scaled_glow = pygame.transform.scale(rotated_image, (self._square_size
123            * GLOW_SCALE_FACTOR, self._square_size * GLOW_SCALE_FACTOR))
124            offset = self._square_size * ((GLOW_SCALE_FACTOR - 1) / 2)
125            glow_list.append((scaled_glow, (square_x - offset, square_y - offset)))
126
127        # Scaled glow surfaces drawn on top with the RGB_ADD blend mode
128        if glow:
129            screen.fblits(glow_list, pygame.BLEND_RGB_ADD)
130
131        screen.blits(laser_list)
132
133    def draw(self, screen):
134        """
135            Draws all lasers on the screen.

```

```

129
130     Args:
131         screen (pygame.Surface): The screen to draw on.
132         """
133     for laser_list in self._laser_lists:
134         self.draw_laser(screen, laser_list)
135
136     def handle_resize(self, board_position, board_size):
137         """
138             Handles resizing of the board.
139
140         Args:
141             board_position (tuple[int, int]): The new position of the board.
142             board_size (tuple[int, int]): The new size of the board.
143             """
144         self._board_position = board_position
145         self._square_size = board_size[0] / 10

```

### 3.4.2 Particles

The `ParticlesDraw` class draws particles in both the game and review screens. The particles are either fragmented pieces when destroyed, or laser particles emitted from the Sphinx. Particles are given custom velocity, rotation, opacity and size parameters.

`particles_draw.py`

```

1 import pygame
2 from random import randint
3 from data.helpers.asset_helpers import get_perimeter_sample, get_vector,
4     get_angle_between_vectors, get_next_corner
5 from data.states.game.components.piece_sprite import PieceSprite
6 from data.helpers.data_helpers import get_user_settings
7
8 particles_disabled = not(get_user_settings()['particles'])
9
10 class ParticlesDraw:
11     def __init__(self, gravity=0.2, rotation=180, shrink=0.5, opacity=150):
12         self._particles = []
13         self._glow_particles = []
14
15         self._gravity = gravity
16         self._rotation = rotation
17         self._shrink = shrink
18         self._opacity = opacity
19
20     def fragment_image(self, image, number):
21         image_size = image.get_rect().size
22         """
23             1. Takes an image surface and samples random points on the perimeter.
24             2. Iterates through points, and depending on the nature of two consecutive
25                 points, finds a corner between them.
26             3. Draws a polygon with the points as the vertices to mask out the area
27                 not in the fragment.
28
29         Args:
30             image (pygame.Surface): Image to fragment.
31             number (int): The number of fragments to create.
32
33         Returns:
34             list[pygame.Surface]: List of image surfaces with fragment of original
35             surface drawn on top.

```

```

32     """
33     center = image.get_rect().center
34     points_list = get_perimeter_sample(image_size, number)
35     fragment_list = []
36
37     points_list.append(points_list[0])
38
39     # Iterate through points_list, using the current point and the next one
40     for i in range(len(points_list) - 1):
41         vertex_1 = points_list[i]
42         vertex_2 = points_list[i + 1]
43         vector_1 = get_vector(center, vertex_1)
44         vector_2 = get_vector(center, vertex_2)
45         angle = get_angle_between_vectors(vector_1, vector_2)
46
47         cropped_image = pygame.Surface(image_size, pygame.SRCALPHA)
48         cropped_image.fill((0, 0, 0, 0))
49         cropped_image.blit(image, (0, 0))
50
51         corners_to_draw = None
52
53         if vertex_1[0] == vertex_2[0] or vertex_1[1] == vertex_2[1]: # Points
54             on the same side
55             corners_to_draw = 4
56
57         elif abs(vertex_1[0] - vertex_2[0]) == image_size[0] or abs(vertex_1
58             [1] - vertex_2[1]) == image_size[1]: # Points on opposite sides
59             corners_to_draw = 2
60
61         elif angle < 180: # Points on adjacent sides
62             corners_to_draw = 3
63
64         else:
65             corners_to_draw = 1
66
67         corners_list = []
68         for j in range(corners_to_draw):
69             if len(corners_list) == 0:
70                 corners_list.append(get_next_corner(vertex_2, image_size))
71             else:
72                 corners_list.append(get_next_corner(corners_list[-1],
73                     image_size))
74
75         pygame.draw.polygon(cropped_image, (0, 0, 0, 0), (center, vertex_2, *
76         corners_list, vertex_1))
77
78         fragment_list.append(cropped_image)
79
80     return fragment_list
81
82 def add_captured_piece(self, piece, colour, rotation, position, size):
83     """
84     Adds a captured piece to fragment into particles.
85
86     Args:
87         piece (Piece): The piece type.
88         colour (Colour): The active colour of the piece.
89         rotation (int): The rotation of the piece.
90         position (tuple[int, int]): The position where particles originate
91         from.
92         size (tuple[int, int]): The size of the piece.
93     """

```

```

89         if particles_disabled:
90             return
91
92         piece_sprite = PieceSprite(piece, colour, rotation)
93         piece_sprite.set_geometry((0, 0), size)
94         piece_sprite.set_image()
95
96         particles = self.fragment_image(piece_sprite.image, 5)
97
98         for particle in particles:
99             self.add_particle(particle, position)
100
101     def add_sparks(self, radius, colour, position):
102         """
103             Adds laser spark particles.
104
105             Args:
106                 radius (int): The radius of the sparks.
107                 colour (Colour): The active colour of the sparks.
108                 position (tuple[int, int]): The position where particles originate
109                 from.
110             """
111
112         if particles_disabled:
113             return
114
115         for i in range(randint(10, 15)):
116             velocity = [randint(-15, 15) / 10, randint(-20, 0) / 10]
117             random_colour = [min(max(val + randint(-20, 20), 0), 255) for val in
118                             colour]
119             self._particles.append([None, [radius, random_colour], [*position],
120                                   velocity, 0])
121
122     def add_particle(self, image, position):
123         """
124             Adds a particle.
125
126             Args:
127                 image (pygame.Surface): The image of the particle.
128                 position (tuple): The position of the particle.
129             """
130
131         if particles_disabled:
132             return
133
134         velocity = [randint(-15, 15) / 10, randint(-20, 0) / 10]
135
136         # Each particle is stored with its attributes: [surface, copy of surface,
137         position, velocity, lifespan]
138         self._particles.append([image, image.copy(), [*position], velocity, 0])
139
140     def update(self):
141         """
142             Updates each particle and its attributes.
143         """
144
145         for i in range(len(self._particles) - 1, -1, -1):
146             particle = self._particles[i]
147
148             #update position
149             particle[2][0] += particle[3][0]
150             particle[2][1] += particle[3][1]
151
152             #update lifespan
153             self._particles[i][4] += 0.01

```

```

147
148     if self._particles[i][4] >= 1:
149         self._particles.pop(i)
150         continue
151
152     if isinstance(particle[1], pygame.Surface): # Particle is a piece
153         # Update velocity
154         particle[3][1] += self._gravity
155
156         # Update size
157         image_size = particle[1].get_rect().size
158         end_size = ((1 - self._shrink) * image_size[0], (1 - self._shrink)
159                     * image_size[1])
160         target_size = (image_size[0] - particle[4] * (image_size[0] -
161             end_size[0]), image_size[1] - particle[4] * (image_size[1] - end_size[1]))
162
163         # Update rotation
164         rotation = (self._rotation if particle[3][0] <= 0 else -self.
165                     _rotation) * particle[4]
166
167         updated_image = pygame.transform.scale(pygame.transform.rotate(
168             particle[1], rotation), target_size)
169
170
171         elif isinstance(particle[1], list): # Particle is a spark
172             # Update size
173             end_radius = (1 - self._shrink) * particle[1][0]
174             target_radius = particle[1][0] - particle[4] * (particle[1][0] -
175                 end_radius)
176
177             updated_image = pygame.Surface((target_radius * 2, target_radius *
178                 2), pygame.SRCALPHA)
179             pygame.draw.circle(updated_image, particle[1][1], (target_radius,
180                 target_radius), target_radius)
181
182             # Update opacity
183             alpha = 255 - particle[4] * (255 - self._opacity)
184
185             updated_image.fill((255, 255, 255, alpha), None, pygame.
186                 BLEND_RGBA_MULT)
187
188             particle[0] = updated_image
189
190     def draw(self, screen):
191         """
192             Draws the particles, indexing the surface and position attributes for each
193             particle.
194
195         Args:
196             screen (pygame.Surface): The screen to draw on.
197         """
198
199         screen.blit([
200             (particle[0], particle[2]) for particle in self._particles
201         ])

```

### 3.4.3 Widget Bases

Widget bases are used as the base classes for my widgets system. They contain both attributes and getter methods that provide both basic functionalities such as size and position, and abstract methods to be overridden. These bases are designed to be used with **multiple inheritance**, where multiple bases can be combined to add functionality to the final widget. **Encapsulation**

also allows me to simplify interactions between widgets, as using getter methods instead of protected attributes allows me to add logic while accessing an attribute, such as in `widget.py`, where the logic to fetch the parent surface instead of the windows screen is hidden within the base class.

## Widget

All widgets are a subclass of the `Widget` class.

`widget.py`

```

1 import pygame
2 from data.utils.constants import SCREEN_SIZE
3 from data.managers.theme import theme
4 from data.utils.assets import DEFAULT_FONT
5
6 DEFAULT_SURFACE_SIZE = SCREEN_SIZE
7 REQUIRED_KWARGS = ['relative_position', 'relative_size']
8
9 class _Widget(pygame.sprite.Sprite):
10     def __init__(self, **kwargs):
11         """
12             Every widget has the following attributes:
13
14             surface (pygame.Surface): The surface the widget is drawn on.
15             raw_surface_size (tuple[int, int]): The initial size of the window screen,
16             remains constant.
17             parent (_Widget, optional): The parent widget position and size is
18             relative to.
19             Relative to current surface:
20                 relative_position (tuple[float, float]): The position of the widget
21                 relative to its surface.
22                 relative_size (tuple[float, float]): The scale of the widget relative to
23                 its surface.
24
25                 Remains constant, relative to initial screen size:
26                 relative_font_size (float, optional): The relative font size of the widget
27
28                 relative_margin (float): The relative margin of the widget.
29                 relative_border_width (float): The relative border width of the widget.
30                 relative_border_radius (float): The relative border radius of the widget.
31
32                 anchor_x (str): The horizontal anchor direction ('left', 'right', 'center').
33                 anchor_y (str): The vertical anchor direction ('top', 'bottom', 'center').
34                 fixed_position (tuple[int, int], optional): The fixed position of the
35                 widget in pixels.
36                 border_colour (pygame.Color): The border color of the widget.
37                 text_colour (pygame.Color): The text color of the widget.
38                 fill_colour (pygame.Color): The fill color of the widget.
39                 font (pygame.freetype.Font): The font used for the widget.
40             """
41             super().__init__()
42
43             for required_kwarg in REQUIRED_KWARGS:
44                 if required_kwarg not in kwargs:
45                     raise KeyError(f'({_Widget.__init__}) Required keyword "{required_kwarg}" not in base kwargs')
46
47             self._surface = None # Set in WidgetGroup, as needs to be reassigned every
48             frame

```

```

43         self._raw_surface_size = DEFAULT_SURFACE_SIZE
44
45         self._parent = kwargs.get('parent')
46
47         self._relative_font_size = None # Set in subclass
48
49         self._relative_position = kwargs.get('relative_position')
50         self._relative_margin = theme['margin'] / self._raw_surface_size[1]
51         self._relative_border_width = theme['borderWidth'] / self.
52             _raw_surface_size[1]
53         self._relative_border_radius = theme['borderRadius'] / self.
54             _raw_surface_size[1]
55
56         self._border_colour = pygame.Color(theme['borderPrimary'])
57         self._text_colour = pygame.Color(theme['textPrimary'])
58         self._fill_colour = pygame.Color(theme['fillPrimary'])
59         self._font = DEFAULT_FONT
60
61         self._anchor_x = kwargs.get('anchor_x') or 'left'
62         self._anchor_y = kwargs.get('anchor_y') or 'top'
63         self._fixed_position = kwargs.get('fixed_position')
64         scale_mode = kwargs.get('scale_mode') or 'both'
65
66         if kwargs.get('relative_size'):
67             match scale_mode:
68                 case 'height':
69                     self._relative_size = kwargs.get('relative_size')
70                 case 'width':
71                     self._relative_size = ((kwargs.get('relative_size')[0] * self.
72             surface_size[0]) / self.surface_size[1], (kwargs.get('relative_size')[1] *
73             self.surface_size[0]) / self.surface_size[1])
74                 case 'both':
75                     self._relative_size = ((kwargs.get('relative_size')[0] * self.
76             surface_size[0]) / self.surface_size[1], kwargs.get('relative_size')[1])
77                 case _:
78                     raise ValueError('_Widget.__init__) Unknown scale mode:', scale_mode)
79             else:
80                 self._relative_size = (1, 1)
81
82             if 'margin' in kwargs:
83                 self._relative_margin = kwargs.get('margin') / self._raw_surface_size
84                 [1]
85
86                 if (self._relative_margin * 2) > min(self._relative_size[0], self.
87                     _relative_size[1]):
88                     raise ValueError('_Widget.__init__) Margin larger than specified
89                     size!')
90
91             if 'border_width' in kwargs:
92                 self._relative_border_width = kwargs.get('border_width') / self.
93                     _raw_surface_size[1]
94
95             if 'border_radius' in kwargs:
96                 self._relative_border_radius = kwargs.get('border_radius') / self.
97                     _raw_surface_size[1]
98
99             if 'border_colour' in kwargs:
100                 self._border_colour = pygame.Color(kwargs.get('border_colour'))
101
102             if 'fill_colour' in kwargs:
103                 self._fill_colour = pygame.Color(kwargs.get('fill_colour'))

```

```

94
95     if 'text_colour' in kwargs:
96         self._text_colour = pygame.Color(kwargs.get('text_colour'))
97
98     if 'font' in kwargs:
99         self._font = kwargs.get('font')
100
101 @property
102 def surface_size(self):
103     """
104         Gets the size of the surface widget is drawn on.
105         Can be either the window size, or another widget size if assigned to a
106         parent.
107
108     Returns:
109         tuple[int, int]: The size of the surface.
110     """
111     if self._parent:
112         return self._parent.size
113     else:
114         return self._raw_surface_size
115
116 @property
117 def position(self):
118     """
119         Gets the position of the widget.
120         Accounts for fixed position attribute, where widget is positioned in
121         pixels regardless of screen size.
122         Accounts for anchor direction, where position attribute is calculated
123         relative to one side of the screen.
124
125     Returns:
126         tuple[int, int]: The position of the widget.
127     """
128     x, y = None, None
129     if self._fixed_position:
130         x, y = self._fixed_position
131     if x is None:
132         x = self._relative_position[0] * self.surface_size[0]
133     if y is None:
134         y = self._relative_position[1] * self.surface_size[1]
135
136     if self._anchor_x == 'left':
137         x = x
138     elif self._anchor_x == 'right':
139         x = self.surface_size[0] - x - self.size[0]
140     elif self._anchor_x == 'center':
141         x = (self.surface_size[0] / 2 - self.size[0] / 2) + x
142
143     if self._anchor_y == 'top':
144         y = y
145     elif self._anchor_y == 'bottom':
146         y = self.surface_size[1] - y - self.size[1]
147     elif self._anchor_y == 'center':
148         y = (self.surface_size[1] / 2 - self.size[1] / 2) + y
149
150     # Position widget relative to parent, if exists.
151     if self._parent:
152         return (x + self._parent.position[0], y + self._parent.position[1])
153
154     return (x, y)

```

```

153     @property
154     def size(self):
155         return (self._relative_size[0] * self.surface_size[1], self._relative_size
156             [1] * self.surface_size[1])
157
158     @property
159     def margin(self):
160         return self._relative_margin * self._raw_surface_size[1]
161
162     @property
163     def border_width(self):
164         return self._relative_border_width * self._raw_surface_size[1]
165
166     @property
167     def border_radius(self):
168         return self._relative_border_radius * self._raw_surface_size[1]
169
170     @property
171     def font_size(self):
172         return self._relative_font_size * self.surface_size[1]
173
174     def set_image(self):
175         """
176             Abstract method to draw widget.
177         """
178         raise NotImplementedError
179
180     def set_geometry(self):
181         """
182             Sets the position and size of the widget.
183         """
184         self.rect = self.image.get_rect()
185
185     if self._anchor_x == 'left':
186         if self._anchor_y == 'top':
187             self.rect.topleft = self.position
188         elif self._anchor_y == 'bottom':
189             self.rect.topleft = self.position
190         elif self._anchor_y == 'center':
191             self.rect.topleft = self.position
192     elif self._anchor_x == 'right':
193         if self._anchor_y == 'top':
194             self.rect.topleft = self.position
195         elif self._anchor_y == 'bottom':
196             self.rect.topleft = self.position
197         elif self._anchor_y == 'center':
198             self.rect.topleft = self.position
199     elif self._anchor_x == 'center':
200         if self._anchor_y == 'top':
201             self.rect.topleft = self.position
202         elif self._anchor_y == 'bottom':
203             self.rect.topleft = self.position
204         elif self._anchor_y == 'center':
205             self.rect.topleft = self.position
206
207     def set_surface_size(self, new_surface_size):
208         """
209             Sets the new size of the surface widget is drawn on.
210
211             Args:
212                 new_surface_size (tuple[int, int]): The new size of the surface.
213         """

```

```

214         self._raw_surface_size = new_surface_size
215
216     def process_event(self, event):
217         """
218             Abstract method to handle events.
219
220             Args:
221                 event (pygame.Event): The event to process.
222
223             raise NotImplementedError

```

### Circular

The `Circular` class provides an internal **circular linked list**, giving functionality to support widgets which rotate between text/icons. `circular.py`

```

1  from data.components.circular_linked_list import CircularLinkedList
2
3  class _Circular:
4      def __init__(self, items_dict, **kwargs):
5          # The key, value pairs are stored within a dictionary, while the keys to
6          # access them are stored within circular linked list.
7          self._items_dict = items_dict
8          self._keys_list = CircularLinkedList(list(items_dict.keys()))
9
10     @property
11     def current_key(self):
12         """
13             Gets the current head node of the linked list, and returns a key stored as
14             the node data.
15             Returns:
16                 Data of linked list head.
17
18     @property
19     def current_item(self):
20         """
21             Gets the value in self._items_dict with the key being self.current_key.
22
23             Returns:
24                 Value stored with key being current head of linked list.
25
26             return self._items_dict[self.current_key]
27
28     def set_next_item(self):
29         """
30             Sets the next item in as the current item.
31
32             self._keys_list.shift_head()
33
34     def set_previous_item(self):
35         """
36             Sets the previous item as the current item.
37
38             self._keys_list.unshift_head()
39
40     def set_to_key(self, key):
41         """
42             Sets the current item to the specified key.

```

```

44     Args:
45         key: The key to set as the current item.
46
47     Raises:
48         ValueError: If no nodes within the circular linked list contains the
49             key as its data.
50         """
51
52     if self._keys_list.data_in_list(key) is False:
53         raise ValueError('(_Circular.set_to_key) Key not found:', key)
54
55     for _ in range(len(self._items_dict)):
56         if self.current_key == key:
57             self.set_image()
58             self.set_geometry()
59
60     return
61
62     self.set_next_item()

```

### Circular Linked List

As described in Section 2.3.2, the `CircularLinkedList` class implements a **circular doubly-linked list**. Used for the internal logic of the `Circular` class.

`circular_linked_list.py`

```

1  class Node:
2      def __init__(self, data):
3          self.data = data
4          self.next = None
5          self.previous = None
6
7  class CircularLinkedList:
8      def __init__(self, list_to_convert=None):
9          """
10          Initialises a CircularLinkedList object.
11
12          Args:
13              list_to_convert (list, optional): Creates a linked list from existing
14                  items. Defaults to None.
15          """
16          self._head = None
17
18          if list_to_convert:
19              for item in list_to_convert:
20                  self.insert_at_end(item)
21
22      def __str__(self):
23          """
24          Returns a string representation of the circular linked list.
25
26          Returns:
27              str: Linked list formatted as string.
28          """
29
30          if self._head is None:
31              return '| empty |'
32
33          characters = '| -> '
34          current_node = self._head
35          while True:
36              characters += str(current_node.data) + ' -> '
37              current_node = current_node.next

```

```

37         if current_node == self._head:
38             characters += '|'
39             return characters
40
41     def insert_at_beginning(self, data):
42         """
43             Inserts a node at the beginning of the circular linked list.
44
45         Args:
46             data: The data to insert.
47         """
48         new_node = Node(data)
49
50         if self._head is None:
51             self._head = new_node
52             new_node.next = self._head
53             new_node.previous = self._head
54         else:
55             new_node.next = self._head
56             new_node.previous = self._head.previous
57             self._head.previous.next = new_node
58             self._head.previous = new_node
59
60         self._head = new_node
61
62     def insert_at_end(self, data):
63         """
64             Inserts a node at the end of the circular linked list.
65
66         Args:
67             data: The data to insert.
68         """
69         new_node = Node(data)
70
71         if self._head is None:
72             self._head = new_node
73             new_node.next = self._head
74             new_node.previous = self._head
75         else:
76             new_node.next = self._head
77             new_node.previous = self._head.previous
78             self._head.previous.next = new_node
79             self._head.previous = new_node
80
81     def insert_at_index(self, data, index):
82         """
83             Inserts a node at a specific index in the circular linked list.
84             The head node is taken as index 0.
85
86         Args:
87             data: The data to insert.
88             index (int): The index to insert the data at.
89
90         Raises:
91             ValueError: Index is out of range.
92         """
93         if index < 0:
94             raise ValueError('Invalid index! (CircularLinkedList.insert_at_index)')
95
96         if index == 0 or self._head is None:
97             self.insert_at_beginning(data)

```

```

98     else:
99         new_node = Node(data)
100        current_node = self._head
101        count = 0
102
103        while count < index - 1 and current_node.next != self._head:
104            current_node = current_node.next
105            count += 1
106
107        if count == (index - 1):
108            new_node.next = current_node.next
109            new_node.previous = current_node
110            current_node.next = new_node
111        else:
112            raise ValueError('Index out of range! (CircularLinkedList.
113 insert_at_index)')
114
115    def delete(self, data):
116        """
117            Deletes a node with the specified data from the circular linked list.
118
119        Args:
120            data: The data to delete.
121
122        Raises:
123            ValueError: No nodes in the list contain the specified data.
124
125        if self._head is None:
126            return
127
128        current_node = self._head
129
130        while current_node.data != data:
131            current_node = current_node.next
132
133        if current_node == self._head:
134            raise ValueError('Data not found in circular linked list! (CircularLinkedList.delete)')
135
136        if self._head.next == self._head:
137            self._head = None
138        else:
139            current_node.previous.next = current_node.next
140            current_node.next.previous = current_node.previous
141
142    def data_in_list(self, data):
143        """
144            Checks if the specified data is in the circular linked list.
145
146        Args:
147            data: The data to check.
148
149        Returns:
150            bool: True if the data is in the list, False otherwise.
151
152        if self._head is None:
153            return False
154
155        current_node = self._head
156        while True:
157            if current_node.data == data:
158                return True

```

```

158
159         current_node = current_node.next
160         if current_node == self._head:
161             return False
162
163     def shift_head(self):
164         """
165             Shifts the head of the circular linked list to the next node.
166         """
167         self._head = self._head.next
168
169     def unshift_head(self):
170         """
171             Shifts the head of the circular linked list to the previous node.
172         """
173         self._head = self._head.previous
174
175     def get_head(self):
176         """
177             Gets the head node of the circular linked list.
178
179             Returns:
180                 Node: The head node.
181
182         return self._head

```

### 3.4.4 Widgets

As described in Section 2.4, each state contains a `WIDGET_DICT` map, which contains and initialises each widget with their own attributes, and provides references to run methods on them in the state code. Each `WIDGET_DICT` is passed into a `WidgetGroup` object, which is responsible for drawing, resizing and handling all widgets for the current state. Below is a list of all the widgets I have implemented (See Section B.25):

- BoardThumbnailButton
- MultipleIconButton
- ReactiveIconButton
- BoardThumbnail
- ReactiveButton
- VolumeSlider
- ColourPicker
- ColourButton
- BrowserStrip
- PieceDisplay
- BrowserItem
- TextButton
- IconButton
- ScrollArea
- Chessboard
- TextInput
- Rectangle
- MoveList
- Dropdown
- Carousel
- Switch
- Timer
- Text
- Icon
- (`_ColourDisplay`)
- (`_ColourSquare`)
- (`_ColourSlider`)
- (`_SliderThumb`)
- (`_Scrollbar`)

## CustomEvent

The `CustomEvent` class is used to pass data between states and widgets. An event argument is passed into interactive widgets; When a widget wants to pass data back to the state, it returns the event, and adds any attributes that is required. The state then receives and handles these returned events accordingly.

## custom\_event.py

```
1 from data.utils.event_types import GameEventType, SettingsEventType,
2   ConfigEventType, BrowserEventType, EditorEventType
3
4 # Required keyword arguments when creating a CustomEvent object with a specific
5 # EventType
6 required_args = {
7     GameEventType.BOARD_CLICK: ['coords'],
8     GameEventType.ROTATE_PIECE: ['rotation_direction'],
9     GameEventType.SET_LASER: ['laser_result'],
10    GameEventType.UPDATE_PIECES: ['move_notation'],
11    GameEventType.TIMER_END: ['active_colour'],
12    GameEventType.PIECE_DROP: ['coords', 'piece', 'colour', 'rotation', 'remove_overlay'],
13    SettingsEventType.COLOUR_SLIDER_SLIDE: ['colour'],
14    SettingsEventType.PRIMARY_COLOUR_PICKER_CLICK: ['colour'],
15    SettingsEventType.SECONDARY_COLOUR_PICKER_CLICK: ['colour'],
16    SettingsEventType.DROPDOWN_CLICK: ['selected_word'],
17    SettingsEventType.VOLUME_SLIDER_CLICK: ['volume', 'volume_type'],
18    SettingsEventType.SHADER_PICKER_CLICK: ['data'],
19    SettingsEventType.PARTICLES_CLICK: ['toggled'],
20    SettingsEventType.OPENGL_CLICK: ['toggled'],
21    ConfigEventType.TIME_TYPE: ['time'],
22    ConfigEventType.FEN_STRING_TYPE: ['time'],
23    ConfigEventType.CPU_DEPTH_CLICK: ['data'],
24    ConfigEventType.PVC_CLICK: ['data'],
25    ConfigEventType.PRESET_CLICK: ['fen_string'],
26    BrowserEventType.BROWSER_STRIP_CLICK: ['selected_index'],
27    BrowserEventType.PAGE_CLICK: ['data'],
28    EditorEventType.PICK_PIECE_CLICK: ['piece', 'active_colour'],
29    EditorEventType.ROTATE_PIECE_CLICK: ['rotation_direction'],
30 }
31
32 class CustomEvent():
33     def __init__(self, type, **kwargs):
34         self.__dict__.update(kwargs)
35         self.type = type
36
37     @classmethod
38     def create_event(event_cls, event_type, **kwargs):
39         """
40             @classmethod Factory method used to instance CustomEvent object, to check
41             for required keyword arguments
42
43             Args:
44                 event_cls (CustomEvent): Reference to own class.
45                 event_type: The state EventType.
46
47             Raises:
48                 ValueError: If required keyword argument for passed event type not
49                 present.
50                 ValueError: If keyword argument passed is not required for passed
51                 event type.
52
53         
```

```

48     Returns :
49         CustomEvent: Initialised CustomEvent instance.
50     """
51     if event_type in required_args:
52
53         for required_arg in required_args[event_type]:
54             if required_arg not in kwargs:
55                 raise ValueError(f"Argument '{required_arg}' required for {event_type.name} event (GameEvent.create_event)")
56
57         for kwarg in kwargs:
58             if kwarg not in required_args[event_type]:
59                 raise ValueError(f"Argument '{kwarg}' not included in required_args dictionary for event '{event_type}'! (GameEvent.create_event)")
60
61     return event_cls(event_type, **kwargs)
62
63 else:
64     return event_cls(event_type)

```

### ReactiveIconButton

The `ReactiveIconButton` widget is a pressable button that changes the icon displayed when it is hovered or pressed.

#### reactive\_icon\_button.py

```

1 from data.widgets.reactive_button import ReactiveButton
2 from data.utils.constants import WidgetState
3 from data.widgets.icon import Icon
4
5 class ReactiveIconButton(ReactiveButton):
6     def __init__(self, base_icon, hover_icon, press_icon, **kwargs):
7         # Composition is used here, to initialise the Icon widgets for each widget
8         state
9         widgets_dict = {
10             WidgetState.BASE: Icon(
11                 parent=kwargs.get('parent'),
12                 relative_size=kwargs.get('relative_size'),
13                 relative_position=(0, 0),
14                 icon=base_icon,
15                 fill_colour=(0, 0, 0, 0),
16                 border_width=0,
17                 margin=0,
18                 fit_icon=True,
19             ),
20             WidgetState.HOVER: Icon(
21                 parent=kwargs.get('parent'),
22                 relative_size=kwargs.get('relative_size'),
23                 relative_position=(0, 0),
24                 icon=hover_icon,
25                 fill_colour=(0, 0, 0, 0),
26                 border_width=0,
27                 margin=0,
28                 fit_icon=True,
29             ),
30             WidgetState.PRESS: Icon(
31                 parent=kwargs.get('parent'),
32                 relative_size=kwargs.get('relative_size'),
33                 relative_position=(0, 0),
34                 icon=press_icon,
35                 fill_colour=(0, 0, 0, 0),
36             )
37         }
38
39         self.widgets = widgets_dict
40
41         super().__init__(**kwargs)
42
43     def _on_press(self):
44         self._set_state(WidgetState.PRESS)
45
46     def _on_release(self):
47         self._set_state(WidgetState.BASE)
48
49     def _on_hover(self):
50         self._set_state(WidgetState.HOVER)
51
52     def _set_state(self, state):
53         self.widget.state = state
54
55         self.widgets[state].parent = self.widget
56         self.widgets[state].relative_size = self.widget.relative_size
57         self.widgets[state].relative_position = self.widget.relative_position
58         self.widgets[state].icon = self.widget.icon
59         self.widgets[state].fill_colour = self.widget.fill_colour
60         self.widgets[state].border_width = self.widget.border_width
61         self.widgets[state].margin = self.widget.margin
62         self.widgets[state].fit_icon = self.widget.fit_icon
63
64         self.widget.icon = self.widgets[state]
65
66     def _on_update(self):
67         self._set_state(WidgetState.BASE)
68
69     def _on_update(self):
70         self._set_state(WidgetState.BASE)
71
72     def _on_update(self):
73         self._set_state(WidgetState.BASE)
74
75     def _on_update(self):
76         self._set_state(WidgetState.BASE)
77
78     def _on_update(self):
79         self._set_state(WidgetState.BASE)
80
81     def _on_update(self):
82         self._set_state(WidgetState.BASE)
83
84     def _on_update(self):
85         self._set_state(WidgetState.BASE)
86
87     def _on_update(self):
88         self._set_state(WidgetState.BASE)
89
90     def _on_update(self):
91         self._set_state(WidgetState.BASE)
92
93     def _on_update(self):
94         self._set_state(WidgetState.BASE)
95
96     def _on_update(self):
97         self._set_state(WidgetState.BASE)
98
99     def _on_update(self):
100        self._set_state(WidgetState.BASE)
101
102    def _on_update(self):
103        self._set_state(WidgetState.BASE)
104
105    def _on_update(self):
106        self._set_state(WidgetState.BASE)
107
108    def _on_update(self):
109        self._set_state(WidgetState.BASE)
110
111    def _on_update(self):
112        self._set_state(WidgetState.BASE)
113
114    def _on_update(self):
115        self._set_state(WidgetState.BASE)
116
117    def _on_update(self):
118        self._set_state(WidgetState.BASE)
119
120    def _on_update(self):
121        self._set_state(WidgetState.BASE)
122
123    def _on_update(self):
124        self._set_state(WidgetState.BASE)
125
126    def _on_update(self):
127        self._set_state(WidgetState.BASE)
128
129    def _on_update(self):
130        self._set_state(WidgetState.BASE)
131
132    def _on_update(self):
133        self._set_state(WidgetState.BASE)
134
135    def _on_update(self):
136        self._set_state(WidgetState.BASE)
137
138    def _on_update(self):
139        self._set_state(WidgetState.BASE)
140
141    def _on_update(self):
142        self._set_state(WidgetState.BASE)
143
144    def _on_update(self):
145        self._set_state(WidgetState.BASE)
146
147    def _on_update(self):
148        self._set_state(WidgetState.BASE)
149
150    def _on_update(self):
151        self._set_state(WidgetState.BASE)
152
153    def _on_update(self):
154        self._set_state(WidgetState.BASE)
155
156    def _on_update(self):
157        self._set_state(WidgetState.BASE)
158
159    def _on_update(self):
160        self._set_state(WidgetState.BASE)
161
162    def _on_update(self):
163        self._set_state(WidgetState.BASE)
164
165    def _on_update(self):
166        self._set_state(WidgetState.BASE)
167
168    def _on_update(self):
169        self._set_state(WidgetState.BASE)
170
171    def _on_update(self):
172        self._set_state(WidgetState.BASE)
173
174    def _on_update(self):
175        self._set_state(WidgetState.BASE)
176
177    def _on_update(self):
178        self._set_state(WidgetState.BASE)
179
180    def _on_update(self):
181        self._set_state(WidgetState.BASE)
182
183    def _on_update(self):
184        self._set_state(WidgetState.BASE)
185
186    def _on_update(self):
187        self._set_state(WidgetState.BASE)
188
189    def _on_update(self):
190        self._set_state(WidgetState.BASE)
191
192    def _on_update(self):
193        self._set_state(WidgetState.BASE)
194
195    def _on_update(self):
196        self._set_state(WidgetState.BASE)
197
198    def _on_update(self):
199        self._set_state(WidgetState.BASE)
200
201    def _on_update(self):
202        self._set_state(WidgetState.BASE)
203
204    def _on_update(self):
205        self._set_state(WidgetState.BASE)
206
207    def _on_update(self):
208        self._set_state(WidgetState.BASE)
209
210    def _on_update(self):
211        self._set_state(WidgetState.BASE)
212
213    def _on_update(self):
214        self._set_state(WidgetState.BASE)
215
216    def _on_update(self):
217        self._set_state(WidgetState.BASE)
218
219    def _on_update(self):
220        self._set_state(WidgetState.BASE)
221
222    def _on_update(self):
223        self._set_state(WidgetState.BASE)
224
225    def _on_update(self):
226        self._set_state(WidgetState.BASE)
227
228    def _on_update(self):
229        self._set_state(WidgetState.BASE)
230
231    def _on_update(self):
232        self._set_state(WidgetState.BASE)
233
234    def _on_update(self):
235        self._set_state(WidgetState.BASE)
236
237    def _on_update(self):
238        self._set_state(WidgetState.BASE)
239
240    def _on_update(self):
241        self._set_state(WidgetState.BASE)
242
243    def _on_update(self):
244        self._set_state(WidgetState.BASE)
245
246    def _on_update(self):
247        self._set_state(WidgetState.BASE)
248
249    def _on_update(self):
250        self._set_state(WidgetState.BASE)
251
252    def _on_update(self):
253        self._set_state(WidgetState.BASE)
254
255    def _on_update(self):
256        self._set_state(WidgetState.BASE)
257
258    def _on_update(self):
259        self._set_state(WidgetState.BASE)
260
261    def _on_update(self):
262        self._set_state(WidgetState.BASE)
263
264    def _on_update(self):
265        self._set_state(WidgetState.BASE)
266
267    def _on_update(self):
268        self._set_state(WidgetState.BASE)
269
270    def _on_update(self):
271        self._set_state(WidgetState.BASE)
272
273    def _on_update(self):
274        self._set_state(WidgetState.BASE)
275
276    def _on_update(self):
277        self._set_state(WidgetState.BASE)
278
279    def _on_update(self):
280        self._set_state(WidgetState.BASE)
281
282    def _on_update(self):
283        self._set_state(WidgetState.BASE)
284
285    def _on_update(self):
286        self._set_state(WidgetState.BASE)
287
288    def _on_update(self):
289        self._set_state(WidgetState.BASE)
290
291    def _on_update(self):
292        self._set_state(WidgetState.BASE)
293
294    def _on_update(self):
295        self._set_state(WidgetState.BASE)
296
297    def _on_update(self):
298        self._set_state(WidgetState.BASE)
299
299

```

```

35         border_width=0,
36         margin=0,
37         fit_icon=True,
38     )
39 }
40
41     super().__init__(
42         widgets_dict=widgets_dict,
43         **kwargs
44     )

```

### ReactiveButton

The `ReactiveButton` widget is the parent class for `ReactiveIconButton`. It provides the methods for clicking, rotating between widget states, positioning etc.

`reactive_button.py`

```

1  from data.components.custom_event import CustomEvent
2  from data.widgets.bases.pressable import _Pressable
3  from data.widgets.bases.circular import _Circular
4  from data.widgets.bases.widget import _Widget
5  from data.utils.constants import WidgetState
6
7  class ReactiveButton(_Pressable, _Circular, _Widget):
8      def __init__(self, widgets_dict, event, center=False, **kwargs):
9          # Multiple inheritance used here, to combine the functionality of multiple
10         super().__init__(
11             self,
12             event=event,
13             hover_func=lambda: self.set_to_key(WidgetState.HOVER),
14             down_func=lambda: self.set_to_key(WidgetState.PRESS),
15             up_func=lambda: self.set_to_key(WidgetState.BASE),
16             **kwargs
17         )
18         # Aggregation used to cycle between external widgets
19         _Circular.__init__(self, items_dict=widgets_dict)
20         _Widget.__init__(self, **kwargs)
21
22         self._center = center
23
24         self.initialise_new_colours(self._fill_colour)
25
26     @property
27     def position(self):
28         """
29             Overrides position getter method, to always position icon in the center if
30             self._center is True.
31
32             Returns:
33                 list[int, int]: Position of widget.
34         """
35
36         position = super().position
37
38         if self._center:
39             self._size_diff = (self.size[0] - self.rect.width, self.size[1] - self.
40             .rect.height)
41             return (position[0] + self._size_diff[0] / 2, position[1] + self.
42             _size_diff[1] / 2)
43         else:
44             return position

```

```

41     def set_image(self):
42         """
43             Sets current icon to image.
44         """
45         self.current_item.set_image()
46         self.image = self.current_item.image
47
48     def set_geometry(self):
49         """
50             Sets size and position of widget.
51         """
52         super().set_geometry()
53         self.current_item.set_geometry()
54         self.current_item.rect.topleft = self.rect.topleft
55
56     def set_surface_size(self, new_surface_size):
57         """
58             Overrides base method to resize every widget state icon, not just the
59             current one.
60
61             Args:
62                 new_surface_size (list[int, int]): New surface size.
63
64             super().set_surface_size(new_surface_size)
65             for item in self._items_dict.values():
66                 item.set_surface_size(new_surface_size)
67
68     def process_event(self, event):
69         """
70             Processes Pygame events.
71
72             Args:
73                 event (pygame.Event): Event to process.
74
75             Returns:
76                 CustomEvent: CustomEvent of current item, with current key included
77
78             widget_event = super().process_event(event)
79             self.current_item.process_event(event)
80
81             if widget_event:
82                 return CustomEvent(**vars(widget_event), data=self.current_key)

```

## ColourSlider

The ColourSlider widget is instanced in the ColourPicker class. It provides a slider for changing between hues for the colour picker, using the functionality of the SliderThumb class.

### colour\_slider.py

```

1 import pygame
2 from data.helpers.widget_helpers import create_slider_gradient
3 from data.helpers.asset_helpers import smoothscale_and_cache
4 from data.widgets.slider_thumb import _SliderThumb
5 from data.widgets.bases.widget import _Widget
6 from data.utils.constants import WidgetState
7
8 class _ColourSlider(_Widget):
9     def __init__(self, relative_width, **kwargs):
10         super().__init__(relative_size=(relative_width, relative_width * 0.2), **
11                         kwargs)

```

```

11      # Initialise slider thumb.
12      self._thumb = _SliderThumb(radius=self.size[1] / 2, border_colour=self.
13      _border_colour)
14
15      self._selected_percent = 0
16      self._last_mouse_x = None
17
18      self._gradient_surface = create_slider_gradient(self.gradient_size, self.
19      border_width, self._border_colour)
20      self._empty_surface = pygame.Surface(self.size, pygame.SRCALPHA)
21
22      @property
23      def gradient_size(self):
24          return (self.size[0] - 2 * (self.size[1] / 2), self.size[1] / 2)
25
26      @property
27      def gradient_position(self):
28          return (self.size[1] / 2, self.size[1] / 4)
29
30      @property
31      def thumb_position(self):
32          return (self.gradient_size[0] * self._selected_percent, 0)
33
34      @property
35      def selected_colour(self):
36          colour = pygame.Color(0)
37          colour.hsva = (int(self._selected_percent * 360), 100, 100, 100)
38
39      def calculate_gradient_percent(self, mouse_pos):
40          """
41              Calculate what percentage slider thumb is at based on change in mouse
42              position.
43
44          Args:
45              mouse_pos (list[int, int]): Position of mouse on window screen.
46
47          Returns:
48              float: Slider scroll percentage.
49
50          if self._last_mouse_x is None:
51              return
52
53          x_change = (mouse_pos[0] - self._last_mouse_x) / (self.gradient_size[0] -
54          2 * self.border_width)
55          return max(0, min(self._selected_percent + x_change, 1))
56
57      def relative_to_global_position(self, position):
58          """
59              Transforms position from being relative to widget rect, to window screen.
60
61          Args:
62              position (list[int, int]): Position relative to widget rect.
63
64          Returns:
65              list[int, int]: Position relative to window screen.
66
67          relative_x, relative_y = position
68          return (relative_x + self.position[0], relative_y + self.position[1])
69
70      def set_colour(self, new_colour):

```

```

69     """
70     Sets selected_percent based on the new colour's hue.
71
72     Args:
73         new_colour (pygame.Color): New slider colour.
74     """
75     colour = pygame.Color(new_colour)
76     hue = colour.hsva[0]
77     self._selected_percent = hue / 360
78     self.set_image()
79
80     def set_image(self):
81         """
82         Draws colour slider to widget image.
83
84         # Scales initialised gradient surface instead of redrawing it everytime
85         # set_image is called
86         gradient_scaled = smoothscale_and_cache(self._gradient_surface, self.
87             gradient_size)
88
89         self.image = pygame.transform.scale(self._empty_surface, (self.size))
90         self.image.blit(gradient_scaled, self.gradient_position)
91
92         # Resets thumb colour, image and position, then draws it to the widget
93         # image
94         self._thumb.initialise_new_colours(self.selected_colour)
95         self._thumb.set_surface(radius=self.size[1] / 2, border_width=self.
96             border_width)
97         self._thumb.set_position(self.relative_to_global_position((self.
98             thumb_position[0], self.thumb_position[1])))
99
100        thumb_surface = self._thumb.get_surface()
101        self.image.blit(thumb_surface, self.thumb_position)
102
103    def process_event(self, event):
104        """
105        Processes Pygame events.
106
107        Args:
108            event (pygame.Event): Event to process.
109
110        Returns:
111            pygame.Color: Current colour slider is displaying.
112
113        if event.type not in [pygame.MOUSEMOTION, pygame.MOUSEBUTTONDOWN, pygame.
114            MOUSEBUTTONUP]:
115            return
116
117            # Gets widget state before and after event is processed by slider thumb
118            before_state = self._thumb.state
119            self._thumb.process_event(event)
120            after_state = self._thumb.state
121
122            # If widget state changes (e.g. hovered -> pressed), redraw widget
123            if before_state != after_state:
124                self.set_image()
125
126            if event.type == pygame.MOUSEMOTION:
127                if self._thumb.state == WidgetState.PRESS:
128                    # Recalculates slider colour based on mouse position change
129                    selected_percent = self.calculate_gradient_percent(event.pos)
130                    self._last_mouse_x = event.pos[0]

```

```

125
126     if selected_percent is not None:
127         self._selected_percent = selected_percent
128
129     return self.selected_colour
130
131     if event.type == pygame.MOUSEBUTTONUP:
132         # When user stops scrolling, return new slider colour
133         self._last_mouse_x = None
134         return self.selected_colour
135
136     if event.type == pygame.MOUSEBUTTONDOWN or before_state != after_state:
137         # Redraws widget when slider thumb is hovered or pressed
138         return self.selected_colour

```

### TextInput

The TextInput widget is used for inputting fen strings and time controls.  
text\_input.py

```

1 import pyperclip
2 import pygame
3 from data.utils.constants import WidgetState, INPUT_COLOURS
4 from data.components.custom_event import CustomEvent
5 from data.widgets.bases.pressable import _Pressable
6 from data.managers.logs import initialise_logger
7 from data.managers.animation import animation
8 from data.widgets.bases.box import _Box
9 from data.utils.enums import CursorMode
10 from data.managers.cursor import cursor
11 from data.managers.theme import theme
12 from data.widgets.text import Text
13
14 logger = initialise_logger(__name__)
15
16 class TextInput(_Box, _Pressable, Text):
17     def __init__(self, event, blinking_interval=530, validator=(lambda x: True),
18                  default='', placeholder='PLACEHOLDER TEXT', placeholder_colour=(200, 200, 200),
19                  cursor_colour=theme['textSecondary'], **kwargs):
20         self._cursor_index = None
21         # Multiple inheritance used here, adding the functionality of pressing,
22         # and custom box colours, to the text widget
23         _Box.__init__(self, box_colours=INPUT_COLOURS)
24         _Pressable.__init__(
25             self,
26             event=None,
27             hover_func=lambda: self.set_state_colour(WidgetState.HOVER),
28             down_func=lambda: self.set_state_colour(WidgetState.PRESS),
29             up_func=lambda: self.set_state_colour(WidgetState.BASE),
30             sfx=None
31         )
32         Text.__init__(self, text="", center=False, box_colours=INPUT_COLOURS[
33             WidgetState.BASE], **kwargs)
34
35         self.initialise_new_colours(self._fill_colour)
36         self.set_state_colour(WidgetState.BASE)
37
38         pygame.key.set_repeat(500, 50)
39
40         self._blinking_fps = 1000 / blinking_interval
41         self._cursor_colour = cursor.colour

```

```

38         self._cursor_colour_copy = cursor_colour
39         self._placeholder_colour = placeholder_colour
40         self._text_colour_copy = self._text_colour
41
42         self._placeholder_text = placeholder
43         self._is_placeholder = None
44         if default:
45             self._text = default
46             self.is_placeholder = False
47         else:
48             self._text = self._placeholder_text
49             self.is_placeholder = True
50
51         self._event = event
52         self._validator = validator
53         self._blinking_cooldown = 0
54
55         self._empty_cursor = pygame.Surface((0, 0), pygame.SRCALPHA)
56
57         self.resize_text()
58         self.set_image()
59         self.set_geometry()
60
61     @property
62     # Encapsulated getter method
63     def is_placeholder(self):
64         return self._is_placeholder
65
66     @is_placeholder.setter
67     # Encapsulated setter method, used to replace text colour if placeholder text
68     # is shown
69     def is_placeholder(self, is_true):
70         self._is_placeholder = is_true
71
72         if is_true:
73             self._text_colour = self._placeholder_colour
74         else:
75             self._text_colour = self._text_colour_copy
76
77     @property
78     def cursor_size(self):
79         cursor_height = (self.size[1] - self.border_width * 2) * 0.75
80         return (cursor_height * 0.1, cursor_height)
81
82     @property
83     def cursor_position(self):
84         current_width = (self.margin / 2)
85         for index, metrics in enumerate(self._font.get_metrics(self._text, size=
86             self.font_size)):
87             if index == self._cursor_index:
88                 return (current_width - self.cursor_size[0], (self.size[1] - self.
89                     cursor_size[1]) / 2)
90
91         glyph_width = metrics[4]
92         current_width += glyph_width
93     return (current_width - self.cursor_size[0], (self.size[1] - self.
94                     cursor_size[1]) / 2)
95
96     @property
97     def text(self):
98         if self.is_placeholder:
99             return ''

```

```

96         return self._text
97
98     def relative_x_to_cursor_index(self, relative_x):
99         """
100             Calculates cursor index using mouse position relative to the widget
101             position.
102
103             Args:
104                 relative_x (int): Horizontal distance of the mouse from the left side
105                 of the widget.
106
107             Returns:
108                 int: Cursor index.
109
110             current_width = 0
111
112             for index, metrics in enumerate(self._font.get_metrics(self._text, size=
113                                         self.font_size)):
113                 glyph_width = metrics[4]
114
115                 if current_width >= relative_x:
116                     return index
117
118                 current_width += glyph_width
119
120             return len(self._text)
121
122     def set_cursor_index(self, mouse_pos):
123         """
124             Sets cursor index based on mouse position.
125
126             Args:
127                 mouse_pos (list[int, int]): Mouse position relative to window screen.
128
129             if mouse_pos is None:
130                 self._cursor_index = mouse_pos
131                 return
132
133             relative_x = mouse_pos[0] - (self.margin / 2) - self.rect.left
134             relative_x = max(0, relative_x)
135             self._cursor_index = self.relative_x_to_cursor_index(relative_x)
136
137     def focus_input(self, mouse_pos):
138         """
139             Draws cursor and sets cursor index when user clicks on widget.
140
141             Args:
142                 mouse_pos (list[int, int]): Mouse position relative to window screen.
143
144             if self.is_placeholder:
145                 self._text = ''
146                 self.is_placeholder = False
147
148             self.set_cursor_index(mouse_pos)
149             self.set_image()
150             cursor.set_mode(CursorMode.IBEAM)
151
152     def unfocus_input(self):
153         """
154             Removes cursor when user unselects widget.

```

```

155         if self._text == '':
156             self._text = self._placeholder_text
157             self.is_placeholder = True
158             self.resize_text()
159
160         self.set_cursor_index(None)
161         self.set_image()
162         cursor.set_mode(CursorMode.ARROW)
163
164     def set_text(self, new_text):
165         """
166             Called by a state object to change the widget text externally.
167
168         Args:
169             new_text (str): New text to display.
170
171         Returns:
172             CustomEvent: Object containing the new text to alert state of a text
173             update.
174
175         super().set_text(new_text)
176         return CustomEvent(**vars(self._event), text=self.text)
177
178     def process_event(self, event):
179         """
180         Processes Pygame events.
181
182         Args:
183             event (pygame.Event): Event to process.
184
185         Returns:
186             CustomEvent: Object containing the new text to alert state of a text
187             update.
188
189         previous_state = self.get_widget_state()
190         super().process_event(event)
191         current_state = self.get_widget_state()
192
193         match event.type:
194             case pygame.MOUSEMOTION:
195                 if self._cursor_index is None:
196                     return
197
198                     # If mouse is hovering over widget, turn mouse cursor into an I-
199                     beam
200                     if self.rect.collidepoint(event.pos):
201                         if cursor.get_mode() != CursorMode.IBEAM:
202                             cursor.set_mode(CursorMode.IBEAM)
203
204                     else:
205                         if cursor.get_mode() == CursorMode.IBEAM:
206                             cursor.set_mode(CursorMode.ARROW)
207
208                     return
209
210             case pygame.MOUSEBUTTONUP:
211                 # When user selects widget
212                 if previous_state == WidgetState.PRESS:
213                     self.focus_input(event.pos)
214
215                 # When user unselects widget
216                 if current_state == WidgetState.BASE and self._cursor_index is not
217                     None:
218                     self.unfocus_input()

```

```

213             return CustomEvent(**vars(self._event), text=self.text)
214
215         case pygame.KEYDOWN:
216             if self._cursor_index is None:
217                 return
218
219             # Handling Ctrl-C and Ctrl-V shortcuts
220             if event.mod & (pygame.KMOD_CTRL):
221                 if event.key == pygame.K_c:
222                     pyperclip.copy(self.text)
223                     logger.info(f'COPIED {self.text}')
224
225                 elif event.key == pygame.K_v:
226                     pasted_text = pyperclip.paste()
227                     pasted_text = ''.join(char for char in pasted_text if 32
228                         <= ord(char) <= 127)
229                     self._text = self._text[:self._cursor_index] + pasted_text
230                     + self._text[self._cursor_index:]
231                     self._cursor_index += len(pasted_text)
232
233             elif event.key == pygame.K_BACKSPACE or event.key == pygame.
234 K_DELETE:
235                 self._text = ''
236                 self._cursor_index = 0
237
238                 self.resize_text()
239                 self.set_image()
240                 self.set_geometry()
241
242             match event.key:
243                 case pygame.K_BACKSPACE:
244                     if self._cursor_index > 0:
245                         self._text = self._text[:self._cursor_index - 1] +
246                         self._text[self._cursor_index:]
247                         self._cursor_index = max(0, self._cursor_index - 1)
248
249                 case pygame.K_RIGHT:
250                     self._cursor_index = min(len(self._text), self.
251 _cursor_index + 1)
252
253                 case pygame.K_LEFT:
254                     self._cursor_index = max(0, self._cursor_index - 1)
255
256                 case pygame.K_ESCAPE:
257                     self.unfocus_input()
258                     return CustomEvent(**vars(self._event), text=self.text)
259
260                 case pygame.K_RETURN:
261                     self.unfocus_input()
262                     return CustomEvent(**vars(self._event), text=self.text)
263
264             case _:
265                 if not event.unicode:
266                     return
267
268                 potential_text = self._text[:self._cursor_index] + event.
269                 unicode + self._text[self._cursor_index:]
270
271                     # Validator lambda function used to check if inputted text
272                     # is valid before displaying

```

```

268             # e.g. Time control input has a validator function
269             checking if text represents a float
270             if self._validator(potential_text) is False:
271                 return
272
273             self._text = potential_text
274             self._cursor_index += 1
275
276             self._blinking_cooldown += 1
277             animation.set_timer(500, lambda: self.subtract_blinking_cooldown
278             (1))
279
280             self.resize_text()
281             self.set_image()
282             self.set_geometry()
283
284     def subtract_blinking_cooldown(self, cooldown):
285         """
286             Subtracts blinking cooldown after certain timeframe. When
287             blinking_cooldown is 1, cursor is able to be drawn.
288
289             Args:
290                 cooldown (float): Duration before cursor can no longer be drawn.
291
292             self._blinking_cooldown = self._blinking_cooldown - cooldown
293
294     def set_image(self):
295         """
296
297             Draws text input widget to image.
298
299             super().set_image()
300
301
302     def update(self):
303         """
304             Overrides based update method, to handle cursor blinking.
305
306             super().update()
307             # Calculate if cursor should be shown or not
308             cursor_frame = animation.calculate_frame_index(0, 2, self._blinking_fps)
309             if cursor_frame == 1 and self._blinking_cooldown == 0:
310                 self._cursor_colour = (0, 0, 0, 0)
311             else:
312                 self._cursor_colour = self._cursor_colour_copy
313             self.set_image()

```

## 3.5 Game

### 3.5.1 Model

As described in Section 2.4, this is the model class for my implementation of a **MVC architecture** for the game screen. It is responsible for processing user inputs through the game controller, processing the board and CPU, and sending information through the view class.

`game_model.py`

```

1 from random import getrandbits
2 from data.states.game.components.fen_parser import encode_fen_string
3 from data.states.game.widget_dict import GAME_WIDGETS
4 from data.states.game.cpu.cpu_thread import CPUThread
5 from data.components.custom_event import CustomEvent
6 from data.helpers.bitboard_helpers import is_occupied
7 from data.helpers import input_helpers as ip_helpers
8 from data.states.game.components.board import Board
9 from data.states.game.components.move import Move
10 from data.utils.event_types import GameEventType
11 from data.managers.logs import initialise_logger
12 from data.managers.animation import animation
13 from data.states.game.cpu.engines import *
14 from data.utils.constants import EMPTY_BB
15 from data.utils.enums import Colour
16
17 logger = initialise_logger(__name__)
18
19 # TEMP
20 CPU_LIMIT_MS = 1500000
21
22 class GameModel:
23     def __init__(self, game_config):
24         self._listeners = {
25             'game': [],
26             'win': [],
27             'pause': []
28         }
29         self.states = {
30             'CPU_ENABLED': game_config['CPU_ENABLED'],
31             'CPU_DEPTH': game_config['CPU_DEPTH'],
32             'AWAITING_CPU': False,
33             'WINNER': None,
34             'PAUSED': False,
35             'ACTIVE_COLOUR': game_config['COLOUR'],
36             'TIME_ENABLED': game_config['TIME_ENABLED'],
37             'TIME': game_config['TIME'],
38             'START_FEN_STRING': game_config['FEN_STRING'],
39             'MOVES': [],
40             'ZOBRIST_KEYS': []
41         }
42
43         self._board = Board(fen_string=game_config['FEN_STRING'])
44
45         self._cpu = IDMinimaxCPU(self.states['CPU_DEPTH'], self.cpu_callback,
46                                   verbose=False)
47         self._cpu_thread = CPUThread(self._cpu)
48         self._cpu_thread.start()
49         self._cpu_move = None
50
51         logger.info(f'Initialising CPU depth of {self.states["CPU_DEPTH"]}')
52
53     def register_listener(self, listener, parent_class):
54         """
55             Registers listener method of another MVC class.
56
57             Args:
58                 listener (callable): Listener callback function.
59                 parent_class (str): Class name.
56
59         self._listeners[parent_class].append(listener)
60
61

```

```

62     def alert_listeners(self, event):
63         """
64             Alerts all registered classes of an event by calling their listener
65             function.
66
67             Args:
68                 event (GameEventType): Event to pass as argument.
69
70             Raises:
71                 Exception: If an unrecognised event tries to be passed onto listeners.
72             """
73         for parent_class, listeners in self._listeners.items():
74             match event.type:
75                 case GameEventType.UPDATE_PIECES:
76                     if parent_class in 'game':
77                         for listener in listeners: listener(event)
78
79                 case GameEventType.SET_LASER:
80                     if parent_class == 'game':
81                         for listener in listeners: listener(event)
82
83                 case GameEventType.PAUSE_CLICK:
84                     if parent_class in ['pause', 'game']:
85                         for listener in listeners:
86                             listener(event)
87
88                 case _:
89                     raise Exception('Unhandled event type (GameModel.alert_listeners)')
90
91     def set_winner(self, colour=None):
92         """
93             Sets winner.
94
95             Args:
96                 colour (Colour, optional): Describes winner colour, or draw. Defaults
97                 to None.
98
99             self.states['WINNER'] = colour
100
101     def toggle_paused(self):
102         """
103             Toggles pause screen, and alerts pause view.
104
105             self.states['PAUSED'] = not self.states['PAUSED']
106             game_event = CustomEvent.create_event(GameEventType.PAUSE_CLICK)
107             self.alert_listeners(game_event)
108
109     def get_terminal_move(self):
110         """
111             Debugging method for inputting a move from the terminal.
112
113             Returns:
114                 Move: Parsed move.
115
116             while True:
117                 try:
118                     move_type = ip_helpers.parse_move_type(input('Input move type (m/r
119 ): '))
119                     src_square = ip_helpers.parse_notation(input("From: "))
120                     dest_square = ip_helpers.parse_notation(input("To: "))
121                     rotation = ip_helpers.parse_rotation(input("Enter rotation (a/b/c/

```

```

d): ""))
    return Move.instance_from_notation(move_type, src_square,
dest_square, rotation)
except ValueError as error:
    logger.warning('Input error (Board.get_move): ' + str(error))

123
124 def make_move(self, move):
125 """
126     Takes a Move object and applies it to the board.
127
128     Args:
129         move (Move): Move to apply.
130
131     colour = self._board.bitboards.get_colour_on(move.src)
132     piece = self._board.bitboards.get_piece_on(move.src, colour)
133     # Apply move and get results of laser trajectory
134     laser_result = self._board.apply_move(move, add_hash=True)
135
136     self.alert_listeners(CustomEvent.create_event(GameEventType.SET_LASER,
laser_result=laser_result))
137
138     # Sets new active colour and checks for a win
139     self.states['ACTIVE_COLOUR'] = self._board.get_active_colour()
140     self.set_winner(self._board.check_win())
141
142     move_notation = move.to_notation(colour, piece, laser_result.
hit_square_bitboard)
143
144     self.alert_listeners(CustomEvent.create_event(GameEventType.UPDATE_PIECES,
move_notation=move_notation))
145
146     # Adds move to move history list for review screen
147     self.states['MOVES'].append({
148         'time': {
149             Colour.BLUE: GAME_WIDGETS['blue_timer'].get_time(),
150             Colour.RED: GAME_WIDGETS['red_timer'].get_time()
151         },
152         'move': move_notation,
153         'laserResult': laser_result
154     })
155
156 def make_cpu_move(self):
157 """
158     Starts CPU calculations on the separate thread.
159
160     self.states['AWAITING_CPU'] = True
161
162     # Employ time management system to kill search if using an iterative
deepening CPU
163     # if isinstance(self._cpu, IDMinimaxCPU):
164     #     move_id = getrandbits(32)
165     #     self._cpu_thread.start_cpu(self.get_board(), id=move_id)
166     #     animation.set_timer(CPU_LIMIT_MS, lambda: self._cpu_thread.stop_cpu(
id=move_id))
167     # else:
168     #     self._cpu_thread.start_cpu(self.get_board())
169
170 def cpu_callback(self, move):
171 """
172     Callback function passed to CPU thread. Called when CPU stops processing.
173
174     Args:

```

```

175         move (Move): Move that CPU found.
176         """
177     if self.states['WINNER'] is None:
178         # CPU move passed back to main thread by reassigning variable
179         self._cpu_move = move
180         self.states['AWAITING_CPU'] = False
181
182     def check_cpu(self):
183         """
184             Constantly checks if CPU calculations are finished, so that make_move can
185             be run on the main thread.
186         """
187         if self._cpu_move is not None:
188             self.make_move(self._cpu_move)
189             self._cpu_move = None
190
191     def kill_thread(self):
192         """
193             Interrupt and kill CPU thread.
194         """
195         self._cpu_thread.kill_thread()
196         self.states['AWAITING_CPU'] = False
197
198     def is_selectable(self, bitboard):
199         """
200             Checks if square is occupied by a piece of the current active colour.
201
202         Args:
203             bitboard (int): Bitboard representing single square.
204
205         Returns:
206             bool: True if square is occupied by a piece of the current active
207             colour. False if not.
208         """
209         return is_occupied(self._board.bitboards.combined_colour_bitboards[self.
210                         states['ACTIVE_COLOUR']], bitboard)
211
212     def get_available_moves(self, bitboard):
213         """
214             Gets all surrounding empty squares. Used for drawing overlay.
215
216         Args:
217             bitboard (int): Bitboard representing single center square.
218
219         Returns:
220             int: Bitboard representing all empty surrounding squares.
221
222         if (bitboard & self._board.get_all_active_pieces()) != EMPTY_BB:
223             return self._board.get_valid_squares(bitboard)
224
225         return EMPTY_BB
226
227     def get_piece_list(self):
228         """
229
230         Returns:
231             list[Piece, ...]: Array of all pieces on the board.
232         """
233         return self._board.get_piece_list()
234
235     def get_piece_info(self, bitboard):
236         """
237
238         Args:

```

```

234         bitboard (int): Square containing piece.
235
236     Returns:
237         tuple[Colour, Rotation, Piece]: Piece information.
238     """
239     colour = self._board.bitboards.get_colour_on(bitboard)
240     rotation = self._board.bitboards.get_rotation_on(bitboard)
241     piece = self._board.bitboards.get_piece_on(bitboard, colour)
242     return (piece, colour, rotation)
243
244     def get_fen_string(self):
245         return encode_fen_string(self._board.bitboards)
246
247     def get_board(self):
248         return self._board

```

### 3.5.2 View

As described in Section 2.4, the view class is responsible for displaying changes to information regarding the gameplay. The `process_model_event` procedure is registered with the model class, which executes it whenever the display needs to be updated (e.g. piece move), and the appropriate handling function within the view class is called by mapping the event type to the corresponding handler function.

`game_view.py`

```

1  import pygame
2  from data.utils.enums import Colour, StatusText, Miscellaneous, ShaderType
3  from data.states.game.components.overlay_draw import OverlayDraw
4  from data.states.game.components.capture_draw import CaptureDraw
5  from data.states.game.components.piece_group import PieceGroup
6  from data.states.game.components.laser_draw import LaserDraw
7  from data.states.game.components.father import DragAndDrop
8  from data.helpers.bitboard_helpers import bitboard_to_coords
9  from data.helpers.board_helpers import screen_pos_to_coords
10 from data.states.game.widget_dict import GAME_WIDGETS
11 from data.components.custom_event import CustomEvent
12 from data.components.widget_group import WidgetGroup
13 from data.utils.event_types import GameEventType
14 from data.managers.window import window
15 from data.managers.audio import audio
16 from data.utils.assets import SFX
17
18 class GameView:
19     def __init__(self, model):
20         self._model = model
21         self._hide_pieces = False
22         self._selected_coords = None
23         self._event_to_func_map = {
24             GameEventType.UPDATE_PIECES: self.handle_update_pieces,
25             GameEventType.SET LASER: self.handle_set_laser,
26             GameEventType.PAUSE_CLICK: self.handle_pause,
27         }
28
29     # Register model event handling with process_model_event()
30     self._model.register_listener(self.process_model_event, 'game')
31
32     # Initialise WidgetGroup with map of widgets
33     self._widget_group = WidgetGroup(GAME_WIDGETS)
34     self._widget_group.handle_resize(window.size)
35     self.initialise_widgets()

```

```

36
37         self._laser_draw = LaserDraw(self.board_position, self.board_size)
38         self._overlay_draw = OverlayDraw(self.board_position, self.board_size)
39         self._drag_and_drop = DragAndDrop(self.board_position, self.board_size)
40         self._capture_draw = CaptureDraw(self.board_position, self.board_size)
41         self._piece_group = PieceGroup()
42         self.handle_update_pieces()
43
44         self.set_status_text(StatusText.PLAYER_MOVE)
45
46     @property
47     def board_position(self):
48         return GAME_WIDGETS['chessboard'].position
49
50     @property
51     def board_size(self):
52         return GAME_WIDGETS['chessboard'].size
53
54     @property
55     def square_size(self):
56         return self.board_size[0] / 10
57
58     def initialise_widgets(self):
59         """
60             Run methods on widgets stored in GAME_WIDGETS dictionary to reset them.
61         """
62         GAME_WIDGETS['move_list'].reset_move_list()
63         GAME_WIDGETS['move_list'].kill()
64         GAME_WIDGETS['help'].kill()
65         GAME_WIDGETS['tutorial'].kill()
66
67         GAME_WIDGETS['scroll_area'].set_image()
68
69         GAME_WIDGETS['chessboard'].refresh_board()
70
71         GAME_WIDGETS['blue_piece_display'].reset_piece_list()
72         GAME_WIDGETS['red_piece_display'].reset_piece_list()
73
74     def set_status_text(self, status):
75         """
76             Sets text on status text widget.
77
78             Args:
79                 status (StatusText): The game stage for which text should be displayed
80             for.
81         """
82
83         match status:
84             case StatusText.PLAYER_MOVE:
85                 GAME_WIDGETS['status_text'].set_text(f"{self._model.states['ACTIVE_COLOUR'].name}'s turn to move")
86             case StatusText.CPU_MOVE:
87                 GAME_WIDGETS['status_text'].set_text("CPU thinking...") # CPU
88             calculating a crazy move...
89             case StatusText.WIN:
90                 if self._model.states['WINNER'] == Miscellaneous.DRAW:
91                     GAME_WIDGETS['status_text'].set_text("Game is a draw! Boring
92             ...")
93             else:
94                 GAME_WIDGETS['status_text'].set_text(f"{self._model.states['WINNER'].name} won!")
95             case StatusText.DRAW:
96                 GAME_WIDGETS['status_text'].set_text("Game is a draw! Boring...")

```

```

93
94     def handle_resize(self):
95         """
96             Handles resizing of the window.
97         """
98         self._overlay_draw.handle_resize(self.board_position, self.board_size)
99         self._capture_draw.handle_resize(self.board_position, self.board_size)
100        self._piece_group.handle_resize(self.board_position, self.board_size)
101        self._laser_draw.handle_resize(self.board_position, self.board_size)
102        self._laser_draw.handle_resize(self.board_position, self.board_size)
103        self._widget_group.handle_resize(window.size)
104
105        if self._laser_draw.firing:
106            self.update_laser_mask()
107
108    def handle_update_pieces(self, event=None):
109        """
110            Callback function to update pieces after move.
111
112            Args:
113                event (GameEventType, optional): If updating pieces after player move,
114                    event contains move information. Defaults to None.
115                toggle_timers (bool, optional): Toggle timers on and off for new
116                    active colour. Defaults to True.
117
118            """
119        piece_list = self._model.get_piece_list()
120        self._piece_group.initialise_pieces(piece_list, self.board_position, self.
121            board_size)
122
123        if event:
124            GAME_WIDGETS['move_list'].append_to_move_list(event.move_notation)
125            GAME_WIDGETS['scroll_area'].set_image()
126            audio.play_sfx(SFX['piece_move'])
127
128            # If active colour is starting colour, as player always moves first
129            if ['b', 'r'][self._model.states['ACTIVE_COLOUR']] == self._model.states['
130                START_FEN_STRING'][-1]:
131                self.set_status_text(StatusText.PLAYER_MOVE)
132            else:
133                if self._model.states['CPU_ENABLED']:
134                    self.set_status_text(StatusText.CPU_MOVE)
135                else:
136                    self.set_status_text(StatusText.PLAYER_MOVE)
137
138        if self._model.states['TIME_ENABLED']:
139            self.toggle_timer(self._model.states['ACTIVE_COLOUR'], True)
140            self.toggle_timer(self._model.states['ACTIVE_COLOUR'].get_flipped_colour(),
141                False)
142
143        if self._model.states['WINNER'] is not None:
144            self.handle_game_end()
145
146        # Update occlusion mask for rays shader with new piece positions
147        self.update_laser_mask()
148
149    def handle_game_end(self, play_sfx=True):
150        self.toggle_timer(self._model.states['ACTIVE_COLOUR'], False)
151        self.toggle_timer(self._model.states['ACTIVE_COLOUR'].get_flipped_colour()
152            , False)
153
154        if self._model.states['WINNER'] == Miscellaneous.DRAW:
155            self.set_status_text(StatusText.DRAW)

```

```

149         else:
150             self.set_status_text(StatusText.WIN)
151
152     if play_sfx:
153         audio.play_sfx(SFX['sphinx_destroy_1'])
154         audio.play_sfx(SFX['sphinx_destroy_2'])
155         audio.play_sfx(SFX['sphinx_destroy_3'])
156
157     def handle_set_laser(self, event):
158         """
159             Callback function to draw laser after move.
160
161             Args:
162                 event (GameEventType): Contains laser trajectory information.
163             """
164
165     laser_result = event.laser_result
166
167     # If laser has hit a piece
168     if laser_result.hit_square_bitboard:
169         coords_to_remove = bitboard_to_coords(laser_result.hit_square_bitboard)
170
171         self._piece_group.remove_piece(coords_to_remove)
172
173         if laser_result.piece_colour == Colour.BLUE:
174             GAME_WIDGETS['red_piece_display'].add_piece(laser_result.piece_hit)
175
176         elif laser_result.piece_colour == Colour.RED:
177             GAME_WIDGETS['blue_piece_display'].add_piece(laser_result.piece_hit)
178
179         # Draw piece capture GFX
180         self._capture_draw.add_capture(
181             laser_result.piece_hit,
182             laser_result.piece_colour,
183             laser_result.piece_rotation,
184             coords_to_remove,
185             laser_result.laser_path[0][0],
186             self._model.states['ACTIVE_COLOUR']
187         )
188
189         self._laser_draw.add_laser(laser_result, self._model.states['ACTIVE_COLOUR'])
190
191     def handle_pause(self, event=None):
192         """
193             Callback function for pausing timer.
194
195             Args:
196                 event (None): Event argument not used.
197             """
198
199     is_active = not(self._model.states['PAUSED'])
200     self.toggle_timer(self._model.states['ACTIVE_COLOUR'], is_active)
201
202     def initialise_timers(self):
203         """
204             Initialises both timers with the correct amount of time and starts the
205             timer for the active colour.
206             """
207
208         if self._model.states['TIME_ENABLED']:
209             GAME_WIDGETS['blue_timer'].set_time(self._model.states['TIME'] * 60 *
210             1000)
211             GAME_WIDGETS['red_timer'].set_time(self._model.states['TIME'] * 60 *
212             1000)

```

```

1000)
205     else:
206         GAME_WIDGETS['blue_timer'].kill()
207         GAME_WIDGETS['red_timer'].kill()
208
209     self.toggle_timer(self._model.states['ACTIVE_COLOUR'], True)
210
211 def toggle_timer(self, colour, is_active):
212     """
213     Stops or resumes timer.
214
215     Args:
216         colour (Colour): Timer to toggle.
217         is_active (bool): Whether to pause or resume timer.
218     """
219
220     if colour == Colour.BLUE:
221         GAME_WIDGETS['blue_timer'].set_active(is_active)
222     elif colour == Colour.RED:
223         GAME_WIDGETS['red_timer'].set_active(is_active)
224
225 def update_laser_mask(self):
226     """
227     Uses pygame.mask to create a mask for the pieces.
228     Used for occluding the ray shader.
229     """
230
231     temp_surface = pygame.Surface(window.size, pygame.SRCALPHA)
232     self._piece_group.draw(temp_surface)
233     mask = pygame.mask.from_surface(temp_surface, threshold=127)
234     mask_surface = mask.to_surface(unsetColor=(0, 0, 0, 255), setColor=(255,
235     0, 0, 255))
236
237     window.set_apply_arguments(ShaderType.RAYS, occlusion=mask_surface)
238
239 def draw(self):
240     """
241     Draws GUI and pieces onto the screen.
242
243     self._widget_group.update()
244     self._capture_draw.update()
245
246     self._widget_group.draw()
247     self._overlay_draw.draw(window.screen)
248
249     if self._hide_pieces is False:
250         self._piece_group.draw(window.screen)
251
252     self._laser_draw.draw(window.screen)
253     self._drag_and_drop.draw(window.screen)
254     self._capture_draw.draw(window.screen)
255
256 def process_model_event(self, event):
257     """
258     Registered listener function for handling GameModel events.
259     Each event is mapped to a callback function, and the appropriate one is run
260
261     Args:
262         event (GameEventType): Game event to process.
263
264     Raises:
265         KeyError: If an unrecognised event type is passed as the argument.
266     """

```

```

264     try:
265         self._event_to_func_map.get(event.type)(event)
266     except:
267         raise KeyError('Event type not recognized in Game View (GameView.
process_model_event):', event.type)
268
269     def set_overlay_coords(self, available_coords_list, selected_coord):
270         """
271             Set board coordinates for potential moves overlay.
272
273         Args:
274             available_coords_list (list[tuple[int, int]], ...): Array of
275             coordinates
276             selected_coord (list[int, int]): Coordinates of selected piece.
277
278         self._selected_coords = selected_coord
279         self._overlay_draw.set_selected_coords(selected_coord)
280         self._overlay_draw.set_available_coords(available_coords_list)
281
282     def get_selected_coords(self):
283         return self._selected_coords
284
285     def set_dragged_piece(self, piece, colour, rotation):
286         """
287             Passes information of the dragged piece to the dragging drawing class.
288
289         Args:
290             piece (Piece): Piece type of dragged piece.
291             colour (Colour): Colour of dragged piece.
292             rotation (Rotation): Rotation of dragged piece.
293
294         self._drag_and_drop.set_dragged_piece(piece, colour, rotation)
295
296     def remove_dragged_piece(self):
297         """
298             Stops drawing dragged piece when user lets go of piece.
299
300         self._drag_and_drop.remove_dragged_piece()
301
302     def convert_mouse_pos(self, event):
303         """
304             Passes information of what mouse cursor is interacting with to a
305             GameController object.
306
307         Args:
308             event (pygame.Event): Mouse event to process.
309
310         Returns:
311             CustomEvent | None: Contains information what mouse is doing.
312
313         clicked_coords = screen_pos_to_coords(event.pos, self.board_position, self.
314             .board_size)
315
316         if event.type == pygame.MOUSEBUTTONDOWN:
317             if clicked_coords:
318                 return CustomEvent.create_event(GameEventType.BOARD_CLICK, coords=
319                     clicked_coords)
320
321         else:
322             return None
323
324         elif event.type == pygame.MOUSEBUTTONUP:

```

```

321         if self._drag_and_drop.dragged_sprite:
322             piece, colour, rotation = self._drag_and_drop.get_dragged_info()
323             piece_dragged = self._drag_and_drop.remove_dragged_piece()
324             return CustomEvent.create_event(GameEventType.PIECE_DROP, coords=
325             clicked_coords, piece=piece, colour=colour, rotation=rotation, remove_overlay=
326             piece_dragged)
327
328     def add_help_screen(self):
329         """
330             Draw help overlay when player clicks on the help button.
331         """
332         self._widget_group.add(GAME_WIDGETS['help'])
333         self._widget_group.handle_resize(window.size)
334
335     def add_tutorial_screen(self):
336         """
337             Draw tutorial overlay when player clicks on the tutorial button.
338         """
339         self._widget_group.add(GAME_WIDGETS['tutorial'])
340         self._widget_group.handle_resize(window.size)
341         self._hide_pieces = True
342
343     def remove_help_screen(self):
344         GAME_WIDGETS['help'].kill()
345
346     def remove_tutorial_screen(self):
347         GAME_WIDGETS['tutorial'].kill()
348         self._hide_pieces = False
349
350     def process_widget_event(self, event):
351         """
352             Passes Pygame event to WidgetGroup to allow individual widgets to process
353             events.
354
355             Args:
356                 event (pygame.Event): Event to process.
357
358             Returns:
359                 CustomEvent | None: A widget event.
360         """
361         return self._widget_group.process_event(event)

```

### 3.5.3 Controller

As described in Section 2.4, the controller class is responsible for receiving external input through Pygame events, and processing them via the model and view classes.

`game_controller.py`

```

1 import pygame
2 from data.helpers import bitboard_helpers as bb_helpers
3 from data.utils.enums import MoveType, Miscellaneous
4 from data.states.game.components.move import Move
5 from data.utils.event_types import GameEventType
6 from data.managers.logs import initialise_logger
7
8 logger = initialise_logger(__name__)
9
10 class GameController:
11     def __init__(self, model, view, win_view, pause_view, to_menu, to_review,
12                  to_new_game):

```

```

12         self._model = model
13         self._view = view
14         self._win_view = win_view
15         self._pause_view = pause_view
16
17         self._to_menu = to_menu
18         self._to_review = to_review
19         self._to_new_game = to_new_game
20
21         self._view.initialise_timers()
22         self._win_view.set_win_type('CAPTURE')
23
23     def cleanup(self, next):
24         """
25             Handles game quit, either leaving to main menu or restarting a new game.
26
27         Args:
28             next (str): New state to switch to.
29         """
30
31         self._model.kill_thread()
32
32         if next == 'menu':
33             self._to_menu()
34         elif next == 'game':
35             self._to_new_game()
36         elif next == 'review':
37             self._to_review()
38
39     def make_move(self, move):
40         """
41             Handles player move.
42
43         Args:
44             move (Move): Move to make.
45         """
46
47         self._model.make_move(move)
48         self._view.set_overlay_coords([], None)
49
50         if self._model.states['CPU_ENABLED']:
51             self._model.make_cpu_move()
52
53         if self._model.states['WINNER'] == Miscellaneous.DRAW:
54             self._win_view.set_win_type('DRAW')
55
56     def handle_pause_event(self, event):
57         """
58             Processes events when game is paused.
59
60         Args:
61             event (GameEventType): Event to process.
62
63         Raises:
64             Exception: If event type is unrecognised.
65         """
66
67         game_event = self._pause_view.convert_mouse_pos(event)
68
68         if game_event is None:
69             return
70
71         match game_event.type:
72             case GameEventType.PAUSE_CLICK:
73                 self._model.toggle_paused()

```

```

74
75     case GameEventType.MENU_CLICK:
76         self.cleanup('menu')
77
78     case _:
79         raise Exception('Unhandled event type (GameController.handle_event
)')
80
81     def handle_winner_event(self, event):
82         """
83             Processes events when game is over.
84
85             Args:
86                 event (GameEventType): Event to process.
87
88             Raises:
89                 Exception: If event type is unrecognised.
90
91             game_event = self._win_view.convert_mouse_pos(event)
92
93             if game_event is None:
94                 return
95
96             match game_event.type:
97                 case GameEventType.MENU_CLICK:
98                     self.cleanup('menu')
99                     return
100
101            case GameEventType.GAME_CLICK:
102                self.cleanup('game')
103                return
104
105            case GameEventType.REVIEW_CLICK:
106                self.cleanup('review')
107
108            case _:
109                raise Exception('Unhandled event type (GameController.handle_event
)')
110
111    def handle_game_widget_event(self, event):
112        """
113            Processes events for game GUI widgets.
114
115            Args:
116                event (GameEventType): Event to process.
117
118            Raises:
119                Exception: If event type is unrecognised.
120
121            Returns:
122                CustomEvent | None: A widget event.
123
124            widget_event = self._view.process_widget_event(event)
125
126            if widget_event is None:
127                return None
128
129            match widget_event.type:
130                case GameEventType.ROTATE_PIECE:
131                    src_coords = self._view.get_selected_coords()
132
133                    if src_coords is None:

```

```

134         logger.info('None square selected')
135         return
136
137         move = Move.instance_from_coords(MoveType.ROTATE, src_coords,
138             src_coords, rotation_direction=widget_event.rotation_direction)
139             self.make_move(move)
140
141     case GameEventType.RESIGN_CLICK:
142         self._model.set_winner(self._model.states['ACTIVE_COLOUR'].
143             get_flipped_colour())
144         self._view.handle_game_end(play_sfx=False)
145         self._win_view.set_win_type('RESIGN')
146
147     case GameEventType.DRAW_CLICK:
148         self._model.set_winner(Miscellaneous.DRAW)
149         self._view.handle_game_end(play_sfx=False)
150         self._win_view.set_win_type('DRAW')
151
152     case GameEventType.TIMER_END:
153         if self._model.states['TIME_ENABLED']:
154             self._model.set_winner(widget_event.active_colour.
155                 get_flipped_colour())
156             self._win_view.set_win_type('TIME')
157             self._view.handle_game_end(play_sfx=False)
158
159     case GameEventType.MENU_CLICK:
160         self.cleanup('menu')
161
162     case GameEventType.HELP_CLICK:
163         self._view.add_help_screen()
164
165     case _:
166         raise Exception('Unhandled event type (GameController.handle_event
167 )')
168
169     return widget_event.type
170
171 def check_cpu(self):
172     """
173     Checks if CPU calculations are finished every frame.
174     """
175     if self._model.states['CPU_ENABLED'] and self._model.states['AWAITING_CPU']
176     ] is False:
177         self._model.check_cpu()
178
179 def handle_game_event(self, event):
180     """
181     Processes Pygame events for main game.
182
183     Args:
184         event (pygame.Event): If event type is unrecognised.
185
186     Raises:
187         Exception: If event type is unrecognised.
188
189     # Pass event for widgets to process
190     widget_event = self.handle_game_widget_event(event)
191
192     if event.type in [pygame.MOUSEBUTTONDOWN, pygame.MOUSEBUTTONUP, pygame.

```

```

KEYDOWN]:
    if event.type != pygame.KEYDOWN:
        game_event = self._view.convert_mouse_pos(event)
    else:
        game_event = None

    if game_event is None:
        if widget_event is None:
            if event.type in [pygame.MOUSEBUTTONUP, pygame.KEYDOWN]:
                # If user releases mouse click not on a widget
                self._view.remove_help_screen()
                self._view.remove_tutorial_screen()
            if event.type == pygame.MOUSEBUTTONUP:
                # If user releases mouse click on neither a widget or
                board
                    self._view.set_overlay_coords(None, None)

    return

match game_event.type:
    case GameEventType.BOARD_CLICK:
        if self._model.states['AWAITING_CPU']:
            return

        clicked_coords = game_event.coords
        clicked_bitboard = bb_helpers.coords_to_bitboard(
            clicked_coords)
        selected_coords = self._view.get_selected_coords()

        if selected_coords:
            if clicked_coords == selected_coords:
                # If clicking on an already selected square, start
                dragging piece on that square
                self._view.set_dragged_piece(*self._model.
                    get_piece_info(clicked_bitboard))
            return

        selected_bitboard = bb_helpers.coords_to_bitboard(
            selected_coords)
        available_bitboard = self._model.get_available_moves(
            selected_bitboard)

        if bb_helpers.is_occupied(clicked_bitboard,
            available_bitboard):
            # If the newly clicked square is not the same as the
            old one, and is an empty surrounding square, make a move
            move = Move.instance_from_coords(MoveType.MOVE,
                selected_coords, clicked_coords)
            self.make_move(move)
        else:
            # If the newly clicked square is not the same as the
            old one, but is an invalid square, unselect the currently selected square
            self._view.set_overlay_coords(None, None)

        # Select hovered square if it is same as active colour
        elif self._model.is_selectable(clicked_bitboard):
            available_bitboard = self._model.get_available_moves(
                clicked_bitboard)
            self._view.set_overlay_coords(bb_helpers.
                bitboard_to_coords_list(available_bitboard), clicked_coords)
            self._view.set_dragged_piece(*self._model.get_piece_info(
                clicked_bitboard))

```

```

239
240     case GameEventType.PIECE_DROP:
241         hovered_coords = game_event.coords
242
243         # if piece is dropped onto the board
244         if hovered_coords:
245             hovered_bitboard = bb_helpers.coords_to_bitboard(
246                 hovered_coords)
247             selected_coords = self._view.get_selected_coords()
248             selected_bitboard = bb_helpers.coords_to_bitboard(
249                 selected_coords)
250             available_bitboard = self._model.get_available_moves(
251                 selected_bitboard)
252
253             if bb_helpers.is_occupied(hovered_bitboard,
254                 available_bitboard):
255                 # Make a move if mouse is hovered over an empty
256                 # surrounding square
257                 move = Move.instance_from_coords(MoveType.MOVE,
258                     selected_coords, hovered_coords)
259                 self.make_move(move)
260
261             if game_event.remove_overlay:
262                 self._view.set_overlay_coords(None, None)
263
264             self._view.remove_dragged_piece()
265
266         case _:
267             raise Exception('Unhandled event type (GameController.
268 handle_event)', game_event.type)
269
270     def handle_event(self, event):
271         """
272             Passes a Pygame event to the correct handling function according to the
273             game state.
274
275         Args:
276             event (pygame.Event): Event to process.
277         """
278
279         if event.type in [pygame.MOUSEBUTTONDOWN, pygame.MOUSEBUTTONUP, pygame.
280             MOUSEMOTION, pygame.KEYDOWN]:
281             if self._model.states['PAUSED']:
282                 self.handle_pause_event(event)
283             elif self._model.states['WINNER'] is not None:
284                 self.handle_winner_event(event)
285             else:
286                 self.handle_game_event(event)
287
288         if event.type == pygame.KEYDOWN:
289             if event.key == pygame.K_ESCAPE:
290                 self._model.toggle_paused()
291             # Debug shortcut to kill CPU
292             elif event.key == pygame.K_l:
293                 logger.info('\nSTOPPING CPU')
294                 self._model._cpu_thread.stop_cpu()

```

### 3.5.4 Board

The `Board` class implements the Laser Chess board, and is responsible for handling moves, captures, and win conditions.

board.py

```

1 from collections import defaultdict
2 from data.utils.constants import A_FILE_MASK, J_FILE_MASK, ONE_RANK_MASK,
   EIGHT_RANK_MASK, EMPTY_BB
3 from data.utils.enums import Colour, Piece, Rank, File, MoveType,
   RotationDirection, Miscellaneous
4 from data.states.game.components.bitboard_collection import BitboardCollection
5 from data.helpers import bitboard_helpers as bb_helpers
6 from data.states.game.components.laser import Laser
7 from data.states.game.components.move import Move
8
9
10 class Board:
11     def __init__(self, fen_string="sc3ncfcnspb2/2pc7/3Pd6/pa1Pc1rbra1pb1Pd/
12     pb1Pd1RaRb1pa1Pc/6pb3/7Pa2/2PdNaFaNa3Sa b"):
13         self.bitboards = BitboardCollection(fen_string)
14         self.hash_list = [self.bitboards.get_hash()]
15
16     def __str__(self):
17         """
18             Returns a string representation of the board.
19
20             Returns:
21                 str: Board formatted as string.
22         """
23         characters = '8 '
24         pieces = defaultdict(int)
25
26         for rank_idx, rank in enumerate(reversed(Rank)):
27             for file_idx, file in enumerate(File):
28                 mask = 1 << (rank * 10 + file)
29                 blue_piece = self.bitboards.get_piece_on(mask, Colour.BLUE)
30                 red_piece = self.bitboards.get_piece_on(mask, Colour.RED)
31
32                 if blue_piece:
33                     pieces[blue_piece.value.upper()] += 1
34                     characters += f'{blue_piece.upper()} '
35                 elif red_piece:
36                     pieces[red_piece.value] += 1
37                     characters += f'{red_piece} '
38                 else:
39                     characters += '. '
40
41             characters += f'\n\n{7 - rank_idx} '
42         characters += 'A B C D E F G H I J\n\n'
43         characters += str(dict(pieces))
44         characters += f'\nCURRENT PLAYER TO MOVE: {self.bitboards.active_colour.
45         name}\n'
46         return characters
47
48     def get_piece_list(self):
49         """
50             Converts the board bitboards to a list of pieces.
51
52             Returns:
53                 list: List of Pieces.
54         """
55         return self.bitboards.convert_to_piece_list()
56
57     def get_active_colour(self):
58         """
59

```

```

57     Gets the active colour.
58
59     Returns:
60         Colour: The active colour.
61         """
62     return self.bitboards.active_colour
63
64     def to_hash(self):
65         """
66         Gets the hash of the current board state.
67
68         Returns:
69             int: A Zobrist hash.
70             """
71     return self.bitboards.get_hash()
72
73     def check_win(self):
74         """
75         Checks for a Pharaoh capture or threefold-repetition.
76
77         Returns:
78             Colour | Miscellaneous: The winning colour, or Miscellaneous.DRAW.
79             """
80         for colour in Colour:
81             if self.bitboards.get_piece_bitboard(Piece.PHARAOH, colour) == EMPTY_BB:
82                 return colour.get_flipped_colour()
83
84             if self.hash_list.count(self.hash_list[-1]) >= 3:
85                 return Miscellaneous.DRAW
86
87         return None
88
89     def apply_move(self, move, fire_laser=True, add_hash=False):
90         """
91         Applies a move to the board.
92
93         Args:
94             move (Move): The move to apply.
95             fire_laser (bool): Whether to fire the laser after the move.
96             add_hash (bool): Whether to add the board state hash to the hash list.
97
98         Returns:
99             Laser: The laser trajectory result.
100             """
101         piece_symbol = self.bitboards.get_piece_on(move.src, self.bitboards.
102                                         active_colour)
103
104         if piece_symbol is None:
105             raise ValueError(f'Invalid move - no piece found on source square. {move}')
106         elif piece_symbol == Piece.SPHINX:
107             raise ValueError(f'Invalid move - sphinx piece is immovable. {move}')
108
109         if move.move_type == MoveType.MOVE:
110             possible_moves = self.get_valid_squares(move.src)
111             if bb_helpers.is_occupied(move.dest, possible_moves) is False:
112                 raise ValueError('Invalid move - destination square is occupied')
113
114             piece_rotation = self.bitboards.get_rotation_on(move.src)
115             self.bitboards.update_move(move.src, move.dest)

```

```

116         self.bitboards.update_rotation(move.src, move.dest, piece_rotation)
117
118     elif move.move_type == MoveType.ROTATE:
119         piece_symbol = self.bitboards.get_piece_on(move.src, self.bitboards.
120             active_colour)
121         piece_rotation = self.bitboards.get_rotation_on(move.src)
122
123         if move.rotation_direction == RotationDirection.CLOCKWISE:
124             new_rotation = piece_rotation.get_clockwise()
125         elif move.rotation_direction == RotationDirection.ANTICLOCKWISE:
126             new_rotation = piece_rotation.get_anticlockwise()
127
128         self.bitboards.update_rotation(move.src, move.src, new_rotation)
129
130     laser = None
131     if fire_laser:
132         laser = self.fire_laser(add_hash)
133
134     if add_hash:
135         self.hash_list.append(self.bitboards.get_hash())
136
137     self.bitboards.flip_colour()
138
139     return laser
140
141     def undo_move(self, move, laser_result):
142         """
143             Undoes a move on the board.
144
145             Args:
146                 move (Move): The move to undo.
147                 laser_result (Laser): The laser trajectory result.
148
149             self.bitboards.flip_colour()
150
151             if laser_result.hit_square_bitboard:
152                 # Get info of destroyed piece, and add it to the board again
153                 src = laser_result.hit_square_bitboard
154                 piece = laser_result.piece_hit
155                 colour = laser_result.piece_colour
156                 rotation = laser_result.piece_rotation
157
158                 self.bitboards.set_square(src, piece, colour)
159                 self.bitboards.clear_rotation(src)
160                 self.bitboards.set_rotation(src, rotation)
161
162             # Create new Move object that is the inverse of the passed move
163             if move.move_type == MoveType.MOVE:
164                 reversed_move = Move.instance_from_bitboards(MoveType.MOVE, move.dest,
165                     move.src)
166             elif move.move_type == MoveType.ROTATE:
167                 reversed_move = Move.instance_from_bitboards(MoveType.ROTATE, move.src
168                     , move.src, move.rotation_direction.get_opposite())
169
170             self.apply_move(reversed_move, fire_laser=False)
171             self.bitboards.flip_colour()
172
173     def remove_piece(self, square_bitboard):
174         """
175             Removes a piece from a given square.
176
177             Args:
```

```

175         square_bitboard (int): The bitboard representation of the square.
176     """
177     self.bitboards.clear_square(square_bitboard, Colour.BLUE)
178     self.bitboards.clear_square(square_bitboard, Colour.RED)
179     self.bitboards.clear_rotation(square_bitboard)
180
181     def get_valid_squares(self, src_bitboard, colour=None):
182     """
183         Gets valid squares for a piece to move to.
184
185         Args:
186             src_bitboard (int): The bitboard representation of the source square.
187             colour (Colour, optional): The active colour of the piece.
188
189         Returns:
190             int: The bitboard representation of valid squares.
191     """
192     target_top_left = (src_bitboard & A_FILE_MASK & EIGHT_RANK_MASK) << 9
193     target_top_middle = (src_bitboard & EIGHT_RANK_MASK) << 10
194     target_top_right = (src_bitboard & J_FILE_MASK & EIGHT_RANK_MASK) << 11
195     target_middle_right = (src_bitboard & J_FILE_MASK) << 1
196
197     target_bottom_right = (src_bitboard & J_FILE_MASK & ONE_RANK_MASK) >> 9
198     target_bottom_middle = (src_bitboard & ONE_RANK_MASK) >> 10
199     target_bottom_left = (src_bitboard & A_FILE_MASK & ONE_RANK_MASK)>> 11
200     target_middle_left = (src_bitboard & A_FILE_MASK) >> 1
201
202     possible_moves = target_top_left | target_top_middle | target_top_right |
203     target_middle_right | target_bottom_right | target_bottom_middle |
204     target_bottom_left | target_middle_left
205
206     if colour is not None:
207         valid_possible_moves = possible_moves & ~self.bitboards.
208         combined_colour_bitboards[colour]
209     else:
210         valid_possible_moves = possible_moves & ~self.bitboards.
211         combined_all_bitboard
212
213     return valid_possible_moves
214
215     def get_mobility(self, colour):
216     """
217         Gets all valid squares for a given colour.
218
219         Args:
220             colour (Colour): The colour of the pieces.
221
222         Returns:
223             int: The bitboard representation of all valid squares.
224     """
225     active_pieces = self.get_all_active_pieces(colour)
226     possible_moves = 0
227
228     for square in bb_helpers.occupied_squares(active_pieces):
229         possible_moves += bb_helpers.pop_count(self.get_valid_squares(square))
230
231     return possible_moves
232
233     def get_all_active_pieces(self, colour=None):
234     """
235         Gets all active pieces for the current player.

```

```

233     Args:
234         colour (Colour): Active colour of pieces to retrieve. Defaults to None
235
236     Returns:
237         int: The bitboard representation of all active pieces.
238         """
239     if colour is None:
240         colour = self.bitboards.active_colour
241
242     active_pieces = self.bitboards.combined_colour_bitboards[colour]
243     sphinx_bitboard = self.bitboards.get_piece_bitboard(Piece.SPHINX, colour)
244     return active_pieces ^ sphinx_bitboard
245
246     def fire_laser(self, remove_hash):
247         """
248         Fires the laser and removes hit pieces.
249
250         Args:
251             remove_hash (bool): Whether to clear the hash list if a piece is hit.
252
253         Returns:
254             Laser: The result of firing the laser.
255             """
256     laser = Laser(self.bitboards)
257
258     if laser.hit_square_bitboard:
259         self.remove_piece(laser.hit_square_bitboard)
260
261         if remove_hash:
262             self.hash_list = [] # Remove all hashes for threefold repetition,
263             as the position is impossible to be repeated after a piece is removed
264             return laser
265
266     def generate_square_moves(self, src):
267         """
268         Generates all valid moves for a piece on a given square.
269
270         Args:
271             src (int): The bitboard representation of the source square.
272
273         Yields:
274             Move: A valid move for the piece.
275             """
276     for dest in bb_helpers.occupied_squares(self.get_valid_squares(src)):
277         yield Move(MoveType.MOVE, src, dest)
278
279     def generate_all_moves(self, colour):
280         """
281         Generates all valid moves for a given colour.
282
283         Args:
284             colour (Colour): The colour of the pieces.
285
286         Yields:
287             Move: A valid move for the active colour.
288             """
289     sphinx_bitboard = self.bitboards.get_piece_bitboard(Piece.SPHINX, colour)
290     # Remove source squares for Sphinx pieces, as they cannot be moved
291     sphinx_masked_bitboard = self.bitboards.combined_colour_bitboards[colour]
292     ~ sphinx_bitboard
293
294

```

```

292     for square in bb_helpers.occupied_squares(sphinx_masked_bitboard):
293         # Generate movement moves
294         yield from self.generate_square_moves(square)
295
296         # Generate rotational moves
297         for rotation_direction in RotationDirection:
298             yield Move(MoveType.ROTATE, square, rotation_direction=
rotation_direction)

```

### 3.5.5 Bitboards

As described in Section 2.2.3, the `BitboardCollection` class uses helper functions found in `bitboard_helpers.py` such as `pop_count`, to initialise and manage bitboard transformations.

```

1  from data.utils.enums import Rank, File, Piece, Colour, Rotation, RotationIndex
2  from data.states.game.components.fen_parser import parse_fen_string
3  from data.states.game.cpu.zobrist_hasher import ZobristHasher
4  from data.helpers import bitboard_helpers as bb_helpers
5  from data.managers.logs import initialise_logger
6  from data.utils.constants import EMPTY_BB
7
8  logger = initialise_logger(__name__)
9
10 class BitboardCollection:
11     def __init__(self, fen_string):
12         self.piece_bitboards = [{char: EMPTY_BB for char in Piece}, {char: EMPTY_BB for char in Piece}]
13         self.combined_colour_bitboards = [EMPTY_BB, EMPTY_BB]
14         self.combined_all_bitboard = EMPTY_BB
15         self.rotation_bitboards = [EMPTY_BB, EMPTY_BB]
16         self.active_colour = Colour.BLUE
17         self._hasher = ZobristHasher()
18
19     try:
20         if fen_string:
21             self.piece_bitboards, self.combined_colour_bitboards, self.
22             combined_all_bitboard, self.rotation_bitboards, self.active_colour =
23             parse_fen_string(fen_string)
24             self.initialise_hash()
25         except ValueError as error:
26             logger.error('Please input a valid FEN string:', error)
27             raise error
28
29     def __str__(self):
30         """
31             Returns a string representation of the bitboards.
32
33             Returns:
34                 str: Bitboards formatted with piece type and colour shown.
35         """
36         characters = ''
37         for rank in reversed(Rank):
38             for file in File:
39                 bitboard = 1 << (rank * 10 + file)
40
41                 colour = self.get_colour_on(bitboard)
42                 piece = self.get_piece_on(bitboard, Colour.BLUE) or self.
43                 get_piece_on(bitboard, Colour.RED)

```

```

42             if piece is not None:
43                 characters += f'{piece.upper() if colour == Colour.BLUE
44             else piece} '
45             else:
46                 characters += '.   '
47
48             characters += '\n\n'
49
50     return characters
51
52 def get_rotation_string(self):
53     """
54     Returns a string representation of the board rotations.
55
56     Returns:
57         str: Board formatted with only rotations shown.
58     """
59     characters = ''
60     for rank in reversed(Rank):
61
62         for file in File:
63             mask = 1 << (rank * 10 + file)
64             rotation = self.get_rotation_on(mask)
65             has_piece = bb_helpers.is_occupied(self.combined_all_bitboard,
66                                              mask)
67
68             if has_piece:
69                 characters += f'{rotation.upper()} '
70             else:
71                 characters += '.   '
72
73     characters += '\n\n'
74
75     return characters
76
77 def initialise_hash(self):
78     """
79     Initialises the Zobrist hash for the current board state.
80     """
81     for piece in Piece:
82         for colour in Colour:
83             piece_bitboard = self.get_piece_bitboard(piece, colour)
84
85             for occupied_bitboard in bb_helpers.occupied_squares(
86                 piece_bitboard):
87                 self._hasher.apply_piece_hash(occupied_bitboard, piece, colour)
88
89     for bitboard in bb_helpers.loop_all_squares():
90         rotation = self.get_rotation_on(bitboard)
91         self._hasher.apply_rotation_hash(bitboard, rotation)
92
93     if self.active_colour == Colour.RED:
94         self._hasher.apply_red_move_hash()
95
96 def flip_colour(self):
97     """
98     Flips the active colour and updates the Zobrist hash.
99     """
100    self.active_colour = self.active_colour.get_flipped_colour()
101
102    if self.active_colour == Colour.RED:
103        self._hasher.apply_red_move_hash()
104
105    if self.active_colour == Colour.BLUE:
106        self._hasher.apply_blue_move_hash()

```

```

100         self._hasher.apply_red_move_hash()
101
102     def update_move(self, src, dest):
103         """
104             Updates the bitboards for a move.
105
106             Args:
107                 src (int): The bitboard representation of the source square.
108                 dest (int): The bitboard representation of the destination square.
109             """
110
111         piece = self.get_piece_on(src, self.active_colour)
112
113         self.clear_square(src, Colour.BLUE)
114         self.clear_square(dest, Colour.BLUE)
115         self.clear_square(src, Colour.RED)
116         self.clear_square(dest, Colour.RED)
117
118         self.set_square(dest, piece, self.active_colour)
119
120     def update_rotation(self, src, dest, new_rotation):
121         """
122             Updates the rotation bitboards for a move.
123
124             Args:
125                 src (int): The bitboard representation of the source square.
126                 dest (int): The bitboard representation of the destination square.
127                 new_rotation (Rotation): The new rotation.
128             """
129
130         self.clear_rotation(src)
131         self.set_rotation(dest, new_rotation)
132
133     def clear_rotation(self, bitboard):
134         """
135             Clears the rotation for a given square.
136
137             Args:
138                 bitboard (int): The bitboard representation of the square.
139             """
140
141         old_rotation = self.get_rotation_on(bitboard)
142         rotation_1, rotation_2 = self.rotation_bitboards
143         self.rotation_bitboards[RotationIndex.FIRSTBIT] = bb_helpers.clear_square(
144             rotation_1, bitboard)
145         self.rotation_bitboards[RotationIndex.SECONDBIT] = bb_helpers.clear_square(
146             rotation_2, bitboard)
147
148         self._hasher.apply_rotation_hash(bitboard, old_rotation)
149
150     def clear_square(self, bitboard, colour):
151         """
152             Clears a square piece and rotation for a given colour.
153
154             Args:
155                 bitboard (int): The bitboard representation of the square.
156                 colour (Colour): The colour to clear.
157             """
158
159         piece = self.get_piece_on(bitboard, colour)
160
161         if piece is None:
162             return
163
164         piece_bitboard = self.get_piece_bitboard(piece, colour)
165         colour_bitboard = self.combined_colour_bitboards[colour]

```

```

160         all_bitboard = self.combined_all_bitboard
161
162         self.piece_bitboards[colour][piece] = bb_helpers.clear_square(
163             piece_bitboard, bitboard)
163         self.combined_colour_bitboards[colour] = bb_helpers.clear_square(
164             colour_bitboard, bitboard)
164         self.combined_all_bitboard = bb_helpers.clear_square(all_bitboard,
165             bitboard)
165
166         self._hasher.apply_piece_hash(bitboard, piece, colour)
167
168     def set_rotation(self, bitboard, rotation):
169         """
170             Sets the rotation for a given square.
171
172             Args:
173                 bitboard (int): The bitboard representation of the square.
174                 rotation (Rotation): The rotation to set.
175             """
176
176     rotation_1, rotation_2 = self.rotation_bitboards
177     self._hasher.apply_rotation_hash(bitboard, rotation)
178
179     match rotation:
180         case Rotation.UP:
181             return
182         case Rotation.RIGHT:
183             self.rotation_bitboards[RotationIndex.FIRSTBIT] = bb_helpers.
183             set_square(rotation_1, bitboard)
184             return
185         case Rotation.DOWN:
186             self.rotation_bitboards[RotationIndex.SECONDBIT] = bb_helpers.
186             set_square(rotation_2, bitboard)
187             return
188         case Rotation.LEFT:
189             self.rotation_bitboards[RotationIndex.FIRSTBIT] = bb_helpers.
189             set_square(rotation_1, bitboard)
190             self.rotation_bitboards[RotationIndex.SECONDBIT] = bb_helpers.
190             set_square(rotation_2, bitboard)
191             return
192         case _:
193             raise ValueError('Invalid rotation input (bitboard.py):', rotation)
194
195     def set_square(self, bitboard, piece, colour):
196         """
197             Sets a piece on a given square.
198
199             Args:
200                 bitboard (int): The bitboard representation of the square.
201                 piece (Piece): The piece to set.
202                 colour (Colour): The colour of the piece.
203             """
204
204     piece_bitboard = self.get_piece_bitboard(piece, colour)
205     colour_bitboard = self.combined_colour_bitboards[colour]
206     all_bitboard = self.combined_all_bitboard
207
208     self.piece_bitboards[colour][piece] = bb_helpers.set_square(piece_bitboard
208 , bitboard)
209     self.combined_colour_bitboards[colour] = bb_helpers.set_square(
209 colour_bitboard, bitboard)
210     self.combined_all_bitboard = bb_helpers.set_square(all_bitboard, bitboard)
211

```

```

212         self._hasher.apply_piece_hash(bitboard, piece, colour)
213
214     def get_piece_bitboard(self, piece, colour):
215         """
216             Gets the bitboard for a piece type for a given colour.
217
218         Args:
219             piece (Piece): The piece bitboard to get.
220             colour (Colour): The colour of the piece.
221
222         Returns:
223             int: The bitboard representation for all squares occupied by that
224             piece type.
225
226     def get_piece_on(self, target_bitboard, colour):
227         """
228
229         Gets the piece on a given square for a given colour.
230
231         Args:
232             target_bitboard (int): The bitboard representation of the square.
233             colour (Colour): The colour of the piece.
234
235         Returns:
236             Piece: The piece on the square, or None if square is empty.
237
238         if not (bb_helpers.is_occupied(self.combined_colour_bitboards[colour],
239             target_bitboard)):
240             return None
241
242         return next(
243             (piece for piece in Piece if
244                 bb_helpers.is_occupied(self.get_piece_bitboard(piece, colour),
245                 target_bitboard)),
246             None)
247
248     def get_rotation_on(self, target_bitboard):
249         """
250
251         Gets the rotation on a given square.
252
253         Args:
254             target_bitboard (int): The bitboard representation of the square.
255
256         Returns:
257             Rotation: The rotation on the square.
258
259             rotationBits = [bb_helpers.is_occupied(self.rotation_bitboards[
260                 RotationIndex.SECONDBIT], target_bitboard), bb_helpers.is_occupied(self.
261                 rotation_bitboards[RotationIndex.FIRSTBIT], target_bitboard)]
262
263             match rotationBits:
264                 case [False, False]:
265                     return Rotation.UP
266                 case [False, True]:
267                     return Rotation.RIGHT
268                 case [True, False]:
269                     return Rotation.DOWN
270                 case [True, True]:
271                     return Rotation.LEFT
272
273     def get_colour_on(self, target_bitboard):

```

```

269     """
270     Gets the colour of the piece on a given square.
271
272     Args:
273         target_bitboard (int): The bitboard representation of the square.
274
275     Returns:
276         Colour: The colour of the piece on the square.
277         """
278     for piece in Piece:
279         if self.get_piece_bitboard(piece, Colour.BLUE) & target_bitboard != EMPTY_BB:
280             return Colour.BLUE
281         elif self.get_piece_bitboard(piece, Colour.RED) & target_bitboard != EMPTY_BB:
282             return Colour.RED
283
284     def get_piece_count(self, piece, colour):
285         """
286         Gets the count of a given piece type and colour.
287
288         Args:
289             piece (Piece): The piece to count.
290             colour (Colour): The colour of the piece.
291
292         Returns:
293             int: The number of that piece of that colour on the board.
294         """
295         return bb_helpers.pop_count(self.get_piece_bitboard(piece, colour))
296
297     def get_hash(self):
298         """
299         Gets the Zobrist hash of the current board state.
300
301         Returns:
302             int: The Zobrist hash.
303         """
304         return self._hasher.hash
305
306     def convert_to_piece_list(self):
307         """
308         Converts all bitboards to a list of pieces.
309
310         Returns:
311             list: Board represented as a 2D list of Piece and Rotation objects.
312         """
313         piece_list = []
314
315         for i in range(80):
316             if x := self.get_piece_on(1 << i, Colour.BLUE):
317                 rotation = self.get_rotation_on(1 << i)
318                 piece_list.append((x.upper(), rotation))
319             elif y := self.get_piece_on(1 << i, Colour.RED):
320                 rotation = self.get_rotation_on(1 << i)
321                 piece_list.append((y, rotation))
322             else:
323                 piece_list.append(None)
324
325         return piece_list

```

## 3.6 CPU

This section includes my implementation for the CPU engine run on minimax, including its various improvements and accessory classes.

Every CPU engine class is a subclass of a `BaseCPU` abstract class, and therefore contains the same attribute and method names. This means **polymorphism** can be used again to easily test and vary the difficulty by switching out which CPU engine is used.

The method `find_move` is called by the CPU thread. `search` is then called recursively to traverse the minimax tree, and find an optimal move. The move is then returned to `find_move` and passed and run with the callback function. A `stats` dictionary is also created in the base class, used to collect information for each search.

### 3.6.1 Minimax

As described in Section 2.2.1, the minimax engine uses **DFS** to traverse the game tree and evaluate node accordingly, by **recursively** calling the `search` function.

`minimax.py`

```

1  from random import choice
2  from data.states.game.cpu.base import BaseCPU
3  from data.utils.enums import Score, Colour
4
5  class MinimaxCPU(BaseCPU):
6      def __init__(self, max_depth, callback, verbose=False):
7          super().__init__(callback, verbose)
8          self._max_depth = max_depth
9
10     def find_move(self, board, stop_event):
11         """
12             Finds the best move for the current board state.
13
14             Args:
15                 board (Board): The current board state.
16                 stop_event (threading.Event): Event used to kill search from an
17                     external class.
18
19             Returns:
20                 tuple[int, Move]: The best score and the best move found.
21
22         """
23         self.initialise_stats()
24         best_score, best_move = self.search(board, self._max_depth, stop_event)
25
26         if self._verbose:
27             self.print_stats(best_score, best_move)
28
29         self._callback(best_move)
30
31     def search(self, board, depth, stop_event):
32         """
33             Recursively DFS through minimax tree with evaluation score.
34
35             Args:
36                 board (Board): The current board state.
37                 depth (int): The current search depth.
38                 stop_event (threading.Event): Event used to kill search from an
39                     external class.
40
41             Returns:
42                 tuple[int, Move]: The best score and the best move found.
43
44         """
45         if (base_case := super().search(board, depth, stop_event)):
46             return base_case

```

```

39
40     best_move = None
41
42     # Blue is the maximising player
43     if board.get_active_colour() == Colour.BLUE:
44         max_score = -Score.INFINITE
45
46     for move in board.generate_all_moves(Colour.BLUE):
47         laser_result = board.apply_move(move)
48
49
50         new_score = self.search(board, depth - 1, stop_event)[0]
51
52         # if depth < self._max_depth:
53         #     print('DEPTH', depth, new_score, move)
54
55         if new_score > max_score:
56             max_score = new_score
57             best_move = move
58
59         if new_score == (Score.CHECKMATE + self._max_depth):
60             board.undo_move(move, laser_result)
61             return max_score, best_move
62
63     elif new_score == max_score:
64         # If evaluated scores are equal, pick a random move
65         best_move = choice([best_move, move])
66
67     board.undo_move(move, laser_result)
68
69     return max_score, best_move
70
71 else:
72     min_score = Score.INFINITE
73
74     for move in board.generate_all_moves(Colour.RED):
75         laser_result = board.apply_move(move)
76         # print('DEPTH', depth, move)
77         new_score = self.search(board, depth - 1, stop_event)[0]
78
79         if new_score < min_score:
80             # print('setting new', new_score, move)
81             min_score = new_score
82             best_move = move
83
84         if new_score == (-Score.CHECKMATE - self._max_depth):
85             board.undo_move(move, laser_result)
86             return min_score, best_move
87
88     elif new_score == min_score:
89         best_move = choice([best_move, move])
90
91     board.undo_move(move, laser_result)
92
93     return min_score, best_move

```

### 3.6.2 Alpha-beta Pruning

As described in Section 2.2.2, the `ABMinimaxCPU` class introduces pruning to reduce the number of nodes evaluated during a minimax search.

```

alpha_beta.py

1 from data.states.game.cpu.move_orderer import MoveOrderer
2 from data.states.game.cpu.base import BaseCPU
3 from data.utils.enums import Score, Colour
4
5 class ABMinimaxCPU(BaseCPU):
6     def __init__(self, max_depth, callback, verbose=True):
7         super().__init__(callback, verbose)
8         self._max_depth = max_depth
9         self._orderer = MoveOrderer()
10
11     def initialise_stats(self):
12         """
13             Initialises the number of prunes to the statistics dictionary to be logged
14
15             """
16         super().initialise_stats()
17         self._stats['beta_prunes'] = 0
18         self._stats['alpha_prunes'] = 0
19
20     def find_move(self, board, stop_event):
21         """
22             Finds the best move for the current board state.
23
24             Args:
25                 board (Board): The current board state.
26                 stop_event (threading.Event): Event used to kill search from an
27                     external class.
28
29             """
30         self.initialise_stats()
31         best_score, best_move = self.search(board, self._max_depth, -Score.INFINITE, Score.INFINITE, stop_event)
32
33         self._callback(best_move)
34
35     def search(self, board, depth, alpha, beta, stop_event, hint=None,
36               laser_coords=None):
37         """
38             Recursively DFS through minimax tree while pruning branches using the
39             alpha and beta bounds.
40
41             Args:
42                 board (Board): The current board state.
43                 depth (int): The current search depth.
44                 alpha (int): The upper bound value.
45                 beta (int): The lower bound value.
46                 stop_event (threading.Event): Event used to kill search from an
47                     external class.
48
49             Returns:
50                 tuple[int, Move]: The best score and the best move found.
51
52             """
53         if (base_case := super().search(board, depth, stop_event)):
54             return base_case
55
56         best_move = None
57
58         # Blue is the maximising player

```

```

55         if board.get_active_colour() == Colour.BLUE:
56             max_score = -Score.INFINITE
57
58             for move in self._orderer.get_moves(board, hint=hint, laser_coords=
59                                         laser_coords):
60                 laser_result = board.apply_move(move)
61                 new_score = self.search(board, depth - 1, alpha, beta, stop_event,
62                                         laser_coords=laser_result.pieces_on_trajectory)[0]
63
64                 if new_score > max_score:
65                     max_score = new_score
66                     best_move = move
67
68                 board.undo_move(move, laser_result)
69
70                 alpha = max(alpha, max_score)
71
72                 if beta <= alpha:
73                     self._stats['alpha_prunes'] += 1
74                     break
75
76             return max_score, best_move
77
78     else:
79         min_score = Score.INFINITE
80
81         for move in self._orderer.get_moves(board, hint=hint, laser_coords=
82                                         laser_coords):
83             laser_result = board.apply_move(move)
84             new_score = self.search(board, depth - 1, alpha, beta, stop_event,
85                                         laser_coords=laser_result.pieces_on_trajectory)[0]
86
87             if new_score < min_score:
88                 min_score = new_score
89                 best_move = move
90
91             board.undo_move(move, laser_result)
92
93             beta = min(beta, min_score)
94             if beta <= alpha:
95                 self._stats['beta_prunes'] += 1
96                 break
97
98         return min_score, best_move

```

### 3.6.3 Transposition Table

For adding transposition table functionality to my other engine classes, as described in Section 2.2.2, I have decided to use a mixin design architecture. This allows me to **reuse code** by adding mixins to many different classes, and inject additional transposition table methods and functionality into other engines.

`transposition_table.py`

```

1 from data.states.game.cpu.transposition_table import TranspositionTable
2 from data.states.game.cpu.engines.alpha_beta import ABMinimaxCPU
3
4 class TranspositionTableMixin:
5     def __init__(self, *args, **kwargs):
6         super().__init__(*args, **kwargs)
7         self._table = TranspositionTable()

```

```

8
9     def find_move(self, *args, **kwargs):
10        self._table = TranspositionTable()
11        super().find_move(*args, **kwargs)
12
13    def search(self, board, depth, alpha, beta, stop_event, hint=None,
14              laser_coords=None):
15        """
16            Searches transposition table for a cached move before running a full
17            search if necessary.
18            Caches the searched result.
19
20            Args:
21                board (Board): The current board state.
22                depth (int): The current search depth.
23                alpha (int): The upper bound value.
24                beta (int): The lower bound value.
25                stop_event (threading.Event): Event used to kill search from an
26                    external class.
27
28            Returns:
29                tuple[int, Move]: The best score and the best move found.
30
31        hash = board.to_hash()
32        score, move = self._table.get_entry(hash, depth, alpha, beta)
33
34        if score is not None:
35            self._stats['cache_hits'] += 1
36            self._stats['nodes'] += 1
37
38            return score, move
39        else:
40            # If board hash entry not found in cache, run a full search
41            score, move = super().search(board, depth, alpha, beta, stop_event,
42                                         hint)
43            self._table.insert_entry(score, move, hash, depth, alpha, beta)
44
45        return score, move
46
47    class TTMinimaxCPU(TranspositionTableMixin, ABMinimaxCPU):
48        def initialise_stats(self):
49            """
50                Initialises cache statistics to be logged.
51            """
52            super().initialise_stats()
53            self._stats['cache_hits'] = 0
54
55        def print_stats(self, score, move):
56            """
57                Logs the statistics for the search.
58
59                Args:
60                    score (int): The best score found.
61                    move (Move): The best move found.
62
63                # Calculate number of cached entries retrieved as a percentage of all
64                # nodes
65                self._stats['cache_hits_percentage'] = round(self._stats['cache_hits'] /
66                self._stats['nodes'], 3)
67                self._stats['cache_entries'] = len(self._table._table)
68                super().print_stats(score, move)

```

### 3.6.4 Iterative Deepening

As described in 2.2.2, the depth for each search is increased for each iteration through the for loop, with the best move found on one depth being used as the starting move for the following depth.

```

1 from copy import deepcopy
2 from random import choice
3 from data.states.game.cpu.engines.transposition_table import
4     TranspositionTableMixin
5 from data.states.game.cpu.transposition_table import TranspositionTable
6 from data.states.game.cpu.engines.alpha_beta import ABMinimaxCPU
7 from data.managers.logs import initialise_logger
8 from data.utils.enums import Score
9
10 logger = initialise_logger(__name__)
11
12 class IterativeDeepeningMixin:
13     def find_move(self, board, stop_event):
14         """
15             Iterates through increasing depths to find the best move.
16
17             Args:
18                 board (Board): The current board state.
19                 stop_event (threading.Event): Event used to kill search from an
20                     external class.
21
22             best_move = None
23
24             for depth in range(1, self._max_depth + 1):
25                 self.initialise_stats()
26
27                 # Use copy of board as search can be terminated before all tested
28                 moves are undone
29                 board_copy = deepcopy(board)
30
31                 try:
32                     best_score, best_move = self.search(board_copy, depth, -Score.
33                     INFINITE, Score.INFINITE, stop_event, hint=best_move)
34                 except TimeoutError:
35                     # If allocated time is up, use previous depth's best move
36                     logger.info(f'Terminated CPU search early at depth {depth}. Using
37                     existing best move: {best_move}')
38
39                     if best_move is None:
40                         # If search is terminated at depth 0, use random move
41                         best_move = choice(board_copy.generate_all_moves())
42                         logger.warning('CPU terminated before any best move found!
43                         Using random move.')
44
45                     if self._verbose:
46                         self.print_stats(best_score, best_move)
47
48                     self._callback(best_move)
49

```

```

50 class IDMinimaxCPU(TranspositionTableMixin, IterativeDeepeningMixin, ABMinimaxCPU):
51     :
52     def initialise_stats(self):
53         super().initialise_stats()
54         self._stats['cache_hits'] = 0
55
56     def print_stats(self, score, move):
57         self._stats['cache_hits_percentage'] = round(self._stats['cache_hits'] /
58             self._stats['nodes'], 3)
59         self._stats['cache_entries'] = len(self._table._table)
60         super().print_stats(score, move)

```

### 3.6.5 Evaluator

As described in Section 2.2.4, I have opted to separate the evaluation class into separate methods for each aspect of the evaluation, and amalgamating all of them to form one unified `evaluate` function, as this allows me to debug each function easily.

`evaluator.py`

```

1 from data.helpers.bitboard_helpers import pop_count, occupied_squares,
2     bitboard_to_index
3 from data.states.game.components.psqt import PSQT, FLIP
4 from data.utils.enums import Colour, Piece, Score
5 from data.managers.logs import initialise_logger
6
7 logger = initialise_logger(__name__)
8
9 class Evaluator:
10     def __init__(self, verbose=True):
11         self._verbose = verbose
12
13     def evaluate(self, board, absolute=False):
14         """
15             Evaluates and returns a numerical score for the board state.
16
17             Args:
18                 board (Board): The current board state.
19                 absolute (bool): Whether to always return the absolute score from the
20                     active colour's perspective (for Negamax).
21
22             Returns:
23                 int: Score representing advantage/disadvantage for the player.
24
25         blue_score = (
26             self.evaluate_material(board, Colour.BLUE),
27             self.evaluate_position(board, Colour.BLUE),
28             self.evaluate_mobility(board, Colour.BLUE),
29             self.evaluate_pharaoh_safety(board, Colour.BLUE)
30         )
31
32         red_score = (
33             self.evaluate_material(board, Colour.RED),
34             self.evaluate_position(board, Colour.RED),
35             self.evaluate_mobility(board, Colour.RED),
36             self.evaluate_pharaoh_safety(board, Colour.RED)
37         )
38
39         if self._verbose:
40             logger.info(f'Material: {blue_score[0]} | {red_score[0]}')
41             logger.info(f'Position: {blue_score[1]} | {red_score[1]}')

```

```

40         logger.info(f'Mobility: {blue_score[2]} | {red_score[2]}')
41         logger.info(f'Safety: {blue_score[3]} | {red_score[3]}')
42         logger.info(f'Overall score: {sum(blue_score) - sum(red_score)}\n')
43
44     if absolute and board.get_active_colour() == Colour.RED:
45         return sum(red_score) - sum(blue_score)
46     else:
47         return sum(blue_score) - sum(red_score)
48
49     def evaluate_material(self, board, colour):
50         """
51             Evaluates the material score for a given colour.
52
53         Args:
54             board (Board): The current board state.
55             colour (Colour): The colour to evaluate.
56
57         Returns:
58             int: Sum of all piece scores.
59         """
60         return (
61             Score.SPHINX * board.bitboards.get_piece_count(Piece.SPHINX, colour) +
62             Score.PYRAMID * board.bitboards.get_piece_count(Piece.PYRAMID, colour)
63             +
64             Score.ANUBIS * board.bitboards.get_piece_count(Piece.ANUBIS, colour) +
65             Score.SCARAB * board.bitboards.get_piece_count(Piece.SCARAB, colour)
66         )
67
68     def evaluate_position(self, board, colour):
69         """
70             Evaluates the positional score for a given colour.
71
72         Args:
73             board (Board): The current board state.
74             colour (Colour): The colour to evaluate.
75
76         Returns:
77             int: Score representing positional advantage/disadvantage.
78         """
79         score = 0
80
81         for piece in Piece:
82             if piece == Piece.SPHINX:
83                 continue
84
85             piece_bitboard = board.bitboards.get_piece_bitboard(piece, colour)
86
87             for bitboard in occupied_squares(piece_bitboard):
88                 index = bitboard_to_index(bitboard)
89                 # Flip PSQT if using from blue player's perspective
90                 index = FLIP[index] if colour == Colour.BLUE else index
91
92                 score += PSQT[piece][index] * Score.POSITION
93
94         return score
95
96     def evaluate_mobility(self, board, colour):
97         """
98             Evaluates the mobility score for a given colour.
99
100            Args:
101                board (Board): The current board state.
```

```

101         colour (Colour): The colour to evaluate.
102
103     Returns:
104         int: Score on numerical representation of mobility.
105         """
106
107     number_of_moves = board.get_mobility(colour)
108     return number_of_moves * Score.MOVE
109
110 def evaluate_pharaoh_safety(self, board, colour):
111     """
112     Evaluates the safety of the Pharaoh for a given colour.
113
114     Args:
115         board (Board): The current board state.
116         colour (Colour): The colour to evaluate.
117
118     Returns:
119         int: Score representing mobility of the Pharaoh.
120         """
121
122     pharaoh_bitboard = board.bitboards.get_piece_bitboard(Piece.PHARAOH,
123     colour)
124
125     if pharaoh_bitboard:
126         pharaoh_available_moves = pop_count(board.get_valid_squares(
127             pharaoh_bitboard, colour))
128         return (8 - pharaoh_available_moves) * Score.PHARAOH_SAFETY
129     else:
130         return 0

```

### 3.6.6 Multithreading

As described in Section 2.2.6, when the game starts, a `CPUThread` object is created with the selected CPU. The `start` method is called whenever it is the CPU’s turn, passing the board as an argument to work on. Each run is also given a random ID, to ensure that only the right search is able to be forcibly terminated early. Using **multithreading** allows the game MVC to continue running smoothly while the CPU calculates its moves on a separate thread.

`cpu_thread.py`

```

1 import threading
2 import time
3 from data.managers.logs import initialise_logger
4
5 logger = initialise_logger(__name__)
6
7 class CPUThread(threading.Thread):
8     def __init__(self, cpu, verbose=False):
9         super().__init__()
10        self._stop_event = threading.Event()
11        self._running = True
12        self._verbose = verbose
13        self.daemon = True
14
15        self._board = None
16        self._cpu = cpu
17        self._id = None
18
19    def kill_thread(self):
20        """
21        Kills the CPU and terminates the thread by stopping the run loop.
22        """

```

```

23         self._stop_cpu(force=True)
24         self._running = False
25
26     def stop_cpu(self, id=None, force=False):
27         """
28             Kills the CPU's move search.
29
30         Args:
31             id (int, optional): Id of search to kill, only kills if matching.
32             force (bool, optional): Forcibly kill search regardless of id.
33         """
34         if self._id == id or force:
35             self._stop_event.set()
36             self._board = None
37
38     def start_cpu(self, board, id=None):
39         """
40             Starts the CPU's move search.
41
42         Args:
43             board (Board): The current board state.
44             id (int, optional): Id of current search.
45         """
46         self._stop_event.clear()
47         self._board = board
48         self._id = id
49
50     def run(self):
51         """
52             Periodically checks if the board variable is set.
53             If it is, then starts CPU search.
54         """
55         while self._running:
56             if self._board and self._cpu:
57                 self._cpu.find_move(self._board, self._stop_event)
58                 self._stop_cpu()
59             else:
60                 time.sleep(1)
61                 if self._verbose:
62                     logger.debug(f'(CPUThread.run) Thread {threading.get_native_id()} idling...')


```

### 3.6.7 Zobrist Hashing

As described in Section 2.2.2, the `zobristHasher` class provides methods to successively `hash` a given board for every move played, with the initial hash being generated in the `Board` class.

`zobrist_hasher.py`

```

1  from random import randint
2  from data.helpers.bitboard_helpers import bitboard_to_index
3  from data.utils.enums import Piece, Colour, Rotation
4
5  # Initialise random values for each piece type on every square
6  # (5 x 2 colours) pieces + 4 rotations, for 80 squares
7  zobrist_table = [[randint(0, 2 ** 64) for i in range(14)] for j in range(80)]
8  # Hash for when the red player's move
9  red_move_hash = randint(0, 2 ** 64)
10
11 # Maps piece to the correct random value
12 piece_lookup = {


```

```

13     Colour.BLUE: {
14         piece: i for i, piece in enumerate(Piece)
15     },
16     Colour.RED: {
17         piece: i + 5 for i, piece in enumerate(Piece)
18     },
19 }
20
21 # Maps rotation to the correct random value
22 rotation_lookup = {
23     rotation: i + 10 for i, rotation in enumerate(Rotation)
24 }
25
26 class ZobristHasher:
27     def __init__(self):
28         self.hash = 0
29
30     def get_piece_hash(self, index, piece, colour):
31         """
32             Gets the random value for the piece type on the given square.
33
34         Args:
35             index (int): The index of the square.
36             piece (Piece): The piece on the square.
37             colour (Colour): The colour of the piece.
38
39         Returns:
40             int: A 64-bit value.
41         """
42         piece_index = piece_lookup[colour][piece]
43         return zobrist_table[index][piece_index]
44
45     def get_rotation_hash(self, index, rotation):
46         """
47             Gets the random value for the rotation on the given square.
48
49         Args:
50             index (int): The index of the square.
51             rotation (Rotation): The rotation on the square.
52             colour (Colour): The colour of the piece.
53
54         Returns:
55             int: A 64-bit value.
56         """
57         rotation_index = rotation_lookup[rotation]
58         return zobrist_table[index][rotation_index]
59
60     def apply_piece_hash(self, bitboard, piece, colour):
61         """
62             Updates the Zobrist hash with a new piece.
63
64         Args:
65             bitboard (int): The bitboard representation of the square.
66             piece (Piece): The piece on the square.
67             colour (Colour): The colour of the piece.
68         """
69         index = bitboard_to_index(bitboard)
70         piece_hash = self.get_piece_hash(index, piece, colour)
71         self.hash ^= piece_hash
72
73     def apply_rotation_hash(self, bitboard, rotation):
74         """Updates the Zobrist hash with a new rotation.

```

```

75
76     Args:
77         bitboard (int): The bitboard representation of the square.
78         rotation (Rotation): The rotation on the square.
79         """
80     index = bitboard_to_index(bitboard)
81     rotation_hash = self.get_rotation_hash(index, rotation)
82     self.hash ^= rotation_hash
83
84     def apply_red_move_hash(self):
85         """
86             Applies the Zobrist hash for the red player's move.
87         """
88     self.hash ^= red_move_hash

```

### 3.6.8 Cache

As described in Section 2.2.2, the `TranspositionTable` class maintains an internal hash map to store already evaluated board positions. Since I have chosen to use a dictionary instead of an array, the Zobrist hash for the board can be used as the keys for the dictionary as is, as it doesn't correspond to the index position as will be the case if I use an array.

`transposition_table.py`

```

1  from data.utils.enums import TranspositionFlag
2
3  class TranspositionEntry:
4      def __init__(self, score, move, flag, hash_key, depth):
5          self.score = score
6          self.move = move
7          self.flag = flag
8          self.hash_key = hash_key
9          self.depth = depth
10
11 class TranspositionTable:
12     def __init__(self, max_entries=100000):
13         self._max_entries = max_entries
14         self._table = dict()
15
16     def calculate_entry_index(self, hash_key):
17         """
18             Gets the dictionary key for a given Zobrist hash.
19
20         Args:
21             hash_key (int): A Zobrist hash.
22
23         Returns:
24             int: Key for the given hash.
25         """
26
27     return hash_key
28
29     def insert_entry(self, score, move, hash_key, depth, alpha, beta):
30         """
31             Inserts an entry into the transposition table.
32
33         Args:
34             score (int): The evaluation score.
35             move (Move): The best move found.
36             hash_key (int): The Zobrist hash key.
37             depth (int): The depth of the search.
38             alpha (int): The upper bound value.

```

```

38         beta (int): The lower bound value.
39
40     Raises:
41         Exception: Invalid depth or score.
42     """
43     if depth == 0 or alpha < score < beta:
44         flag = TranspositionFlag.EXACT
45         score = score
46     elif score <= alpha:
47         flag = TranspositionFlag.UPPER
48         score = alpha
49     elif score >= beta:
50         flag = TranspositionFlag.LOWER
51         score = beta
52     else:
53         raise Exception('(TranspositionTable.insert_entry)')
54
55     self._table[self.calculate_entry_index(hash_key)] = TranspositionEntry(
56     score, move, flag, hash_key, depth)
57
58     if len(self._table) > self._max_entries:
59         # Removes the longest-existing entry to free up space for more up-to-
60         # date entries
61         # Expression to remove leftmost item taken from https://docs.python.
62         # org/3/library/collections.html#ordereddict-objects
63         (k := next(iter(self._table))), self._table.pop(k))
64
65     def get_entry(self, hash_key, depth, alpha, beta):
66         """
67         Gets an entry from the transposition table.
68
69         Args:
70             hash_key (int): The Zobrist hash key.
71             depth (int): The depth of the search.
72             alpha (int): The alpha value for pruning.
73             beta (int): The beta value for pruning.
74
75         Returns:
76             tuple[int, Move] | tuple[None, None]: The evaluation score and the
77             best move found, if entry exists.
78         """
79         index = self.calculate_entry_index(hash_key)
80
81         if index not in self._table:
82             return None, None
83
84         entry = self._table[index]
85
86         if entry.hash_key == hash_key and entry.depth >= depth:
87             if entry.flag == TranspositionFlag.EXACT:
88                 return entry.score, entry.move
89
90             if entry.flag == TranspositionFlag.LOWER and entry.score >= beta:
91                 return entry.score, entry.move
92
93         if entry.flag == TranspositionFlag.UPPER and entry.score <= alpha:
94             return entry.score, entry.move
95
96         return None, None

```

## 3.7 States

To switch between different screens, I have decided to use a state machine design pattern. This ensures that there is only one main game loop controlling movement between states, handled with the `Control` object. All `State` object contain a `next` and `previous` attribute to tell the `Control` class which screen to switch to, which also calls all `State` methods accordingly.

The `startup` method is called when switched to a new state, and `cleanup` when exiting. Within the `startup` function, the state widgets dictionary is passed into a `WidgetGroup` object. The `process_event` method is called on the `WidgetGroup` every frame to process user input, and handle the returned events accordingly. The `WidgetGroup` object can therefore be thought of as a controller, and the state as the model, and the widgets as the view.

### 3.7.1 Review

The `Review` state uses this logic to allow users to scroll through moves in their past games. All moves are stored in two `stacks`, as described in Section 2.3.3, and exchanged using `pop` and `append` (push) methods.

`review.py`

```

1 import pygame
2 from collections import deque
3 from data.states.game.components.capture_draw import CaptureDraw
4 from data.states.game.components.piece_group import PieceGroup
5 from data.states.game.components.laser_draw import LaserDraw
6 from data.helpers.bitboard_helpers import bitboard_to_coords
7 from data.helpers.browser_helpers import get_winner_string
8 from data.states.review.widget_dict import REVIEW_WIDGETS
9 from data.states.game.components.board import Board
10 from data.utils.event_types import ReviewEventType
11 from data.components.game_entry import GameEntry
12 from data.managers.logs import initialise_logger
13 from data.utils.constants import ShaderType
14 from data.managers.window import window
15 from data.utils.assets import MUSIC
16 from data.utils.enums import Colour
17 from data.control import _State
18
19 logger = initialise_logger(__name__)
20
21 class Review(_State):
22     def __init__(self):
23         super().__init__()
24
25         self._moves = deque()
26         self._popped_moves = deque()
27         self._game_info = {}
28
29         self._board = None
30         self._piece_group = None
31         self._laser_draw = None
32         self._capture_draw = None
33
34     def cleanup(self):
35         """
36             Cleanup function. Clears shader effects.
37         """
38         super().cleanup()
39

```

```
40         window.clear_apply_arguments(ShaderType.BLOOM)
41         window.clear_effect(ShaderType.RAYS)
42
43     return None
44
45 def startup(self, persist):
46     """
47     Startup function. Initialises all objects, widgets and game data.
48
49     Args:
50         persist (dict): Dict containing game entry data.
51     """
52     super().startup(REVIEW_WIDGETS, MUSIC['review'])
53
54     window.set_apply_arguments(ShaderType.BASE, background_type=ShaderType.
55     BACKGROUND_WAVES)
56     window.set_apply_arguments(ShaderType.BLOOM, highlight_colours=[(pygame.
57     Color('0x95e0cc')).rgb, pygame.Color('0xf14e52').rgb], colour_intensity=0.8)
58     REVIEW_WIDGETS['help'].kill()
59
60     self._moves = deque(GameEntry.parse_moves(persist.pop('moves', '')))
61     self._popped_moves = deque()
62     self._game_info = persist
63
64     self._board = Board(self._game_info['start_fen_string'])
65     self._piece_group = PieceGroup()
66     self._laser_draw = LaserDraw(self.board_position, self.board_size)
67     self._capture_draw = CaptureDraw(self.board_position, self.board_size)
68
69     self.initialise_widgets()
70     self.simulate_all_moves()
71     self.refresh_pieces()
72     self.refresh_widgets()
73
74     self.draw()
75
76 @property
77 def board_position(self):
78     return REVIEW_WIDGETS['chessboard'].position
79
80 @property
81 def board_size(self):
82     return REVIEW_WIDGETS['chessboard'].size
83
84 @property
85 def square_size(self):
86     return self.board_size[0] / 10
87
88 def initialise_widgets(self):
89     """
90     Initializes the widgets for a new game.
91     """
92     REVIEW_WIDGETS['move_list'].reset_move_list()
93     REVIEW_WIDGETS['move_list'].kill()
94     REVIEW_WIDGETS['scroll_area'].set_image()
95
96     REVIEW_WIDGETS['winner_text'].set_text(f'WINNER: {get_winner_string(self.
97     _game_info["winner"])}')
98     REVIEW_WIDGETS['blue_piece_display'].reset_piece_list()
99     REVIEW_WIDGETS['red_piece_display'].reset_piece_list()

100    if self._game_info['time_enabled']:
```

```

99         REVIEW_WIDGETS['timer_disabled_text'].kill()
100    else:
101        REVIEW_WIDGETS['blue_timer'].kill()
102        REVIEW_WIDGETS['red_timer'].kill()
103
104    def refresh_widgets(self):
105        """
106            Refreshes the widgets after every move.
107        """
108        REVIEW_WIDGETS['move_number_text'].set_text(f'MOVE NO: {(len(self._moves) / 2:.1f) / ((len(self._moves) + len(self._popped_moves)) / 2:.1f)}')
109        REVIEW_WIDGETS['move_colour_text'].set_text(f'{self.calculate_colour().name} TO MOVE')
110
111        if self._game_info['time_enabled']:
112            if len(self._moves) == 0:
113                REVIEW_WIDGETS['blue_timer'].set_time(float(self._game_info['time']) * 60 * 1000)
114                REVIEW_WIDGETS['red_timer'].set_time(float(self._game_info['time']) * 60 * 1000)
115            else:
116                REVIEW_WIDGETS['blue_timer'].set_time(float(self._moves[-1]['blue_time']) * 60 * 1000)
117                REVIEW_WIDGETS['red_timer'].set_time(float(self._moves[-1]['red_time']) * 60 * 1000)
118
119        REVIEW_WIDGETS['scroll_area'].set_image()
120
121    def refresh_pieces(self):
122        """
123            Refreshes the pieces on the board.
124        """
125        self._piece_group.initialise_pieces(self._board.get_piece_list(), self.board_position, self.board_size)
126
127    def simulate_all_moves(self):
128        """
129            Simulates all moves at the start of every game to obtain laser results and
130            fill up piece display and move list widgets.
131        """
132        for index, move_dict in enumerate(self._moves):
133            laser_result = self._board.apply_move(move_dict['move'], fire_laser=True)
134            self._moves[index]['laser_result'] = laser_result
135
136            if laser_result.hit_square_bitboard:
137                if laser_result.piece_colour == Colour.BLUE:
138                    REVIEW_WIDGETS['red_piece_display'].add_piece(laser_result.piece_hit)
139                elif laser_result.piece_colour == Colour.RED:
140                    REVIEW_WIDGETS['blue_piece_display'].add_piece(laser_result.piece_hit)
141
142            REVIEW_WIDGETS['move_list'].append_to_move_list(move_dict['unparsed_move'])
143
144    def calculate_colour(self):
145        """
146            Calculates the current active colour to move.
147
148            Returns:
149                Colour: The current colour to move.

```

```

149     """
150     if self._game_info['start_fen_string'][-1].lower() == 'b':
151         initial_colour = Colour.BLUE
152     elif self._game_info['start_fen_string'][-1].lower() == 'r':
153         initial_colour = Colour.RED
154
155     if len(self._moves) % 2 == 0:
156         return initial_colour
157     else:
158         return initial_colour.get_flipped_colour()
159
160     def handle_move(self, move, add_piece=True):
161         """
162             Handles applying or undoing a move.
163
164             Args:
165                 move (dict): The move to handle.
166                 add_piece (bool): Whether to add the captured piece to the display.
167             Defaults to True.
168
169             laser_result = move['laser_result']
170             active_colour = self.calculate_colour()
171             self._laser_draw.add_laser(laser_result, laser_colour=active_colour)
172
173             if laser_result.hit_square_bitboard:
174                 if laser_result.piece_colour == Colour.BLUE:
175                     if add_piece:
176                         REVIEW_WIDGETS['red_piece_display'].add_piece(laser_result.
177                             piece_hit)
178                     else:
179                         REVIEW_WIDGETS['red_piece_display'].remove_piece(laser_result.
180                             piece_hit)
181                     elif laser_result.piece_colour == Colour.RED:
182                         if add_piece:
183                             REVIEW_WIDGETS['blue_piece_display'].add_piece(laser_result.
184                             piece_hit)
185                     else:
186                         REVIEW_WIDGETS['blue_piece_display'].remove_piece(laser_result
187                             .piece_hit)
188
189                     self._capture_draw.add_capture(
190                         laser_result.piece_hit,
191                         laser_result.piece_colour,
192                         laser_result.piece_rotation,
193                         bitboard_to_coords(laser_result.hit_square_bitboard),
194                         laser_result.laser_path[0][0],
195                         active_colour,
196                         shake=False
197                     )
198
199     def update_laser_mask(self):
200         """
201             Updates the laser mask for the light rays effect.
202
203             temp_surface = pygame.Surface(window.size, pygame.SRCALPHA)
204             self._piece_group.draw(temp_surface)
205             mask = pygame.mask.from_surface(temp_surface, threshold=127)
206             mask_surface = mask.to_surface(unsetColor=(0, 0, 255), setColor=(255,
207                 0, 0, 255))
208
209             window.set_apply_arguments(ShaderType.RAYS, occlusion=mask_surface)
210
211

```

```

205     def get_event(self, event):
206         """
207             Processes Pygame events.
208
209             Args:
210                 event (pygame.event.Event): The event to handle.
211             """
212         if event.type in [pygame.MOUSEBUTTONUP, pygame.KEYDOWN]:
213             REVIEW_WIDGETS['help'].kill()
214
215         widget_event = self._widget_group.process_event(event)
216
217         if widget_event is None:
218             return
219
220         match widget_event.type:
221             case None:
222                 return
223
224             case ReviewEventType.MENU_CLICK:
225                 self.next = 'menu'
226                 self.done = True
227
228             case ReviewEventType.PREVIOUS_CLICK:
229                 if len(self._moves) == 0:
230                     return
231
232                 # Pop last applied move off first stack
233                 move = self._moves.pop()
234                 # Pushed onto second stack
235                 self._popped_moves.append(move)
236
237                 # Undo last applied move
238                 self._board.undo_move(move['move'], laser_result=move['laser_result'])
239                 self.handle_move(move, add_piece=False)
240                 REVIEW_WIDGETS['move_list'].pop_from_move_list()
241
242                 self.refresh_pieces()
243                 self.refresh_widgets()
244                 self.update_laser_mask()
245
246             case ReviewEventType.NEXT_CLICK:
247                 if len(self._popped_moves) == 0:
248                     return
249
250                 # Peek at second stack to get last undone move
251                 move = self._popped_moves[-1]
252
253                 # Reapply last undone move
254                 self._board.apply_move(move['move'])
255                 self.handle_move(move, add_piece=True)
256                 REVIEW_WIDGETS['move_list'].append_to_move_list(move['unparsed_move'])
257
258                 # Pop last undone move from second stack
259                 self._popped_moves.pop()
260                 # Push onto first stack
261                 self._moves.append(move)
262
263                 self.refresh_pieces()
264                 self.refresh_widgets()

```

```

265         self.update_laser_mask()
266
267     case ReviewEventType.HELP_CLICK:
268         self._widget_group.add(REVIEW_WIDGETS['help'])
269         self._widget_group.handle_resize(window.size)
270
271     def handle_resize(self):
272         """
273             Handles resizing of the window.
274         """
275
276         super().handle_resize()
277         self._piece_group.handle_resize(self.board_position, self.board_size)
278         self._laser_draw.handle_resize(self.board_position, self.board_size)
279         self._capture_draw.handle_resize(self.board_position, self.board_size)
280
281         if self._laser_draw.firing:
282             self.update_laser_mask()
283
284     def draw(self):
285         """
286             Draws all components onto the window screen.
287         """
288
289         self._capture_draw.update()
290         self._widget_group.draw()
291         self._piece_group.draw(window.screen)
292         self._laser_draw.draw(window.screen)
293         self._capture_draw.draw(window.screen)

```

## 3.8 Database

This section outlines my database implementation using the Python module sqlite3.

### 3.8.1 DDL

As mentioned in Section 2.3.1, the `migrations` directory contains a collection of Python scripts that edit the game table schema. The files are named with a description of their changes and datetime for organisational purposes.

`create_games_table_19112024.py`

```

1 import sqlite3
2 from pathlib import Path
3
4 database_path = (Path(__file__).parent / '../database.db').resolve()
5
6 def upgrade():
7     """
8         Upgrade function to create games table.
9     """
10    connection = sqlite3.connect(database_path)
11    cursor = connection.cursor()
12
13    cursor.execute('''
14        CREATE TABLE games(
15            id INTEGER PRIMARY KEY,
16            cpu_enabled INTEGER NOT NULL,
17            cpu_depth INTEGER,
18            winner INTEGER,
19            time_enabled INTEGER NOT NULL,

```

```

20         time REAL,
21         number_of_ply INTEGER NOT NULL,
22         moves TEXT NOT NULL
23     )
24   ...
25
26 connection.commit()
27 connection.close()
28
29 def downgrade():
30     """
31     Downgrade function to revert table creation.
32     """
33     connection = sqlite3.connect(database_path)
34     cursor = connection.cursor()
35
36     cursor.execute('''
37         DROP TABLE games
38     ''')
39
40     connection.commit()
41     connection.close()
42
43 upgrade()
44 # downgrade()

```

Using the `ALTER` command allows me to rename table columns.

```

change_fen_string_column_name_23122024.py
1 import sqlite3
2 from pathlib import Path
3
4 database_path = (Path(__file__).parent / '../database.db').resolve()
5
6 def upgrade():
7     """
8     Upgrade function to rename fen_string column.
9     """
10    connection = sqlite3.connect(database_path)
11    cursor = connection.cursor()
12
13    cursor.execute('''
14        ALTER TABLE games RENAME COLUMN fen_string TO final_fen_string
15    ''')
16
17    connection.commit()
18    connection.close()
19
20 def downgrade():
21     """
22     Downgrade function to revert fen_string column renaming.
23     """
24    connection = sqlite3.connect(database_path)
25    cursor = connection.cursor()
26
27    cursor.execute('''
28        ALTER TABLE games RENAME COLUMN final_fen_string TO fen_string
29    ''')
30
31    connection.commit()
32    connection.close()

```

```

33
34 upgrade()
35 # downgrade()

3.8.2 DML

As described in Section 2.3.1, this file provides functions to help modify the database, with Aggregate and Window commands used to retrieve the number of rows and sort them to be returned. database_helpers.py

1 import sqlite3
2 from pathlib import Path
3 from datetime import datetime
4
5 database_path = (Path(__file__).parent / '../database/database.db').resolve()
6
7 def insert_into_games(game_entry):
8     """
9         Inserts a new row into games table.
10
11     Args:
12         game_entry (GameEntry): GameEntry object containing game information.
13     """
14     connection = sqlite3.connect(database_path, detect_types=sqlite3.
15         PARSE_DECLTYPES)
16     connection.row_factory = sqlite3.Row
17     cursor = connection.cursor()
18
19     # Datetime added for created_dt column
20     game_entry = (*game_entry, datetime.now())
21
22     cursor.execute('''
23         INSERT INTO games (cpu_enabled, cpu_depth, winner, time_enabled, time,
24         number_of_ply, moves, start_fen_string, final_fen_string, created_dt)
25         VALUES (?, ?, ?, ?, ?, ?, ?, ?, ?, ?, ?)
26     ''', game_entry)
27
28     connection.commit()
29
30     # Return inserted row
31     cursor.execute('''
32         SELECT * FROM games WHERE id = LAST_INSERT_ROWID()
33     ''')
34     inserted_row = cursor.fetchone()
35
36     connection.close()
37
38     return dict(inserted_row)
39
40 def get_all_games():
41     """
42         Get all rows in games table.
43
44     Returns:
45         list[dict]: List of game entries represented as dictionaries.
46     """
47     connection = sqlite3.connect(database_path, detect_types=sqlite3.
48         PARSE_DECLTYPES)
49     connection.row_factory = sqlite3.Row
50     cursor = connection.cursor()

```

```

48
49     cursor.execute('''
50         SELECT * FROM games
51     ''')
52     games = cursor.fetchall()
53
54     connection.close()
55
56     return [dict(game) for game in games]
57
58 def delete_all_games():
59     """
60     Delete all rows in games table.
61     """
62     connection = sqlite3.connect(database_path)
63     cursor = connection.cursor()
64
65     cursor.execute('''
66         DELETE FROM games
67     ''')
68
69     connection.commit()
70     connection.close()
71
72 def delete_game(id):
73     """
74     Deletes specific row in games table using id attribute.
75
76     Args:
77         id (int): Primary key for row.
78     """
79     connection = sqlite3.connect(database_path)
80     cursor = connection.cursor()
81
82     cursor.execute('''
83         DELETE FROM games WHERE id = ?
84     ''', (id,))
85
86     connection.commit()
87     connection.close()
88
89 def get_ordered_games(column, ascend=True, start_row=1, end_row=10):
90     """
91     Get specific number of rows from games table ordered by a specific column(s).
92
93     Args:
94         column (_type_): Column to sort by.
95         ascend (bool, optional): Sort ascending or descending. Defaults to True.
96         start_row (int, optional): First row returned. Defaults to 1.
97         end_row (int, optional): Last row returned. Defaults to 10.
98
99     Raises:
100         ValueError: If ascend argument or column argument are invalid types.
101
102     Returns:
103         list[dict]: List of ordered game entries represented as dictionaries.
104     """
105     if not isinstance(ascend, bool) or not isinstance(column, str):
106         raise ValueError('database_helpers.get_ordered_games) Invalid input
arguments!')
107

```

```

108     connection = sqlite3.connect(database_path, detect_types=sqlite3.
109         PARSE_DECLTYPES)
110     connection.row_factory = sqlite3.Row
111     cursor = connection.cursor()
112
113     # Match ascend_bool to correct SQL keyword
114     if ascend:
115         ascend_arg = 'ASC'
116     else:
117         ascend_arg = 'DESC'
118
119     # Partition by winner, then order by time and number_of_ply
120     if column == 'winner':
121         cursor.execute(f"""
122             SELECT * FROM
123                 (SELECT ROW_NUMBER() OVER (
124                     PARTITION BY winner
125                         ORDER BY time {ascend_arg}, number_of_ply {ascend_arg}
126                     ) AS row_num, * FROM games)
127             WHERE row_num >= ? AND row_num <= ?
128             ''', (start_row, end_row))
129     else:
130         # Order by time or number_of_ply only
131         cursor.execute(f"""
132             SELECT * FROM
133                 (SELECT ROW_NUMBER() OVER (
134                     ORDER BY {column} {ascend_arg}
135                     ) AS row_num, * FROM games)
136             WHERE row_num >= ? AND row_num <= ?
137             ''', (start_row, end_row))
138
139     games = cursor.fetchall()
140
141     connection.close()
142
143     return [dict(game) for game in games]
144
145     def get_number_of_games():
146         """
147             Returns:
148                 int: Number of rows in the games.
149         """
150
151         connection = sqlite3.connect(database_path)
152         cursor = connection.cursor()
153
154         cursor.execute("""
155             SELECT COUNT(ROWID) FROM games
156             """)
157
158         result = cursor.fetchall()[0][0]
159
160         connection.close()
161
162         return result
163
164     # delete_all_games()

```

## 3.9 Shaders

### 3.9.1 Shader Manager

The `ShaderManager` class is responsible for handling all shader passes, handling the Pygame display, and combining both and drawing the result to the window screen. The class also **inherits** from the `SMPProtocol` class, an **interface** class containing all required `ShaderManager` methods and attributes to aid with syntax highlighting in the fragment shader classes.

Fragment shaders such as `Bloom` are applied by default, and others such as `Ray` are applied during runtime through calling methods on `shaderManager`, and adding the appropriate fragment shader class to the internal shader pass list.

Each fragment shader is written in GLSL and stored in a `.frag` file, and read into the `ShaderManager` class.

`shader.py`

```

1  from pathlib import Path
2  from array import array
3  import moderngl
4  from data.shaders.classes import shader_pass_lookup
5  from data.shaders.protocol import SMPProtocol
6  from data.utils.constants import ShaderType
7
8  shader_path = (Path(__file__).parent / '../shaders/').resolve()
9
10 SHADER_PRIORITY = [
11     ShaderType.CRT,
12     ShaderType.SHAKE,
13     ShaderType.BLOOM,
14     ShaderType.CHROMATIC_ABBREVIATION,
15     ShaderType.RAYS,
16     ShaderType.GRAYSCALE,
17     ShaderType.BASE,
18 ]
19
20 pygame_quad_array = array('f', [
21     -1.0, 1.0, 0.0, 0.0,
22     1.0, 1.0, 0.0, 0.0,
23     -1.0, -1.0, 0.0, 1.0,
24     1.0, -1.0, 1.0, 1.0,
25 ])
26
27 opengl_quad_array = array('f', [
28     -1.0, -1.0, 0.0, 0.0,
29     1.0, -1.0, 1.0, 0.0,
30     -1.0, 1.0, 0.0, 1.0,
31     1.0, 1.0, 1.0, 1.0,
32 ])
33
34 class ShaderManager(SMPProtocol):
35     def __init__(self, ctx: moderngl.Context, screen_size):
36         self._ctx = ctx
37         self._ctx.gc_mode = 'auto'
38
39         self._screen_size = screen_size
40         self._opengl_buffer = self._ctx.buffer(data=opengl_quad_array)
41         self._pygame_buffer = self._ctx.buffer(data=pygame_quad_array)
42         self._shader_list = [ShaderType.BASE]
43
44         self._vert_shaders = {}

```

```

45         self._frag_shaders = {}
46         self._programs = {}
47         self._vaos = {}
48         self._textures = {}
49         self._shader_passes = {}
50         self.framebuffers = {}
51
52         self.load_shader(ShaderType.BASE)
53         self.load_shader(ShaderType._CALIBRATE)
54         self.create_framebuffer(ShaderType._CALIBRATE)
55
56     def load_shader(self, shader_type, **kwargs):
57         """
58             Loads a given shader by creating a VAO reading the corresponding .frag
59             file.
60
61             Args:
62                 shader_type (ShaderType): The type of shader to load.
63                 **kwargs: Additional arguments passed when initialising the fragment
64             shader class.
65             """
66
67         self._shader_passes[shader_type] = shader_pass_lookup[shader_type](self,
68         **kwargs)
69         self.create_vao(shader_type)
70
71     def clear_shaders(self):
72         """
73             Clears the shader list, leaving only the base shader.
74             """
75
76         self._shader_list = [ShaderType.BASE]
77
78     def create_vao(self, shader_type):
79         """
80             Creates a vertex array object (VAO) for the given shader type.
81
82             Args:
83                 shader_type (ShaderType): The type of shader.
84
85             frag_name = shader_type[1:] if shader_type[0] == '_' else shader_type
86             vert_path = Path(shader_path / 'vertex/base.vert').resolve()
87             frag_path = Path(shader_path / f'fragments/{frag_name}.frag').resolve()
88
89             self._vert_shaders[shader_type] = vert_path.read_text()
90             self._frag_shaders[shader_type] = frag_path.read_text()
91
92             program = self._ctx.program(vertex_shader=self._vert_shaders[shader_type],
93             fragment_shader=self._frag_shaders[shader_type])
94             self._programs[shader_type] = program
95
96             if shader_type == ShaderType._CALIBRATE:
97                 self._vaos[shader_type] = self._ctx.vertex_array(self._programs[
98                     shader_type], [(self._pygame_buffer, '2f 2f', 'vert', 'texCoords')])
99             else:
100                 self._vaos[shader_type] = self._ctx.vertex_array(self._programs[
101                     shader_type], [(self._opengl_buffer, '2f 2f', 'vert', 'texCoords')]))
102
103     def create_framebuffer(self, shader_type, size=None, filter=moderngl.NEAREST):
104         """
105             Creates a framebuffer for the given shader type.
106
107             Args:
108                 shader_type (ShaderType): The type of shader.

```

```

101         size (tuple[int, int], optional): The size of the framebuffer.
102         Defaults to screen size.
103         filter (moderngl.Filter, optional): The texture filter. Defaults to
104         NEAREST.
105         """
106         texture_size = size or self._screen_size
107         texture = self._ctx.texture(size=texture_size, components=4)
108         texture.filter = (filter, filter)
109
110         self._textures[shader_type] = texture
111         self.framebuffers[shader_type] = self._ctx.framebuffer(color_attachments=[
112             self._textures[shader_type]])
113
114     def render_to_fbo(self, shader_type, texture, output_fbo=None, program_type=
115         None, use_image=True, **kwargs):
116         """
117         Applies the shaders and renders the resultant texture to a framebuffer
118         object (FBO).
119
120         Args:
121             shader_type (ShaderType): The type of shader.
122             texture (moderngl.Texture): The texture to render.
123             output_fbo (moderngl.Framebuffer, optional): The output framebuffer.
124             Defaults to None.
125             program_type (ShaderType, optional): The program type. Defaults to
126             None.
127             use_image (bool, optional): Whether to use the image uniform. Defaults
128             to True.
129             **kwargs: Additional uniforms for the fragment shader.
130             """
131         fbo = output_fbo or self.framebuffers[shader_type]
132         program = self._programs[program_type] if program_type else self._programs
133         [shader_type]
134         vao = self._vaos[program_type] if program_type else self._vaos[shader_type]
135
136         fbo.use()
137         texture.use(0)
138
139         if use_image:
140             program['image'] = 0
141             for uniform, value in kwargs.items():
142                 program[uniform] = value
143
144         vao.render(mode=moderngl.TRIANGLE_STRIP)
145
146     def apply_shader(self, shader_type, **kwargs):
147         """
148         Applies a shader of the given type and adds it to the list.
149
150         Args:
151             shader_type (ShaderType): The type of shader to apply.
152
153             Raises:
154                 ValueError: If the shader is already being applied.
155             """
156         if shader_type in self._shader_list:
157             return
158
159         self.load_shader(shader_type, **kwargs)
160         self._shader_list.append(shader_type)
161
162         # Sort shader list based on the order in SHADER_PRIORITY, so that more

```

```

    important shaders are applied first
154     self._shader_list.sort(key=lambda shader: -SHADER_PRIORITY.index(shader))
155
156     def remove_shader(self, shader_type):
157         """
158             Removes a shader of the given type from the list.
159
160         Args:
161             shader_type (ShaderType): The type of shader to remove.
162         """
163         if shader_type in self._shader_list:
164             self._shader_list.remove(shader_type)
165
166     def render_output(self):
167         """
168             Renders the final output to the screen.
169         """
170         # Render to the screen framebuffer
171         self._ctx.screen.use()
172
173         # Take the texture of the last framebuffer to be rendered to, and render
174         # that to the screen framebuffer
175         output_shader_type = self._shader_list[-1]
176         self.get_fbo_texture(output_shader_type).use(0)
177         self._programs[output_shader_type]['image'] = 0
178
179         self._vaos[output_shader_type].render(mode=moderngl.TRIANGLE_STRIP)
180
181     def get_fbo_texture(self, shader_type):
182         """
183             Gets the texture from the specified shader type's FBO.
184
185         Args:
186             shader_type (ShaderType): The type of shader.
187
188         Returns:
189             moderngl.Texture: The texture from the FBO.
190         """
191
192         return self.framebuffers[shader_type].color_attachments[0]
193
194     def calibrate_pygame_surface(self, pygame_surface):
195         """
196             Converts the Pygame window surface into an OpenGL texture.
197
198         Args:
199             pygame_surface (pygame.Surface): The finished Pygame surface.
200
201         Returns:
202             moderngl.Texture: The calibrated texture.
203
204         texture = self._ctx.texture(pygame_surface.size, 4)
205         texture.filter = (moderngl.NEAREST, moderngl.NEAREST)
206         texture.swizzle = 'BGRA'
207         # Take the Pygame surface's pixel array and draw it to the new texture
208         texture.write(pygame_surface.get_view('1'))
209
210         # ShaderType._CALIBRATE has a VAO containing the pygame_quad_array
211         # coordinates, as Pygame uses different texture coordinates than ModernGL
212         # textures
213         self.render_to_fbo(ShaderType._CALIBRATE, texture)
214
215         return self.get_fbo_texture(ShaderType._CALIBRATE)
216
217

```

```

212     def draw(self, surface, arguments):
213         """
214             Draws the Pygame surface with shaders applied to the screen.
215
216         Args:
217             surface (pygame.Surface): The final Pygame surface.
218             arguments (dict): A dict of { ShaderType: Args } items, containing
219                 keyword arguments for every fragment shader.
220             """
221         self._ctx.viewport = (0, 0, *self._screen_size)
222         texture = self.calibrate_pygame_surface(surface)
223
224         for shader_type in self._shader_list:
225             self._shader_passes[shader_type].apply(texture, **arguments.get(
226                 shader_type, {}))
227             texture = self.get_fbo_texture(shader_type)
228
229         self.render_output()
230
231     def __del__(self):
232         """
233             Cleans up ModernGL resources when the ShaderManager object is deleted.
234             """
235         self.cleanup()
236
237     def cleanup(self):
238         """
239             Cleans up resources used by the ModernGL.
240             Probably unnecessary as the 'auto' garbage collection mode is used.
241             """
242         self._pygame_buffer.release()
243         self._opengl_buffer.release()
244         for program in self._programs:
245             self._programs[program].release()
246         for texture in self._textures:
247             self._textures[texture].release()
248         for vao in self._vaos:
249             self._vaos[vao].release()
250         for framebuffer in self.framebuffers:
251             self.framebuffers[framebuffer].release()
252
253     def handle_resize(self, new_screen_size):
254         """
255             Handles resizing of the screen.
256
257         Args:
258             new_screen_size (tuple[int, int]): The new screen size.
259             """
260         self._screen_size = new_screen_size
261
262         # Recreate all framebuffers to prevent scaling issues
263         for shader_type in self.framebuffers:
264             filter = self._textures[shader_type].filter[0]
265             self.create_framebuffer(shader_type, size=self._screen_size, filter=
266                 filter)

```

### 3.9.2 Bloom

The `Bloom` shader effect is a common shader effect giving the illusion of a bright light. It consists of blurred fringes of light extending from the borders of bright areas. This effect can be achieved

through obtaining all bright areas of the image, applying a Gaussian blur, and blending the blur additively onto the original image.

My `ShaderManager` class works with this multi-pass shader approach by reading the texture from the last shader's framebuffer for each pass.

### Extracting bright colours

The `highlight_brightness` fragment shader extracts all colours that are bright enough to exert the bloom effect.

`highlight_brightness.frag`

```

1 # version 330 core
2
3 in vec2 uvs;
4 out vec4 f_colour;
5
6 uniform sampler2D image;
7 uniform float threshold;
8 uniform float intensity;
9
10 void main() {
11     vec4 pixel = texture(image, uvs);
12     // Dot product used to calculate brightness of a pixel from its RGB values
13     // Values taken from https://en.wikipedia.org/wiki/Relative_luminance
14     float brightness = dot(pixel.rgb, vec3(0.2126, 0.7152, 0.0722));
15     float isBright = step(threshold, brightness);
16
17     f_colour = vec4(vec3(pixel.rgb * intensity) * isBright, 1.0);
18 }
```

### Blur

The `Blur` class implements a two-pass **Gaussian blur**. This is preferably over a one-pass blur, as the complexity is  $O(2n)$ , sampling  $n$  pixels twice, as opposed to  $O(n^2)$ . I have implemented this using the ping-pong technique, with the first pass for blurring the image horizontally, and the second pass for blurring vertically, and the resultant textures being passed repeatedly between two framebuffers.

`blur.py`

```

1 from data.shaders.protocol import SMProtocol
2 from data.utils.constants import ShaderType
3
4 BLUR_ITERATIONS = 4
5
6 class _Blur:
7     def __init__(self, shader_manager: SMProtocol):
8         self._shader_manager = shader_manager
9
10     shader_manager.create_framebuffer(ShaderType._BLUR)
11
12     shader_manager.create_framebuffer("blurPing")
13     shader_manager.create_framebuffer("blurPong")
14
15     def apply(self, texture):
16         """
17             Applies Gaussian blur to a given texture.
18
19             Args:
```

```

20         texture (modernGL.Texture): Texture to blur.
21     """
22     self._shader_manager.get_fbo_texture("blurPong").write(texture.read())
23
24     for _ in range(BLUR_ITERATIONS):
25         # Apply horizontal blur
26         self._shader_manager.render_to_fbo(
27             ShaderType._BLUR,
28             texture=self._shader_manager.get_fbo_texture("blurPong"),
29             output_fbo=self._shader_manager.framebuffers["blurPing"],
30             passes=5,
31             horizontal=True
32         )
33         # Apply vertical blur
34         self._shader_manager.render_to_fbo(
35             ShaderType._BLUR,
36             texture=self._shader_manager.get_fbo_texture("blurPing"), # Use
horizontal blur result as input texture
37             output_fbo=self._shader_manager.framebuffers["blurPong"],
38             passes=5,
39             horizontal=False
40         )
41
42         self._shader_manager.render_to_fbo(ShaderType._BLUR, self._shader_manager.
get_fbo_texture("blurPong"))

```

**blur.frag**

```

1 // Modified from https://learnopengl.com/Advanced-Lighting/Bloom
2 #version 330 core
3
4 in vec2 uvs;
5 out vec4 f_colour;
6
7 uniform sampler2D image;
8 uniform bool horizontal;
9 uniform int passes;
10 uniform float weight[5] = float[] (0.227027, 0.1945946, 0.1216216, 0.054054,
0.016216);
11
12 void main() {
13     vec2 offset = 1.0 / textureSize(image, 0);
14     vec3 result = texture(image, uvs).rgb * weight[0];
15
16     if (horizontal) {
17         for (int i = 1 ; i < passes ; ++i) {
18             result += texture(image, uvs + vec2(offset.x * i, 0.0)).rgb * weight[i];
19         }
20     }
21     else {
22         for (int i = 1 ; i < passes ; ++i) {
23             result += texture(image, uvs + vec2(0.0, offset.y * i)).rgb * weight[i];
24         }
25     }
26 }
27
28

```

```

29     f_colour = vec4(result, 1.0);
30 }

```

## Combining

The `Bloom` class combines the two operations, taking the highlighted areas, blurs them, and adds the RGB values for the final result onto the original texture to simulate bloom.

`bloom.py`

```

1  from data.shaders.classes.highlight_brightness import _HighlightBrightness
2  from data.shaders.classes.highlight_colour import _HighlightColour
3  from data.shaders.protocol import SMProtocol
4  from data.shaders.classes.blur import _Blur
5  from data.utils.constants import ShaderType
6
7  BLOOM_INTENSITY = 0.6
8
9  class Bloom:
10     def __init__(self, shader_manager: SMProtocol):
11         self._shader_manager = shader_manager
12
13         shader_manager.load_shader(ShaderType._BLUR)
14         shader_manager.load_shader(ShaderType._HIGHLIGHT_BRIGHTNESS)
15         shader_manager.load_shader(ShaderType._HIGHLIGHT_COLOUR)
16
17         shader_manager.create_framebuffer(ShaderType.BLOOM)
18         shader_manager.create_framebuffer(ShaderType._BLUR)
19         shader_manager.create_framebuffer(ShaderType._HIGHLIGHT_BRIGHTNESS)
20         shader_manager.create_framebuffer(ShaderType._HIGHLIGHT_COLOUR)
21
22     def apply(self, texture, highlight_surface=None, highlight_colours=[], surface_intensity=BLOOM_INTENSITY, brightness_intensity=BLOOM_INTENSITY, colour_intensity=BLOOM_INTENSITY):
23         """
24             Applies a bloom effect to a given texture.
25
26         Args:
27             texture (moderngl.Texture): Texture to apply bloom to.
28             highlight_surface (pygame.Surface, optional): Surface to use as the highlights. Defaults to None.
29             highlight_colours (list[list[int, int, int], ...], optional): Colours to use as the highlights. Defaults to [].
30             surface_intensity (_type_, optional): Intensity of bloom applied to the highlight surface. Defaults to BLOOM_INTENSITY.
31             brightness_intensity (_type_, optional): Intensity of bloom applied to the highlight brightness. Defaults to BLOOM_INTENSITY.
32             colour_intensity (_type_, optional): Intensity of bloom applied to the highlight colours. Defaults to BLOOM_INTENSITY.
33         """
34
35         if highlight_surface:
36             # Calibrate Pygame surface and apply blur
37             glare_texture = self._shader_manager.calibrate_pygame_surface(
38                 highlight_surface)
39             _Blur(self._shader_manager).apply(glare_texture)
40
41             self._shader_manager.get_fbo_texture(ShaderType._BLUR).use(1)
42             self._shader_manager.render_to_fbo(ShaderType.BLOOM, texture,
43                 blurredImage=1, intensity=surface_intensity)
44
45         # Set bloom-applied texture as the base texture
46         texture = self._shader_manager.get_fbo_texture(ShaderType.BLOOM)

```

```

44      # Extract bright colours (highlights) from the texture
45      _HighlightBrightness(self._shader_manager).apply(texture, intensity=
46          brightness_intensity)
47      highlight_texture = self._shader_manager.get_fbo_texture(ShaderType.
48          _HIGHLIGHT_BRIGHTNESS)
49
50      # Use colour as highlights
51      for colour in highlight_colours:
52          _HighlightColour(self._shader_manager).apply(texture, old_highlight=
53              highlight_texture, colour=colour, intensity=colour_intensity)
54          highlight_texture = self._shader_manager.get_fbo_texture(ShaderType.
55              _HIGHLIGHT_COLOUR)
56
57      # Apply Gaussian blur to highlights
58      _Blur(self._shader_manager).apply(highlight_texture)
59
60      # Add the pixel values for the highlights onto the base texture
61      self._shader_manager.get_fbo_texture(ShaderType._BLUR).use(1)
62      self._shader_manager.render_to_fbo(ShaderType.BLOOM, texture, blurredImage
63          =1, intensity=BLOOM_INTENSITY)

```

### 3.9.3 Rays

As described in Section 2.2.5, the `ray` shader is applied whenever the sphinx shoots a laser. It simulates a 2D light source, providing pixel perfect shadows, through the shadow mapping technique outlined in Section 2.2.5. The laser demo seen on the main menu screen is also achieved using the Ray shader, by clamping the angle at which it emits light to a narrower range.

#### Occlusion

The occlusion fragment shader processes all pixels with a given colour value as being occluding. `occlusion.frag`

```

1 # version 330 core
2
3 in vec2 uvs;
4 out vec4 f_colour;
5
6 uniform sampler2D image;
7 uniform vec3 checkColour;
8
9 void main() {
10     vec4 pixel = texture(image, uvs);
11
12     // If pixel is occluding colour, set pixel to white
13     if (pixel.rgb == checkColour) {
14         f_colour = vec4(1.0, 1.0, 1.0, 1.0);
15     // Else, set pixel to black
16     } else {
17         f_colour = vec4(vec3(0.0), 1.0);
18     }
19 }

```

#### Shadowmap

The shadowmap fragment shader takes the occluding texture and creates a 1D shadow map. `shadowmap.frag`

```

1 # version 330 core
2
3 #define PI 3.1415926536;
4
5 in vec2 uvs;
6 out vec4 f_colour;
7
8 uniform sampler2D image;
9 uniform float resolution;
10 uniform float THRESHOLD=0.99;
11
12 void main() {
13     float maxDistance = 1.0;
14
15     for (float y = 0.0 ; y < resolution ; y += 1.0) {
16         //rectangular to polar filter
17         float currDistance = y / resolution;
18
19         vec2 norm = vec2(uvs.x, currDistance) * 2.0 - 1.0; // Range from [0, 1] ->
20         [-1, 1]
21         float angle = (1.5 - norm.x) * PI; // Range from [-1, 1] -> [0.5PI, 2.5PI]
22         float radius = (1.0 + norm.y) * 0.5; // Range from [-1, 1] -> [0, 1]
23
24         //coord which we will sample from occlude map
25         vec2 coords = vec2(radius * -sin(angle), radius * -cos(angle)) / 2.0 +
26         0.5;
27
28         // Sample occlusion map
29         vec4 occluding = texture(image, coords);
30
31         // If pixel is not occluding (Red channel value below threshold), set
32         maxDistance to current distance
33         // If pixel is occluding, don't change distance
34         // maxDistance therefore is the distance from the center to the nearest
35         // occluding pixel
36         maxDistance = max(maxDistance * step(occluding.r, THRESHOLD), min(
37         maxDistance, currDistance));
38     }
39
40     f_colour = vec4(vec3(maxDistance), 1.0);
41 }
```

### Lightmap

The lightmap shader checks if a pixel is in shadow, blurs the result, and applies the radial light source.

#### lightmap.frag

```

1 # version 330 core
2
3 #define PI 3.14159265
4
5 in vec2 uvs;
6 out vec4 f_colour;
7
8 uniform float softShadow;
9 uniform float resolution;
10 uniform float falloff;
11 uniform vec3 lightColour;
12 uniform vec2 angleClamp;
13 uniform sampler2D occlusionMap;
```

```

14 uniform sampler2D image;
15
16 vec3 normLightColour = lightColour / 255;
17 vec2 radiansClamp = angleClamp * (PI / 180);
18
19 float sample(vec2 coord, float r) {
20     /*
21     Sample from the 1D distance map.
22
23     Returns:
24     float: 1.0 if sampled radius is greater than the passed radius, 0.0 if not.
25     */
26     return step(r, texture(image, coord).r);
27 }
28
29 void main() {
30     // Cartesian to polar transformation
31     // Range from [0, 1] -> [-1, 1]
32     vec2 norm = uvs.xy * 2.0 - 1.0;
33     float angle = atan(norm.y, norm.x);
34     float r = length(norm);
35
36     // The texture coordinates to sample our 1D lookup texture
37     // Always 0.0 on y-axis, as the texture is 1D
38     float x = (angle + PI) / (2.0 * PI); // Normalise angle to [0, 1]
39     vec2 tc = vec2(x, 0.0);
40
41     // Sample the 1D lookup texture to check if pixel is in light or in shadow
42     // Gives us hard shadows
43     // 1.0 -> in light, 0.0, -> in shadow
44     float inLight = sample(tc, r);
45     // Clamp angle so that only pixels within the range are in light
46     inLight = inLight * step(angle, radiansClamp.y) * step(radiansClamp.x, angle);
47
48     // Multiply the blur amount by the distance from the center
49     // So that the blurring increases as distance increases
50     float blur = (1.0 / resolution) * smoothstep(0.0, 0.1, r);
51
52     // Use gaussian blur to apply blur effecy
53     float sum = 0.0;
54
55     sum += sample(vec2(tc.x - blur * 4.0, tc.y), r) * 0.05;
56     sum += sample(vec2(tc.x - blur * 3.0, tc.y), r) * 0.09;
57     sum += sample(vec2(tc.x - blur * 2.0, tc.y), r) * 0.12;
58     sum += sample(vec2(tc.x - blur * 1.0, tc.y), r) * 0.15;
59
60     sum += inLight * 0.16;
61
62     sum += sample(vec2(tc.x + blur * 1.0, tc.y), r) * 0.15;
63     sum += sample(vec2(tc.x + blur * 2.0, tc.y), r) * 0.12;
64     sum += sample(vec2(tc.x + blur * 3.0, tc.y), r) * 0.09;
65     sum += sample(vec2(tc.x + blur * 4.0, tc.y), r) * 0.05;
66
67     // Mix with the softShadow uniform to toggle degree of softShadows
68     float finalLight = mix(inLight, sum, softShadow);
69
70     // Multiply the final light value with the distance, to give a radial falloff
71     // Use as the alpha value, with the light colour being the RGB values
72     f_colour = vec4(normLightColour, finalLight * smoothstep(1.0, falloff, r));
73 }

```

## Class

The `Rays` class takes in a texture and array of light information, applies the aforementioned shaders, and blends the final result with the original texture.

`rays.py`

```

1  from data.shaders.classes.lightmap import _Lightmap
2  from data.shaders.classes.blend import _Blend
3  from data.shaders.protocol import SMProtocol
4  from data.shaders.classes.crop import _Crop
5  from data.utils.constants import ShaderType
6
7  class Rays:
8      def __init__(self, shader_manager: SMProtocol, lights):
9          self._shader_manager = shader_manager
10         self._lights = lights
11
12         # Load all necessary shaders
13         shader_manager.load_shader(ShaderType._LIGHTMAP)
14         shader_manager.load_shader(ShaderType._BLEND)
15         shader_manager.load_shader(ShaderType._CROP)
16         shader_manager.create_framebuffer(ShaderType.RAYS)
17
18     def apply(self, texture, occlusion=None, softShadow=0.3):
19         """
20             Applies the light rays effect to a given texture.
21
22             Args:
23                 texture (moderngl.Texture): The texture to apply the effect to.
24                 occlusion (pygame.Surface, optional): A Pygame mask surface to use as
25                 the occlusion texture. Defaults to None.
26
27             final_texture = texture
28
29             # Iterate through array containing light information
30             for pos, radius, colour, *args in self._lights:
31                 # Topleft of light source square
32                 light_topleft = (pos[0] - (radius * texture.size[1] / texture.size[0]),
33                 pos[1] - radius)
34                 # Relative size of light compared to texture
35                 relative_size = (radius * 2 * texture.size[1] / texture.size[0],
36                 radius * 2)
37
38                 # Crop texture to light source diameter, and to position light source
39                 # at the center
40                 _Crop(self._shader_manager).apply(texture, relative_pos=light_topleft,
41                 relative_size=relative_size)
42                 cropped_texture = self._shader_manager.get_fbo_texture(ShaderType.
43                 _CROP)
44
45                 if occlusion:
46                     # Calibrate Pygame mask surface and crop it
47                     occlusion_texture = self._shader_manager.calibrate_pygame_surface(
48                     occlusion)
49                     _Crop(self._shader_manager).apply(occlusion_texture, relative_pos=
50                     light_topleft, relative_size=relative_size)
51                     occlusion_texture = self._shader_manager.get_fbo_texture(
52                     ShaderType._CROP)
53                 else:
54                     occlusion_texture = None
55
56             # Apply lightmap shader, shadowmap and occlusion are included within

```

```
the _Lightmap class
    _Lightmap(self._shader_manager).apply(cropped_texture, colour,
softShadow, occlusion_texture, *args)
    light_map = self._shader_manager.get_fbo_texture(ShaderType._LIGHTMAP)
50
51      # Blend the final result with the original texture
52      _Blend(self._shader_manager).apply(final_texture, light_map,
light_topleft)
    final_texture = self._shader_manager.get_fbo_texture(ShaderType._BLEND
)
54
55      self._shader_manager.render_to_fbo(ShaderType.RAYS, final_texture)
```

# Chapter 4

## Testing

### 4.1 Iterative Testing

I have been playtesting the program throughout the development process to find any bugs and fix them accordingly. However, a few issues have required additional measures.

#### 4.1.1 Minimax

Since minimax is recursive algorithm, debugging it has proven a challenge. I have therefore configured the Python `logging` library to help collect information on the minimax tree for every function call.

`base.py`

```
1  def print_stats(self, score, move):
2      """
3          Prints statistics after traversing tree.
4
5          Args:
6              score (int): Final score obtained after traversal.
7              move (Move): Best move obtained after traversal.
8
9          If self._verbose is False:
10              return
11
12          self._stats['time_taken'] = round(1000 * (time.time() - self._stats['
13              time_taken']), 3)
14          self._stats['ms_per_node'] = round(self._stats['time_taken'] / self._stats
15              ['nodes'], 3)
16
17          # Prints stats across multiple lines
18          if self._verbose is True:
19              logger.info(f'\n\n'
20                          f'{self.__str__()} Search Results:\n'
21                          f'{printer.pformat(self._stats)}\n'
22                          f'Best score: {score}    Best move: {move}\n'
23                          )
24
25          # Prints stats in a compacted format
26          elif self._verbose.lower() == 'compact':
27              logger.info(self._stats)
```

```
26     logger.info(f'Best score: {score}    Best move: {move}')
```

Listing 4.1: BaseCPU Method for logging minimax statistics

### 4.1.2 Migrations

To correct errors made to the `games` table, since recreating it would mean deleting all existing games, I have opted to use migrations to fix bugs by editing the table schema, as shown in Section 3.8.1.

## 4.2 Unit Tests

### 4.2.1 Board Evaluator

To test every aspect of the evaluation function, I have set up some unit tests with custom positions using my editor screen. These positions are designed to test every aspect of the evaluation, along with some obviously imbalanced positions to test the overall accuracy of the evaluation function. All positions are set up to give an advantage to the blue player.

Evaluating	FEN string	Score	Passed
Material	<code>sc9/10/10/4paPa4/5Pa4/10/10/9Sa b</code>	124	✓
Position	<code>sc9/4nanana3/10/10/10/4NaNaNa3/10/9Sa b</code>	66	✓
Mobility	See footnote <sup>1</sup>	196	✓
King Safety	<code>sc4fa3pa/10/10/10/10/10/10/5FaPa2Sa b</code>	3	✓
Combined	See footnote <sup>2</sup>	437	✓

Table 4.1: Board evaluator test results

### 4.2.2 CPU

Similarly, to evaluate the strength of my CPU, I have set up some custom positions that I already know the best continuation of, and run each CPU engine on them to test if they can solve it.

Description	FEN string	Best Move	Passed
Mate in 1	<code>sc9/pafa8/Fa9/10/10/10/10/9Sa b</code>	Rotate J3 clockwise	✓
Mate in 1	<code>sc9/10/10/8faRb/8FaRb/10/9Sa b</code>	Move J3 to J2	✓
Mate in 3	<code>sc9/10/10/8Ra1/7FaRafa/8RaRa/9Ra/9Sa b</code>	Move J2 to I1... <sup>3</sup>	✓
Mate in 3	<code>sc5fcnc2/4Pa4Pc/3pb6/2Pc2ra1pb2/10/pb9/7Pa2 /2PdNaFa4Sa b</code>	Move E7 to F7... <sup>4</sup>	✓
Mate in 3	<code>sc2pdfc5/2Ra1ra5/pa3Pc4Rb/pb1rd1Pdra4/7Rd2/3 Ra1Pa4/4Fa5/3PdNaPa3Sa b</code>	Move J6 to J7... <sup>5</sup>	✓

<sup>1</sup>`scpapa7/papapa7/papapa1Pa1Pa1Pa1/10/4Pa1Pa1Pa1/10/4Pa1Pa3/9Sa b`

<sup>2</sup>`scnclfcncpbpb3/pa9/pb1pc1rbpa3Pd/1Pc2Pd4Pc/2Pd1RaRb4/10/7Pa2/2PdNaFaNa3Sa b`

<sup>3</sup>2. Move J4 to J5 3. Move J3 to I2

<sup>4</sup>2. Rotate anticlockwise H8 3. Move F7 to G7

<sup>5</sup>2. Move E7 to F8 3. Move E4 to E5

Description	FEN string	Best Move	Passed
Win Material	s9/2fa7/5NaPb3/pa2ra1Pd4/3pcnd1pd2Rd/3pc6 /10/8FaSa b	Move F6 to G7... <sup>6</sup>	✓

Table 4.2: Iterative Deepening CPU test results

### 4.2.3 Shadow Mapping

To test the shadow mapping algorithm, I have set up some occluding objects together with a light source. Since visuals are subjective, my client and I have deemed the following results to be adequate.

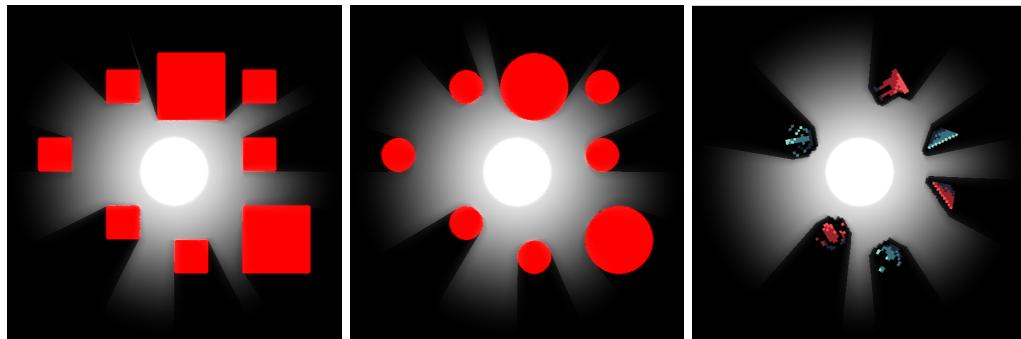


Figure 4.1: Shadow mapping algorithm test (softShadow=0.5, radius=0.5)

## 4.3 Final Tests

### 4.3.1 Objective 1

All laser chess game logic should be properly implemented.

No.	Input	Output	Passed
1	Position piece with non-reflecting side facing laser	Piece is destroyed	✓
2	Laser fires on pyramid	Pyramid reflects laser by 90°	✓
3	Laser fires on scarab	Scarab reflects laser by 90°	✓
4	Laser fires on anubis	Anubis absorbs laser	✓
5	Move piece as blue player	Active colour switches to red player	✓
6	Move piece or rotate piece	Laser fires	✓
7	Fire laser onto pharaoh	Pharaoh is destroyed, and opposite colour wins	✓
8	Repeat same position three times	Game displays game over screen	✓

<sup>6</sup>2. Move E4 to E3 3. Move H5 to D4 4. Move J4 to J3

### 4.3.2 Objective 2

Game should process user input correctly.

No.	Input	Output	Passed
9	Click piece	Overlay appears showing selected piece	✓
10	Click piece and click outside board	Overlay disappears showing deselected piece	✓
11	Click piece and click adjacent square	Piece moves to clicked square	✓
12	Click and hold piece and release over adjacent square	Piece moves to adjacent square	✓
13	Click piece and press rotate anticlockwise button	Piece rotates clockwise	✓
14	Click piece and press rotate clockwise button	Piece rotates anticlockwise	✓

### 4.3.3 Objective 3

Save or load game options should be implemented.

No.	Input	Output	Passed
15	Click on copy FEN string button in editor or browser screen	Position formatted as FEN string copied to clipboard	✓
16	Click browser button	Program shows list of past games to be scrolled through	✓
17	Select time as sorting criterion	Browser updates to show most recent games played	✓
18	Select descending as ordering criterion	Browser updates to show the oldest games played	✓
19	Click next page	Shown games are replaced with another set of games	✓
20	Click on previous game and click delete button	Selected game is deleted and disappears	✓
21	Click on previous game and click review button	Game is displayed in review screen	✓
22	Enter review screen	Program displays list of past moves, winner and move number	✓
23	Click on previous button in review screen	Board undoes move	✓
24	Click on next move button in review screen	Board applies move	✓

### 4.3.4 Objective 4

Other board game requirements should be implemented.

No.	Input	Output	Passed
25	Click on resign button	Game ends and shows win result for opponent	✓
26	Click on draw button	Game ends and shows draw result	✓
27	Click on timer button to enable timer	Timers appear on the left and decrement every second	✓
28	Pause the game	Timer stops decrementing	✓
29	Allow timer to run to zero	Game ends and shows win result for opponent	✓

#### 4.3.5 Objective 5

Game settings and config should be customisable.

No.	Input	Output	Passed
30	Click on CPU button	Opponent moves are played by minimax CPU	✓
31	Click on timer button to disable timer	Timer is not shown	✓
32	Click on timer duration and input new number	Timer starts with inputted duration	✓
33	Press starting colour button to set starting colour to red	Starting move is played by the red player	✓
34	Enter valid FEN string into text input	Board preview updates and game starts with inputted board layout	✓
35	Enter invalid FEN string into text input	Error message appears	✓
36	In editor screen, select piece and click on square	Piece placed on square	✓
37	Click piece and press rotate clockwise button	Piece rotates clockwise	✓
38	Click piece and press rotate anticlockwise button	Piece rotates anticlockwise	✓
39	Click empty button	All pieces disappear (except sphinxes)	✓
40	Click reset button	Board resets to initial layout	✓
41	Click confirm button	Switches to config screen with edited FEN string and board preview	✓
42	Click return button	Switches to config screen with changes discarded	✓
43	In settings screen, change primary board colour to blue	Alternating board squares appear blue	✓
44	Change secondary board colour to red	Board squares alternate blue and red	✓
45	Change display mode to fullscreen	Application window enlarges to fill entire screen	✓

No.	Input	Output	Passed
46	Slide volume thumb to right and left of slider	Music increases and decreases in volume	✓
47	Toggle particle and shader switches to off position	Particles and shaders are disabled after program restart	✓

#### 4.3.6 Objective 6

Game UI should improve player experience.

No.	Input	Output	Passed
48	Click on piece	Highlight overlay is rendered on selected square	✓
49	Click on piece	Circular overlays are rendered on surrounding unoccupied squares	✓
50	Hover cursor over available square	Highlight overlay is rendered on hovered square	✓
51	Fire laser on piece	Audio cue plays and piece is visibly destroyed	✓
52	Fire laser on piece	Piece appears on opponent's piece display	✓
53	Play a game	Status text updates to display the active player's colour or CPU status	✓
54	Hover over board, hold the mouse button, click on text input widget	Mouse cursor switches between arrow, open hand, closed hand and I-beam icons	✓

#### 4.3.7 Objective 7

GUI design should be functional and display concise information.

No.	Input	Output	Passed
55	Click the play button on the main menu screen	Program switches to the config screen	✓
56	Click the browser button on the main menu screen	Program switches to the browser screen	✓
57	Click the settings button on the main menu screen	Program switches to the settings screen	✓
58	Click main menu button	Program switches to the menu screen	✓
59	Click help button	Help overlay appears	✓
60	Resize program window	GUI Widgets resize continuously	✓
61	Drag program window	Program continues running	✓
62	Click quit button	Program quits	✓

## 4.4 Videos

Link to video demonstrating program demo: <https://www.youtube.com/watch?v=sXiJ4SucgmU>

Link to video demonstrating final tests: <https://www.youtube.com/watch?v=G99DXwR0sH0>

Link to video demonstrating unit tests: <https://www.youtube.com/watch?v=imYngKFmffY>

# Chapter 5

## Evaluation

Overall, I believe that my final program has effectively achieved the requirements set out by my client. It is a step-up to current alternatives that I have found online, and seems to be a solid choice for anyone wanting to play laser chess digitally.

### 5.1 Objectives

#### 5.1.1 Objective 1

All laser chess game logic should be properly implemented. Refer to Figure A.4.

Both the play and review screens display a 10x8 laser chess board. The laser fires automatically after every move, and follows the trajectory as directed by the pieces, destroying any that are facing the wrong way (Objectives 1f, 1g). All the pieces reflect and are destroyed by the laser correctly, with the colour to move alternating between both players (Objectives 1a-1e). The game ends when a player either draws or resigns, has their pharaoh destroyed, or reaches three-fold repetition (Objectives 1h, 1i).

The game logic runs successfully, Objective 1 is fulfilled.

#### 5.1.2 Objective 2

Game should process user input correctly. Refer to Figure A.4.

Players can select, move and rotate pieces on their respective turns, through clicking squares, rotate buttons or by dragging the pieces (Objectives 2a, 2c, 2d, 2e). The game cancels any invalid moves (Objective 2b). When a player holds down on a piece, the piece is moved through the drag-and-drop mechanism, and is released on the hovered square (Objective 2d).

Objective 2 is fulfilled.

#### 5.1.3 Objective 3

Save or load game options should be implemented. Refer to Figures A.6 and A.7.

In the browser screen, users can scroll through all previous games, with the option to delete or review them, or copy their FEN string (Objectives 3c, 3f, 3g). Games can be sorted, and pages of games can be scrolled through (Objectives 3d, 3e). The game positions are encoded using a custom FEN string format, and games are saved as rows in a local SQLite database table (Objectives 3a, 3b). In the review screen, users can scroll through all the moves of a

previous game (Objective 3i). The right sidebar displays information such as the winner and move number, and the timer, pieces and move list updates accordingly (Objective 3h).

Objective 3 is fulfilled. A possible improvement would be to add the option of loading up a position to resume playing straight from the review screen. This would be a convenient feature, but is not a priority, as users can currently copy the FEN string from the browser screen to the config screen and load the position there as a current alternative.

#### 5.1.4 Objective 4

Other board game requirements should be implemented. Refer to Figure A.4.

In addition to the core game mechanics, other ancillary aspects are added as well. Timers can be enabled and disabled, decrement correctly, and end the game when they run out (Objectives 4c, 4d). Buttons also exist for drawing and resigning the game (Objectives 4a, 4b).

Objective 4 is fulfilled.

#### 5.1.5 Objective 5

Game settings and config should be customisable. Refer to Figures A.2 and A.3 and A.5.

In the settings screen, the user can change settings to toggle the volume, fullscreen, board colours, particles and shaders (Objectives 5i, 5j). All settings update correctly, and are saved to a local JSON file when the settings screen is exited. The game configurations are changed in the config screen. Here, users can change the game's starting colour, configure timer settings, change to the CPU player and specify the difficulty, select a board preset, or create a custom board layout through the editor screen (Objectives 5a-5c). The editor screen comes with all the basic operations of placing pieces, rotating pieces, and erasing and dragging them, but also helpful buttons to erase or reset the board (Objectives 5f-5h). Another method to change the board layout is through inputting a FEN string, and the board either updates or displays an error message depending on the validity of the string (Objectives 5d, 5e).

Objective 5 is fulfilled.

#### 5.1.6 Objective 6

Game UI should improve player experience. Refer to Figure A.4.

Indicators are present to highlight the selected square and any adjacent squares that it can be moved to (Objectives 6a, 6b). Audio cues also make the game more immersive, and so do the laser visuals and particle effects (Objective 6c). The mouse cursor was also modified to help user-friendliness, by changing its icon depending on the current action being performed, for example, a closed hand icon for grabbing a piece (Objective 6g). The move list and status message widgets are positioned on the right of the game screen, update accordingly and provide information on the game (Objectives 6e, 6f). The piece display also correctly updates to show all destroyed pieces (Objective 6d).

Objective 6 is fulfilled.

#### 5.1.7 Objective 7

GUI design should be functional and display concise information. Refer to Figure A.1.

I have created most of the custom pixel art and icon graphics to improve the game's visual and attempt to make it more engaging (Objective 7c) There are currently 7 screens in the game: menu, settings, config, editor, game, browser and review, each containing their own eponymous function (Objective 7b). Most screens also contain both the main menu button and help button.

Clicking the menu button switches to the main menu screen, and clicking the help button shows an overlay displaying the functionality of drawn widgets (Objective 7d). Shaders are also used to improve the game's visuals, such as by giving the laser a light-emitting effect, but is also used to draw all the backgrounds (Objective 7e). The program runs well, with moments involving heavy calculation being helped by multithreading, and also resizes seamlessly (Objective 7a, 7f).

Objective 7 is fulfilled. Working on Windows, I did not bundle the program to macOS or Linux. Although this was not a priority, having access to other OS testing environments would've widened access to the game.

## 5.2 Client Feedback

An interview was conducted after Mr Myslov received and played through the program, the following transcription is summarised and paraphrased for clarity.

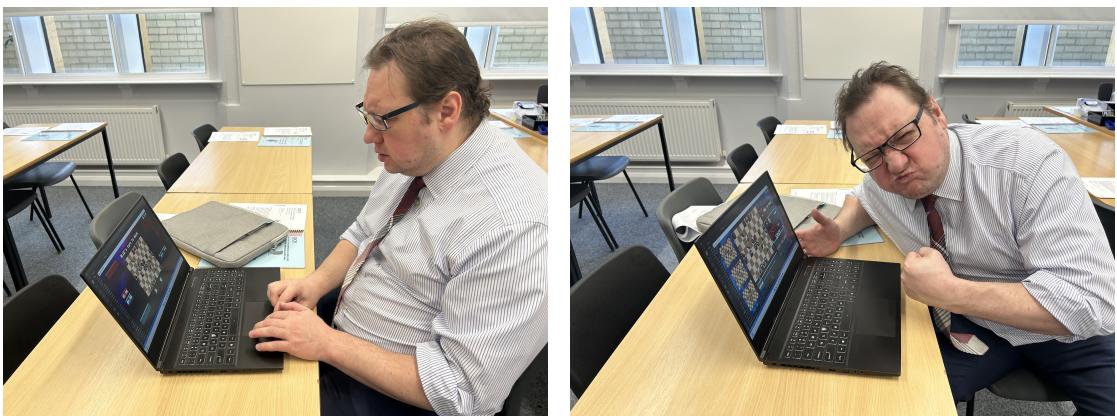


Figure 5.1: (left) Mr Myslov playing through the game (right) Mr Myslov physically threatens me after failing to beat the bot

**Q:** Did the final product meet your expectations?

**A:** Yes, it certainly did. The game plays perfectly, I could move, rotate all the pieces as expected, and the laser works well. All the features I requested for were there, and I also like your indie-style graphics.

---

**Q:** What improvements could be made to the program?

**A:** There seems to be quite a steep learning curve towards your program. It was hard understanding how the pieces worked with the laser. Playing through the game the CPU was also initially difficult, especially on the easy difficulty, as the moves would be played instantly after I moved, and I wasn't sure what move was made or whether the laser fired before or after my move. The bot was also frustrating to play against as it is very defensive, so I couldn't capture any of its pieces, it needs to be dumber; I don't know if the bot is intended to accept my draw, but I think that's good. I also like that you have made your own FEN string implementation confusing, but I'm not too sure how it works or what the characters mean.

---

**Q:** What other aspects would you like to have been added?

**A:** Being able to somehow easily obtain a digital file for a game would be useful, so I could share it with my students easily. To help with learning the game, you could add some puzzles to help

with solving tactics and getting used to the pieces, and also a highlight overlay for moves played because it was hard to follow or figure out.

## Discussion

My client was satisfied with my final program. His perspective revealed some aspects of the program that could've better considered and improved upon. Mr Myslov also helped discover a bug when he tried to offer a draw to the bot, who instantly accepted it despite being in a winning position. He seemed to enjoy this unexpected outcome, so I will consider this a feature.

**User-friendliness** was the core discussion point raised by Mr Myslov. He highlighted the fact that it would be hard for beginners to understand the rules of laser chess, which I agree on, considering that the rules and pieces are very different from regular chess. To amend this, I could add more tutorials or puzzles as per suggested, for instance, by creating a new tutorial or puzzle screen containing a miniaturised board, where the user can learn how the pieces interact with the laser; although a help screen is already implemented, an interactive one would perhaps serve the purpose more efficiently. A similar approach could be applied to my custom FEN string and algebraic move notation.

**Sharing games** was a suggestion made by Mr Myslov. Although the FEN string system allows for sharing of board positions, I realise that there is value in also sharing the entire progression of the game. This could be implemented by exporting the game to the equivalent of a chess 'PGN' file, by writing all the game information (e.g. CPU depth) to a .txt file, and then the contents of the move list.

**CPU** was also another point to consider. Mr Myslov complained that the CPU's thinking time on the easy mode was too short, resulting in his opponent's move being played instantly, confusing the flow of the game and making it hard to see what move was made. To fix this, I could either increase the thinking time artificially for the easy setting by only applying the move after a set timer runs out, or add an overlay similar to the one for selecting pieces, over the squares that a moved piece was on and has moved to. Mr Myslov also complained about the CPU's defensive style and his inability to gain an advantage. Although this can be regarded as a compliment, I agree that the CPU's tendency to defend instead of attack can be annoying. This results from the relative weighing of the evaluation function, which could be updated to contain PSQTs giving higher scores for more aggressive piece positioning, reducing the score allocated for king safety, or adjusting the piece values for a more aggressive play style.

Regardless, given the limited time frame, we were both pleased with the final result.

## 5.3 Further improvements

There are some improvements that I have considered that were not brought up in the objectives or in interview.

A point not raised by Mr Myslov was the ease-of-use of the widgets. The one that I found concerning was the text input, as constantly deleting the entire FEN string, and having to manually press arrow keys to edit specific characters was tedious. I have tried to improve this by adding shortcuts such as **Ctrl+Backspace** to delete the entire contents of the text Input. To improve the text input to make it feel more familiar to standard ones, I would have to use

two pointers to track the indexes of the start and end characters, for the ability to highlight and delete chunks of text. The text displayed can also be hard to read currently, especially if there are a lot of characters. This could be improved by either fixing the font width, detecting if the text width is greater than the widget width and implementing text wrapping, or allowing text scrolling.

Multiplayer was another improvement suggested by Mr Myslov. Admittedly, this is a big feature for a digital board game, however, I did not implement this as it was not a requested objective, and would've required restructuring my code for handling moves and the game logic. This could be achieved within Python through a peer-to-peer system, sending and parsing formatted moves either through pickling or JSON objects via HTTP methods using the `requests` module, although it would also require an overhaul of the GUI and screens to allow the option for multiplayer.

Performance issues did not appear throughout Mr Myslov's playthrough. However, even if the program runs smoothly on my device, some fragment shaders are computationally expensive and may affect the performance on other devices. I have attempted to resolve this by adding the option to disable shaders, however, a better solution would be to optimise the expensive shader code, for example, by approximating masks using widget dimensions instead of the in-built pixel perfect Pygame mask function.

## 5.4 Conclusion

The final product fulfilled all proposed objectives and more, and has been approved by my client.

Throughout 6 months of development, I felt that I improved on many aspects needed to be a proficient developer. Creating bespoke software allowed for conducting research, interviews, and also obtaining continuous feedback. In terms of coding, working on a large project helped in improving file management, documentation, and keeping robust backups through Git. It also gave me the opportunity to learn GLSL for my shaders, LibreSprite for pixel art, and LaTeX for my documentation. Having a greater familiarity with Pygame, I also plan to rework my widget system as a library, to be shared for the benefit of all future Pygame users.

Overall, this project was a success.

# Bibliography

- [1] C. Wiki, “Chessprogramming wiki.” <https://www.chessprogramming.org>.
- [2] OfficialGameRules, “Official khet rules.” <https://www.officialgamerules.org/khet>.
- [3] F.-P. Lin, “Good logging practice in python.” <https://fangpenlin.com/posts/2012/08/26/good-logging-practice-in-python/>.
- [4] M. Vanthoor, “Rustic chess.” <https://rustic-chess.org>.

## Assets

- <https://aspecsgaming.itch.io/pixel-art-cursors?download>
- <https://mounirtohami.itch.io/pixel-art-gui-elements>
- <https://leo-red.itch.io/lucid-icon-pack>
- <https://jdsherberty.itch.io/ultimate-ui-sfx-pack>
- <https://jdwasaki.itch.io/8-bit-16-bit-sound-effects-pack>
- <https://shapeforms.itch.io/shapeforms-audio-free-sfx>
- <https://heltonyan.itch.io/retro-mecha-sfx>
- <https://pixabay.com/sound-effects/game-over-sounds-1-14860/>
- <https://pixabay.com/sound-effects/8-bit-moonlight-sonata-music-loop-20436/>
- <https://pixabay.com/sound-effects/dramatic-synth-echo-43970/>
- <https://jhawk-studios.itch.io/drift-music-pack>
- <https://pixabay.com/music/synthwave-retro-music-260739/>
- <https://pixabay.com/music/upbeat-retro-gaming-271301/>
- <https://pixabay.com/music/video-games-chiptune-medium-boss-218095/>
- <https://www.zapsplat.com/music/game-sound-warm-chime-soft-mallet-start-up-tone/>
- <https://godotshaders.com/shader/balatro-background-shader/>
- <https://godotshaders.com/shader/discrete-ocean/>
- <https://www.shadertoy.com/view/7tBSR1>

## Appendix A

### Screenshots

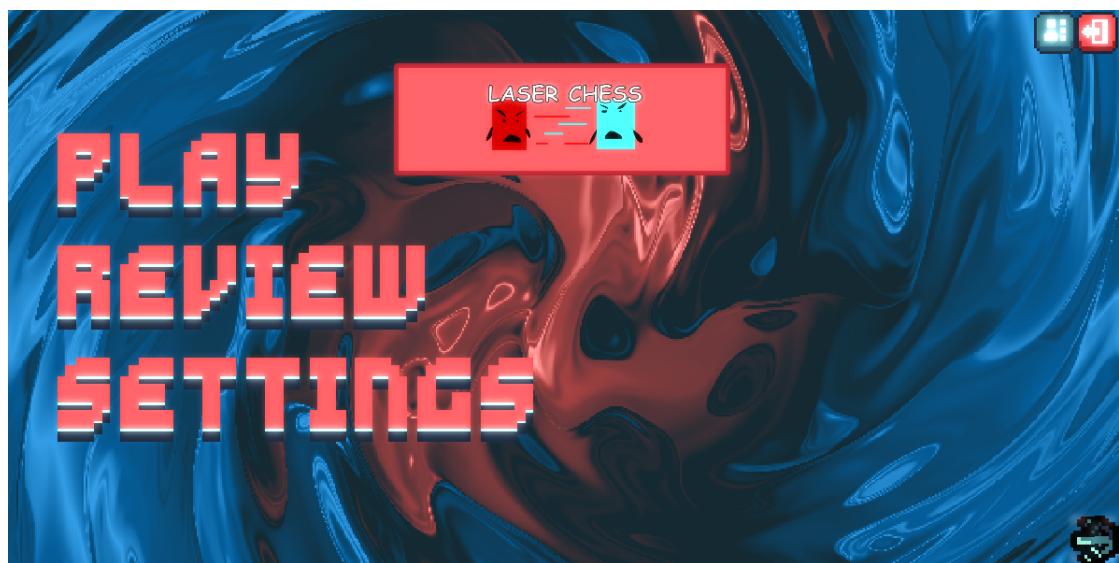


Figure A.1: Main menu screen

## APPENDIX A. SCREENSHOTS

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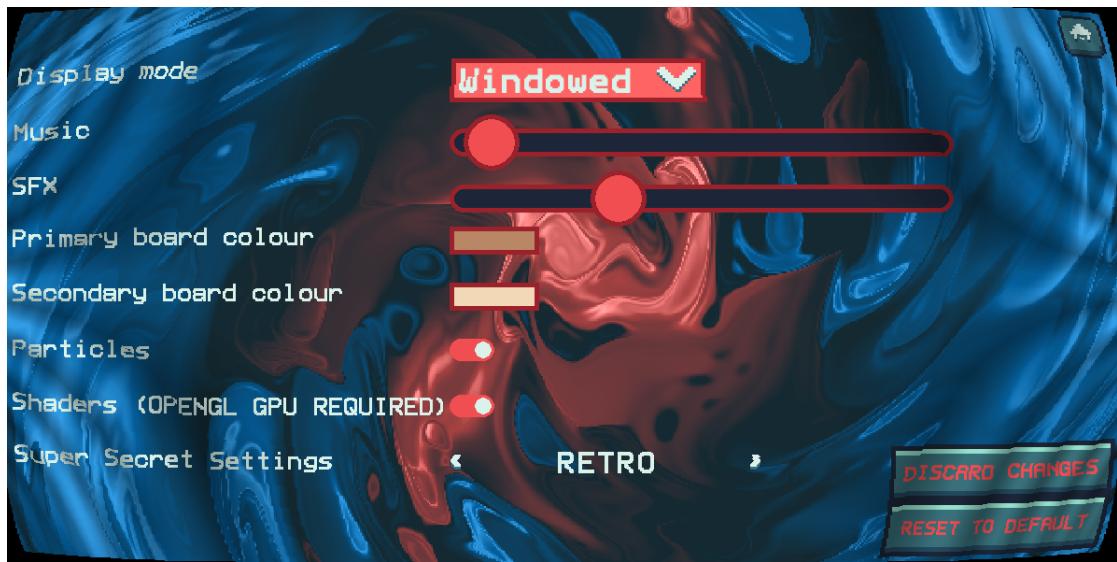


Figure A.2: Settings screen

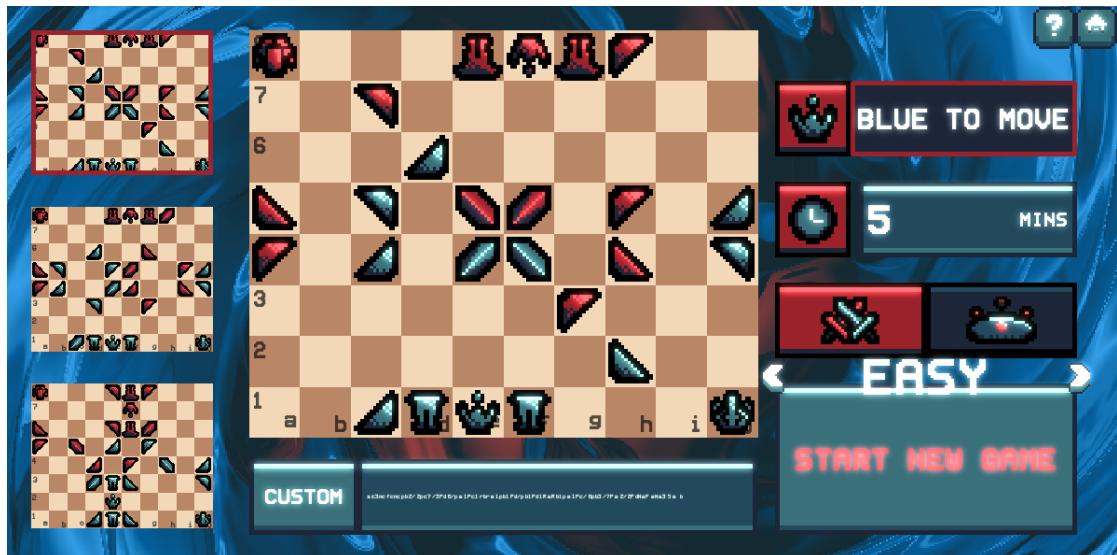


Figure A.3: Config screen

## APPENDIX A. SCREENSHOTS

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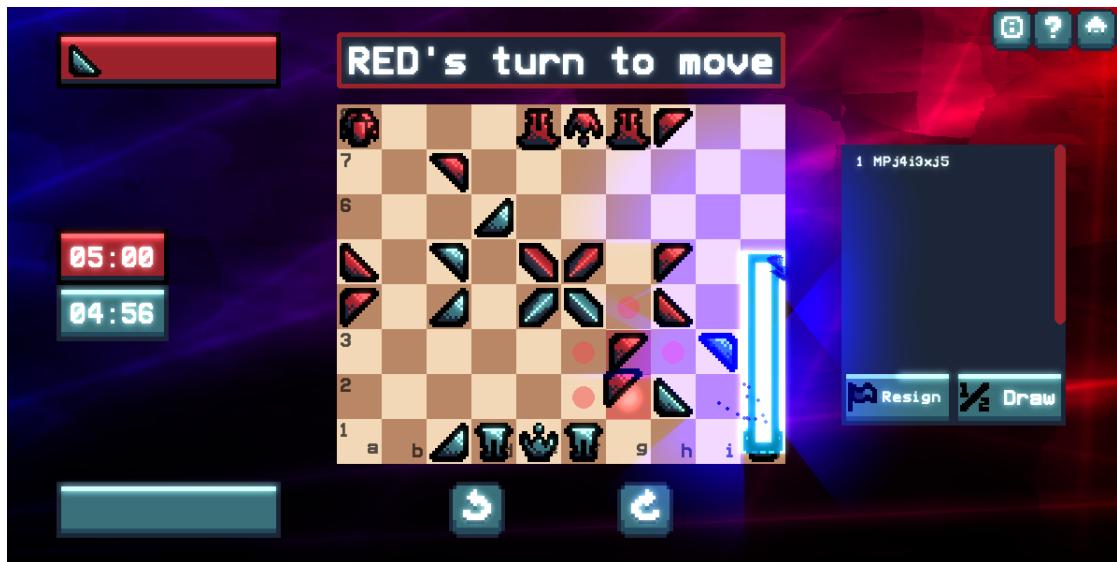


Figure A.4: Game screen



Figure A.5: Editor screen

## APPENDIX A. SCREENSHOTS

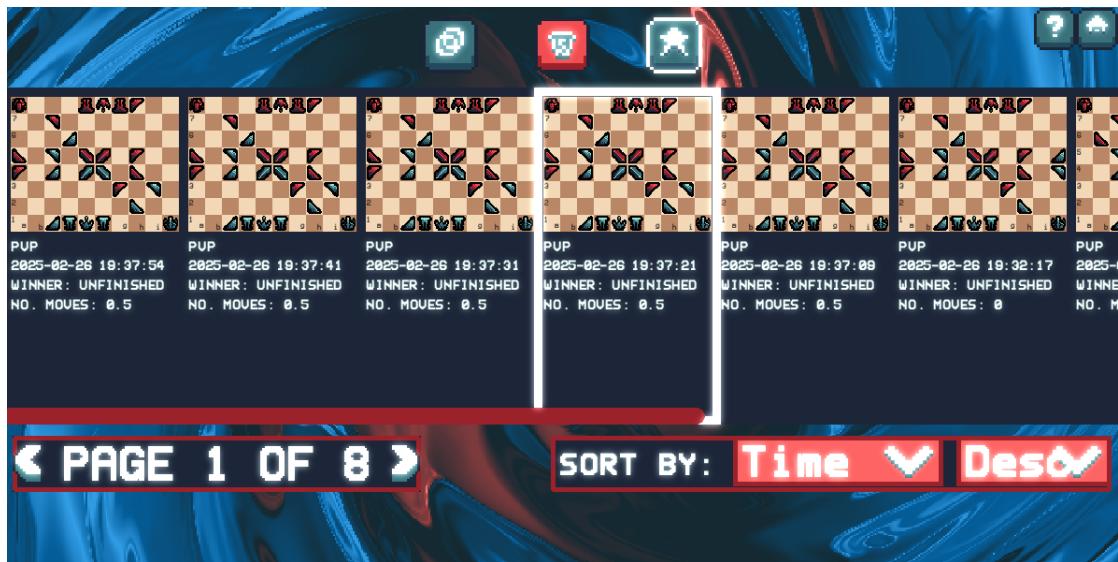


Figure A.6: Browser screen



Figure A.7: Review screen

# Appendix B

## Source Code

This appendix contains all source code not show in the technical solution chapter.

### B.1 data

#### B.1.1 control.py

```
1 import pygame
2 from data.components.widget_group import WidgetGroup
3 from data.managers.logs import initialise_logger
4 from data.managers.cursor import CursorManager
5 from data.managers.animation import animation
6 from data.utils.assets import DEFAULT_FONT
7 from data.managers.window import window
8 from data.managers.audio import audio
9 from data.managers.theme import theme
10
11 logger = initialise_logger(__file__)
12
13 FPS = 60
14 SHOW_FPS = False
15 start_ticks = pygame.time.get_ticks()
16
17 # Control class for managing state machine
18 class Control:
19     def __init__(self):
20         self.done = False
21         self._clock = pygame.time.Clock()
22
23     def setup_states(self, state_dict, start_state):
24         self.state_dict = state_dict
25         self.state_name = start_state
26
27         self.state = self.state_dict[self.state_name]
28         self.state.startup()
29
30     # Method to cleanup previous state and startup new state.
31     def flip_state(self):
32         self.state.done = False
33         persist = self.state.cleanup()
34
35         previous, self.state_name = self.state_name, self.state.next
```

```

36         self.state = self.state_dict[self.state_name]
37         self.state.previous = previous
38         self.state.startup(persist)
39
40     def update(self):
41         if self.state.quit:
42             self.done = True
43         elif self.state.done:
44             self.flip_state()
45
46         self._clock.tick(FPS)
47         animation.set_delta_time()
48
49         self.state.update()
50
51         if SHOW_FPS:
52             self.draw_fps()
53
54         window.update()
55
56     def main_game_loop(self):
57         while not self.done:
58             self.event_loop()
59             self.update()
60
61     def update_window(self, resize=False):
62         if resize:
63             self.update_native_window_size()
64             window.handle_resize()
65             self.state.handle_resize()
66
67         self.update()
68
69     # Debug method to render framerate.
70     def draw_fps(self):
71         fps = str(int(self._clock.get_fps()))
72         DEFAULT_FONT.strength = 0.1
73         DEFAULT_FONT.render_to(window.screen, (0, 0), fps, fgcolor=theme['textError'], size=15)
74
75     # Used to limit window dimensions when resizing application window
76     def update_native_window_size(self):
77         x, y = window.size
78
79         max_window_x = 100000
80         max_window_y = x / 1.4
81         min_window_x = 400
82         min_window_y = min_window_x / 1.4
83
84         # If aspect ratio is less than 1.4, stop allowing width rescaling
85         if x / y < 1.4:
86             min_window_x = x
87
88         window.minimum_size = (min_window_x, min_window_y)
89         window.maximum_size = (max_window_x, max_window_y)
90
91     def event_loop(self):
92         for event in pygame.event.get():
93             if event.type == pygame.QUIT:
94                 self.done = True
95
96

```

```

97         # Only allow left-click for mouse presses
98         if event.type == pygame.MOUSEBUTTONDOWN and event.button != 1:
99             return
100
101     self.state.get_event(event)
102
103 class _State:
104     def __init__(self):
105         self.next = None
106         self.previous = None
107         self.done = False
108         self.quit = False
109         self.persist = {}
110
111         self._cursor = CursorManager()
112         self._widget_group = None
113
114     def startup(self, widgets=None, music=None):
115         if widgets:
116             self._widget_group = WidgetGroup(widgets)
117             self._widget_group.handle_resize(window.size)
118
119         if music:
120             audio.play_music(music)
121
122         logger.info(f'starting {self.__class__.__name__.lower()}.py')
123
124     def cleanup(self):
125         logger.info(f'cleaning {self.__class__.__name__.lower()}.py')
126
127     def draw(self):
128         raise NotImplementedError
129
130     def get_event(self, event):
131         raise NotImplementedError
132
133     def handle_resize(self):
134         self._widget_group.handle_resize(window.size)
135
136     def update(self, **kwargs):
137         self.draw()

```

### B.1.2 loading\_screen.py

See Section 3.3.2.

### B.1.3 main.py

See Section 3.3.1.

### B.1.4 setup.py

```

1 import pygame
2
3 # Initialise Pygame
4 pygame.mixer.init()
5 pygame.init()
6
7 # Initialise OpenGL for Pygame with version 330
8 pygame.display.gl_set_attribute(pygame.GL_CONTEXT_MAJOR_VERSION, 3)

```

```

9  pygame.display.gl_set_attribute(pygame.GL_CONTEXT_MINOR_VERSION, 3)
10 pygame.display.gl_set_attribute(pygame.GL_CONTEXT_PROFILE_MASK, pygame.
11     GL_CONTEXT_PROFILE_CORE)
11 pygame.display.gl_set_attribute(pygame.GL_CONTEXT_FORWARD_COMPATIBLE_FLAG, True)

```

### B.1.5 windows\_setup.py

```

1 import win32gui
2 import win32con
3 import ctypes
4 import sys
5 import os
6
7 def wndProc(oldWndProc, draw_callback, hWnd, message, wParam, lParam):
8     # Run window update function whenever window is being resized
9     if message == win32con.WM_SIZING or message == win32con.WM_TIMER:
10         draw_callback(resize=True)
11         win32gui.RedrawWindow(hWnd, None, None, win32con.RDW_INVALIDATE | win32con.
12             RDW_ERASE)
12     # Run window update function whenever window is being dragged
13     elif message == win32con.WM_MOVE:
14         draw_callback(resize=False)
15
16     return win32gui.CallWindowProc(oldWndProc, hWnd, message, wParam, lParam)
17
18 def set_win_resize_func(resize_function):
19     oldWndProc = win32gui.SetWindowLong(win32gui.GetForegroundWindow(), win32con.
20         GWL_WNDPROC, lambda *args: wndProc(oldWndProc, resize_function, *args))
20
21 user32 = ctypes.windll.user32
22 user32.SetProcessDPIAware() # To deal with Windows High Text Size / Low Display
23     Resolution Settings
23
24 # Only allow Windows Version >= 7
25 if os.name != 'nt' or sys.getwindowsversion()[0] < 6:
26     raise NotImplementedError("Incompatible OS!")

```

## B.2 data\app\_data

### B.2.1 default\_settings.json

```

1 {
2     "primaryBoardColour": "0xB98766",
3     "secondaryBoardColour": "0xF3D8B8",
4     "laserColourBlue": "0x0000ff",
5     "laserColourRed": "0xffff00",
6     "displayMode": "windowed",
7     "musicVolume": 0.5,
8     "sfxVolume": 0.5,
9     "particles": true,
10    "opengl": true,
11    "shader": "default"
12 }

```

### B.2.2 logs\_config.json

```

1 {
2     "version": 1,
3     "disable_existing_loggers": false,

```

```

4     "formatters": {
5         "simple": {
6             "format": "%(asctime)s - %(name)s - %(levelname)s - %(message)s",
7             "datefmt": "%Y-%m-%d %H:%M:%S"
8         }
9     },
10    "handlers": {
11        "console": {
12            "class": "logging.StreamHandler",
13            "formatter": "simple",
14            "stream": "ext://sys.stdout"
15        }
16    },
17},
18
19    "root": {
20        "level": "INFO",
21        "handlers": ["console"],
22        "propagate": false
23    }
24}

```

### B.2.3 logs\_config\_prod.json

```

1  {
2      "version": 1,
3      "disable_existing_loggers": false,
4      "formatters": {
5          "simple": {
6              "format": "%(asctime)s - %(name)s - %(levelname)s - %(message)s"
7          }
8      },
9
10     "handlers": {
11         "console": {
12             "class": "logging.StreamHandler",
13             "level": "DEBUG",
14             "formatter": "simple",
15             "stream": "ext://sys.stdout"
16         },
17
18         "info_file_handler": {
19             "class": "logging.handlers.RotatingFileHandler",
20             "level": "INFO",
21             "formatter": "simple",
22             "filename": "info.log",
23             "maxBytes": 10485760,
24             "backupCount": 20,
25             "encoding": "utf8"
26         },
27
28         "error_file_handler": {
29             "class": "logging.handlers.RotatingFileHandler",
30             "level": "ERROR",
31             "formatter": "simple",
32             "filename": "errors.log",
33             "maxBytes": 10485760,
34             "backupCount": 20,
35             "encoding": "utf8"
36         }
37     },
38 }

```

```

39     "loggers": {
40         "my_module": {
41             "level": "ERROR",
42             "handlers": ["console"],
43             "propagate": false
44         }
45     },
46
47     "root": {
48         "level": "INFO",
49         "handlers": ["console", "info_file_handler", "error_file_handler"]
50     }
51 }

```

#### B.2.4 themes.json

```

1  {
2      "colours": {
3          "text": {
4              "primary": "0xdaf2e9",
5              "secondary": "0xf14e52",
6              "error": "0xf14e52"
7          },
8          "fill": {
9              "primary": "0x1c2638",
10             "secondary": "0xf14e52",
11             "tertiary": "0xdaf2e9",
12             "error": "0x9b222b"
13         },
14         "border": {
15             "primary": "0x9b222b",
16             "secondary": "0xdaf2e9"
17         }
18     },
19     "dimensions": {
20         "borderRadius": 3,
21         "borderWidth": 5,
22         "margin": 10
23     }
24 }

```

#### B.2.5 user\_settings.json

```

1  {
2      "primaryBoardColour": "0xB98766",
3      "secondaryBoardColour": "0xF3D8B8",
4      "laserColourBlue": "0x0000ff",
5      "laserColourRed": "0xffff00",
6      "displayMode": "windowed",
7      "musicVolume": 0.5,
8      "sfxVolume": 0.5,
9      "particles": true,
10     "opengl": true,
11     "shader": "default"
12 }

```

### B.3 data\components

#### B.3.1 circular\_linked\_list.py

See Section 3.4.3.

### B.3.2 cursor.py

```

1 import pygame
2
3 class Cursor(pygame.sprite.Sprite):
4     def __init__(self):
5         super().__init__()
6         self.image = pygame.Surface((1, 1))
7         self.image.fill((255, 0, 0))
8         self.rect = self.image.get_rect()
9
10    # def update(self):
11    #     self.rect.center = pygame.mouse.get_pos()
12
13    def get_sprite_collision(self, mouse_pos, square_group):
14        self.rect.center = mouse_pos
15        sprite = pygame.sprite.spritecollideany(self, square_group)
16
17        return sprite

```

### B.3.3 custom\_event.py

See Section 3.4.4.

### B.3.4 game\_entry.py

```

1 from data.states.game.components.move import Move
2 from data.utils.enums import Colour
3
4 class GameEntry:
5     def __init__(self, game_states, final_fen_string):
6         self._game_states = game_states
7         self._final_fen_string = final_fen_string
8
9     # Debug method used to print GameEntry row
10    def __str__(self):
11        return f'''
12 <GameEntry> :
13     CPU_ENABLED: {self._game_states['CPU_ENABLED']},
14     CPU_DEPTH: {self._game_states['CPU_DEPTH']},
15     WINNER: {self._game_states['WINNER']},
16     TIME_ENABLED: {self._game_states['TIME_ENABLED']},
17     TIME: {self._game_states['TIME']},
18     NUMBER_OF_PLY: {len(self._game_states['MOVES'])},
19     MOVES: {self.convert_moves(self._game_states['MOVES'])}
20     FINAL_FEN_STRING: {self._final_fen_string}
21     START_FEN_STRING: {self._game_states['START_FEN_STRING']}
22 </GameEntry>
23     '''
24
25    def convert_to_row(self):
26        return (self._game_states['CPU_ENABLED'], self._game_states['CPU_DEPTH'],
27                self._game_states['WINNER'], self._game_states['TIME_ENABLED'], self.
28                _game_states['TIME'], len(self._game_states['MOVES']), self.convert_moves(self.
29                _game_states['MOVES']), self._game_states['START_FEN_STRING'], self.
30                _final_fen_string)
31
32    # List comprehension used to format move dictionary into string
33    def convert_moves(self, moves):
34        return '|'.join([

```

```

31         f'{round(move["time"]的心理.BLUEx, 4)},{round(move["time"]的心理.RED
32         }, 4)};{move['move']}"
33             for move in moves
34         ])
35
36     # Inverse method of convert_moves, converts string into dictionary of moves
37     @staticmethod
38     def parse_moves(move_str):
39         moves = move_str.split('||')
40         return [
41             {
42                 'blue_time': move.split(';')[0],
43                 'red_time': move.split(';')[1],
44                 'move': Move.instance_from_notation(move.split(';')[2]),
45                 'unparsed_move': move.split(';')[2],
46             } for move in moves if move != ''
47         ]

```

### B.3.5 widget\_group.py

```

1 import pygame
2 from data.managers.window import window
3
4 # Overriding Pygame widget group to handle own widget system
5 class WidgetGroup(pygame.sprite.Group):
6     def __init__(self, widget_dict):
7         super().__init__()
8
9         # Add widgets from WIDGET_DICT
10        for value in widget_dict.values():
11            if isinstance(value, list):
12                for widget in value:
13                    self.add(widget)
14            elif isinstance(value, dict):
15                for widget in value.values():
16                    self.add(widget)
17            else:
18                self.add(value)
19
20    def handle_resize(self, new_surface_size):
21        for sprite in self.sprites():
22            sprite.set_surface_size(new_surface_size)
23            sprite.set_image()
24            sprite.set_geometry()
25
26    def process_event(self, event):
27        for sprite in self.sprites():
28            widget_event = sprite.process_event(event)
29
30            if widget_event:
31                return widget_event
32
33        return None
34
35    def draw(self):
36        sprites = self.sprites()
37        for spr in sprites:
38            surface = spr._surface or window.screen
39            self.spriteDict[spr] = surface.blit(spr.image, spr.rect)
40        self.lostsprites = []
41        dirty = self.lostsprites
42

```

```

43         return dirty
44
45     # Returns True if mouse cursor is hovering over a widget
46     def on_widget(self, mouse_pos):
47         test_sprite = pygame.sprite.Sprite()
48         test_sprite.rect = pygame.Rect(*mouse_pos, 1, 1)
49         return pygame.sprite.spritecollideany(test_sprite, self)

```

## B.4 data\database

### B.5 data\database\migrations

#### B.5.1 add\_created\_dt\_column27112024.py

```

1 import sqlite3
2 from pathlib import Path
3
4 database_path = (Path(__file__).parent / '../database.db').resolve()
5
6 # Upgrade function used to update games table schema
7 def upgrade():
8     connection = sqlite3.connect(database_path)
9     cursor = connection.cursor()
10
11    cursor.execute('''
12        ALTER TABLE games ADD COLUMN created_dt TIMESTAMP NOT NULL
13        ''')
14
15    connection.commit()
16    connection.close()
17
18 # Downgrade function used to revert changes
19 def downgrade():
20     connection = sqlite3.connect(database_path)
21     cursor = connection.cursor()
22
23    cursor.execute('''
24        ALTER TABLE games DROP COLUMN created_dt
25        ''')
26
27    connection.commit()
28    connection.close()
29
30 upgrade()
31 # downgrade()

```

#### B.5.2 add\_fen\_string\_column\_22112024.py

```

1 import sqlite3
2 from pathlib import Path
3
4 database_path = (Path(__file__).parent / '../database.db').resolve()
5
6 def upgrade():
7     connection = sqlite3.connect(database_path)
8     cursor = connection.cursor()
9
10    cursor.execute('''
11        ALTER TABLE games ADD COLUMN fen_string TEXT NOT NULL

```

```

12     ...)
13
14     connection.commit()
15     connection.close()
16
17 def downgrade():
18     connection = sqlite3.connect(database_path)
19     cursor = connection.cursor()
20
21     cursor.execute('''
22         ALTER TABLE games DROP COLUMN fen_string
23     ''')
24
25     connection.commit()
26     connection.close()
27
28 upgrade()

```

### B.5.3 add\_start\_fen\_string\_column\_23122024.py

```

1 import sqlite3
2 from pathlib import Path
3
4 database_path = (Path(__file__).parent / '../database.db').resolve()
5
6 def upgrade():
7     connection = sqlite3.connect(database_path)
8     cursor = connection.cursor()
9
10    cursor.execute('''
11        ALTER TABLE games ADD COLUMN start_fen_string TEXT NOT NULL
12    ''')
13
14    connection.commit()
15    connection.close()
16
17 def downgrade():
18     connection = sqlite3.connect(database_path)
19     cursor = connection.cursor()
20
21     cursor.execute('''
22        ALTER TABLE games DROP COLUMN start_fen_string
23    ''')
24
25     connection.commit()
26     connection.close()
27
28 upgrade()
29 # downgrade()

```

### B.5.4 change\_fen\_string\_column\_name\_23122024.py

See Section 3.8.1.

### B.5.5 create\_games\_table\_19112024.py

See Section 3.8.1.

## B.6 data\helpers

### B.6.1 asset\_helpers.py

See Section 3.3.3.

### B.6.2 bitboard\_helpers.py

```

1 from data.managers.logs import initialise_logger
2 from data.utils.constants import EMPTY_BB
3 from data.utils.enums import Rank, File
4
5 logger = initialise_logger(__name__)
6
7 # Debug function to return string representation of bitboard
8 def print_bitboard(bitboard):
9     if (bitboard >= (2 ** 80)):
10         raise ValueError('Invalid bitboard: too many bits')
11
12     characters = ''
13     for rank in reversed(Rank):
14
15         for file in File:
16             mask = 1 << (rank * 10 + file)
17             if (bitboard & mask) != 0:
18                 characters += '1 '
19             else:
20                 characters += '. '
21
22     characters += '\n\n'
23
24     logger.info('\n' + characters + '\n')
25
26 def is_occupied(bitboard, target_bitboard):
27     return (target_bitboard & bitboard) != EMPTY_BB
28
29 def clear_square(bitboard, target_bitboard):
30     return (~target_bitboard & bitboard)
31
32 def set_square(bitboard, target_bitboard):
33     return (target_bitboard | bitboard)
34
35 def index_to_bitboard(index):
36     return (1 << index)
37
38 def coords_to_bitboard(coords):
39     index = coords[1] * 10 + coords[0]
40     return index_to_bitboard(index)
41
42 # Converts bitboard square to algebraic board notation
43 def bitboard_to_notation(bitboard):
44     index = bitboard_to_index(bitboard)
45     x = index // 10
46     y = index % 10
47
48     return chr(y + 97) + str(x + 1)
49
50 def notation_to_bitboard(notation):
51     index = (int(notation[1]) - 1) * 10 + int(ord(notation[0])) - 97
52

```

```

53     return index_to_bitboard(index)
54
55 def bitboard_to_index(bitboard):
56     return bitboard.bit_length() - 1
57
58 def bitboard_to_coords(bitboard):
59     list_position = bitboard_to_index(bitboard)
60     x = list_position % 10
61     y = list_position // 10
62
63     return x, y
64
65 # Converts every occupied bit in bitboard to tuple of integers in a list
66 def bitboard_to_coords_list(bitboard):
67     list_positions = []
68
69     for square in occupied_squares(bitboard):
70         list_positions.append(bitboard_to_coords(square))
71
72     return list_positions
73
74 # Yields all individual occupied squares in the form of a bitboard
75 def occupied_squares(bitboard):
76     while bitboard:
77         lsb_square = bitboard & -bitboard
78         bitboard = bitboard ^ lsb_square
79
80         yield lsb_square
81
82 # Returns number of occupied squares in bitboard
83 def pop_count(bitboard):
84     count = 0
85     while bitboard:
86         count += 1
87         # Find least significant occupied bit
88         lsb_square = bitboard & -bitboard
89         bitboard = bitboard ^ lsb_square
90
91     return count
92
93 def loop_all_squares():
94     for i in range(80):
95         yield 1 << i

```

### B.6.3 board\_helpers.py

```

1 import pygame
2 from data.helpers.data_helpers import get_user_settings
3 from data.utils.assets import DEFAULT_FONT
4
5 user_settings = get_user_settings()
6
7 def create_board(board_size, primary_colour, secondary_colour, font=DEFAULT_FONT):
8     square_size = board_size[0] / 10
9     board_surface = pygame.Surface(board_size)
10
11     for i in range(80):
12         x = i % 10
13         y = i // 10
14
15         if (x + y) % 2 == 0:
16             square_colour = primary_colour

```

```

17     else:
18         square_colour = secondary_colour
19
20     square_x = x * square_size
21     square_y = y * square_size
22
23     pygame.draw.rect(board_surface, square_colour, (square_x, square_y,
24     square_size + 1, square_size + 1)) # +1 to fill in black lines
25
26     if y == 7:
27         text_position = (square_x + square_size * 0.7, square_y + square_size
28     * 0.55)
29         text_size = square_size / 3
30         font.render_to(board_surface, text_position, str(chr(x + 1 + 96)),
31         fgcolor=(10, 10, 10, 175), size=text_size)
32     if x == 0:
33         text_position = (square_x + square_size * 0.1, square_y + square_size
34     * 0.1)
35         text_size = square_size / 3
36     font.render_to(board_surface, text_position, str(7-y + 1), fgcolor
37     =(10, 10, 10, 175), size=text_size)
38
39     return board_surface
40
41
42 def create_square_overlay(square_size, colour):
43     overlay = pygame.Surface((square_size, square_size), pygame.SRCALPHA)
44     overlay.fill(colour)
45
46     return overlay
47
48 def create_circle_overlay(square_size, colour):
49     overlay = pygame.Surface((square_size, square_size), pygame.SRCALPHA)
50     pygame.draw.circle(overlay, colour, (square_size / 2, square_size / 2),
51     square_size / 4)
52
53     return overlay
54
55 def coords_to_screen_pos(coords, board_position, square_size):
56     x = board_position[0] + (coords[0] * square_size)
57     y = board_position[1] + ((7 - coords[1]) * square_size)
58
59     return (x, y)
60
61
62 def screen_pos_to_coords(mouse_position, board_position, board_size):
63     if (board_position[0] <= mouse_position[0] <= board_position[0] + board_size
64     [0]) and (board_position[1] <= mouse_position[1] <= board_position[1] +
65     board_size[1]):
66         x = (mouse_position[0] - board_position[0]) // (board_size[0] / 10)
67         y = (board_size[1] - (mouse_position[1] - board_position[1])) // (
68     board_size[0] / 10)
69         return (int(x), int(y))
70
71     return None

```

#### B.6.4 browser\_helpers.py

```

1 from data.utils.enums import Miscellaneous, Colour
2
3 def get_winner_string(winner):
4     if winner is None:
5         return 'UNFINISHED'
6     elif winner == Miscellaneous.DRAW:

```

```

7         return 'DRAW'
8     else:
9         return Colour(winner).name

```

### B.6.5 database\_helpers.py

See Section 3.8.2.

### B.6.6 data\_helpers.py

See Section 3.3.3.

### B.6.7 font\_helpers.py

```

1 def height_to_font_size(font, target_height):
2     test_size = 1
3     while True:
4         glyph_metrics = font.get_metrics('j', size=test_size)
5         descender = font.get_sized_descender(test_size)
6         test_height = abs(glyph_metrics[0][3] - glyph_metrics[0][2]) - descender
7         if test_height > target_height:
8             return test_size - 1
9
10        test_size += 1
11
12 def width_to_font_size(font, target_width):
13     test_size = 1
14     while True:
15         glyph_metrics = font.get_metrics(' ', size=test_size)
16
17         if (glyph_metrics[0][4] * 8) > target_width:
18             return (test_size - 1)
19
20        test_size += 1
21
22 def text_width_to_font_size(text, font, target_width):
23     test_size = 1
24     if len(text) == 0:
25         # print('(text_width_to_font_size) Text must have length greater than 1!')
26         text = " "
27
28     while True:
29         text_rect = font.get_rect(text, size=test_size)
30
31         if text_rect.width > target_width:
32             return (test_size - 1)
33
34     test_size += 1
35
36 def text_height_to_font_size(text, font, target_height):
37     test_size = 1
38
39     if ('(' in text) or (')' in text):
40         text = text.replace('(', 'j') # Pygame freetype thinks '(' or ')' is
41         taller for some reason
42         text = text.replace(')', 'j')
43
44     if len(text) == 0:
45         # print('(text_height_to_font_size) Text must have length greater than
46         1!')

```

```

45     text = "j"
46
47     while True:
48         text_rect = font.get_rect(text, size=test_size)
49
50         if text_rect.height > target_height:
51             return (test_size - 1)
52
53         test_size += 1
54
55 def get_font_height(font, font_size):
56     glyph_metrics = font.get_metrics('j', size=font_size)
57     descender = font.get_sized_descender(font_size)
58     return abs(glyph_metrics[0][3] - glyph_metrics[0][2]) - descender

```

### B.6.8 input\_helpers.py

```

1 from data.utils.enums import MoveType, Rotation
2
3 def parse_move_type(move_type):
4     if move_type.isalpha() is False:
5         raise ValueError('Invalid move type - move type must be a string!')
6     if move_type.lower() not in MoveType:
7         raise ValueError('Invalid move - type - move type must be m or r!')
8
9     return MoveType(move_type.lower())
10
11 def parse_notation(notation):
12     if (notation[0].isalpha() is False) or (notation[1].isnumeric() is False):
13         raise ValueError('Invalid notation - invalid notation input types!')
14     if not (97 <= ord(notation[0]) <= 106):
15         raise ValueError('Invalid notation - file is out of range!')
16     elif not (0 <= int(notation[1]) <= 10):
17         raise ValueError('Invalid notation - rank is out of range!')
18
19     return notation
20
21 def parse_rotation(rotation):
22     if rotation == '':
23         return None
24     if rotation.isalpha() is False:
25         raise ValueError('Invalid rotation - rotation must be a string!')
26     if rotation.lower() not in Rotation:
27         raise ValueError('Invalid rotation - rotation is invalid!')
28
29     return Rotation(rotation.lower())

```

### B.6.9 load\_helpers.py

```

1 import pygame
2 import pygame.freetype
3 from pathlib import Path
4 from data.helpers.asset_helpers import gif_to_frames, pil_image_to_surface
5
6 def convert_gfx_alpha(image, colorkey=(0, 0, 0)):
7     # if image.get_alpha():
8     #     return image.convert_alpha()
9     # else:
10    #     image = image.convert_alpha()
11    #     image.set_colorkey(colorkey)
12

```

```

13     #      return image
14
15 def load_gfx(path, colorkey=(0, 0, 0), accept=(".svg", ".png", ".jpg", ".gif")):
16     file_path = Path(path)
17     name, extension = file_path.stem, file_path.suffix
18
19     if extension.lower() in accept:
20         if extension.lower() == '.gif':
21             frames_list = []
22
23             for frame in gif_to_frames(path):
24                 image_surface = pil_image_to_surface(frame)
25                 frames_list.append(image_surface)
26
27             return frames_list
28
29     if extension.lower() == '.svg':
30         low_quality_image = pygame.image.load_sized_svg(path, (200, 200))
31         image = pygame.image.load(path)
32         image = convert_gfx_alpha(image, colorkey)
33
34     return [image, low_quality_image]
35
36 else:
37     image = pygame.image.load(path)
38     return convert_gfx_alpha(image, colorkey)
39
40 def load_all_gfx(directory, colorkey=(0, 0, 0), accept=(".svg", ".png", ".jpg", ".gif")):
41     graphics = {}
42
43     for file in Path(directory).rglob('*'):
44         name, extension = file.stem, file.suffix
45         path = Path(directory / file)
46
47         if extension.lower() in accept and 'old' not in name:
48             if name == 'piece_spritesheet':
49                 data = load_spritesheet(
50                     path,
51                     (16, 16),
52                     ['pyramid_1', 'scarab_1', 'anubis_1', 'pharaoh_1', 'sphinx_1',
53                     'pyramid_0', 'scarab_0', 'anubis_0', 'pharaoh_0', 'sphinx_0'],
54                     ['_a', '_b', '_c', '_d'])
55
56             graphics = graphics | data
57             continue
58
59             data = load_gfx(path, colorkey, accept)
60
61             if isinstance(data, list):
62                 graphics[name] = data[0]
63                 graphics[f'{name}_lq'] = data[1]
64             else:
65                 graphics[name] = data
66
67     return graphics
68
68 def load_spritesheet(path, sprite_size, col_names, row_names):
69     spritesheet = load_gfx(path)
70     col_count = int(spritesheet.width / sprite_size[0])
71     row_count = int(spritesheet.height / sprite_size[1])
72

```

```

73     sprite_dict = {}
74
75     for column in range(col_count):
76         for row in range(row_count):
77             surface = pygame.Surface(sprite_size, pygame.SRCALPHA)
78             name = col_names[column] + row_names[row]
79
80             surface.blit(spritesheet, (0, 0), (column * sprite_size[0], row *
81             sprite_size[1], *sprite_size))
82             sprite_dict[name] = surface
83
84     return sprite_dict
85
86 def load_all_fonts(directory, accept=( ".ttf", ".otf")):
87     fonts = {}
88
89     for file in Path(directory).rglob('*'):
90         name, extension = file.stem, file.suffix
91         path = Path(directory / file)
92
93         if extension.lower() in accept:
94             font = pygame.freetype.Font(path)
95             fonts[name] = font
96
97     return fonts
98
99 def load_all_sfx(directory, accept=( ".mp3", ".wav", ".ogg")):
100    sound_effects = {}
101
102    for file in Path(directory).rglob('*'):
103        name, extension = file.stem, file.suffix
104        path = Path(directory / file)
105
106        if extension.lower() in accept and 'old' not in name:
107            sound_effects[name] = load_sfx(path)
108
109    return sound_effects
110
111 def load_sfx(path, accept=( ".mp3", ".wav", ".ogg")):
112     file_path = Path(path)
113     name, extension = file_path.stem, file_path.suffix
114
115     if extension.lower() in accept:
116         sfx = pygame.mixer.Sound(path)
117         return sfx
118
119 def load_all_music(directory, accept=( ".mp3", ".wav", ".ogg")):
120     music_paths = {}
121
122     for file in Path(directory).rglob('*'):
123         name, extension = file.stem, file.suffix
124         path = Path(directory / file)
125
126         if extension.lower() in accept:
127             music_paths[name] = path
128
129     return music_paths

```

### B.6.10 widget\_helpers.py

See Section 3.3.3.

## B.7 data\managers

### B.7.1 animation.py

```

1 import pygame
2 from data.helpers.asset_helpers import scale_and_cache
3
4 FPS = 60
5
6 class AnimationManager:
7     def __init__(self):
8         self._current_ms = 0
9         self._timers = []
10
11    def set_delta_time(self):
12        self._current_ms = pygame.time.get_ticks()
13
14        for timer in self._timers:
15            start_ms, target_ms, callback = timer
16            if self._current_ms - start_ms >= target_ms:
17                callback()
18                self._timers.remove(timer)
19
20    def calculate_frame_index(self, start_index, end_index, fps):
21        ms_per_frame = int(1000 / fps)
22        return start_index + ((self._current_ms // ms_per_frame) % (end_index -
start_index))
23
24    def draw_animation(self, screen, animation, position, size, fps=8):
25        frame_index = self.calculate_frame_index(0, len(animation), fps)
26        scaled_animation = scale_and_cache(animation[frame_index], size)
27        screen.blit(scaled_animation, position)
28
29    def draw_image(self, screen, image, position, size):
30        scaled_background = scale_and_cache(image, size)
31        screen.blit(scaled_background, position)
32
33    def set_timer(self, target_ms, callback):
34        self._timers.append((self._current_ms, target_ms, callback))
35
36 animation = AnimationManager()

```

### B.7.2 audio.py

```

1 import pygame
2 from data.helpers.data_helpers import get_user_settings
3 from data.managers.logs import initialise_logger
4
5 logger = initialise_logger(__name__)
6 user_settings = get_user_settings()
7
8 class AudioManager:
9     def __init__(self, num_channels=16):
10         pygame.mixer.set_num_channels(num_channels)
11
12         self._music_volume = user_settings['musicVolume']
13         self._sfx_volume = user_settings['sfxVolume']
14
15         self._current_song = None
16         self._current_channels = []
17

```

```

18     def set_sfx_volume(self, volume):
19         self._sfx_volume = volume
20
21         for channel in self._current_channels:
22             channel.set_volume(self._sfx_volume)
23
24     def set_music_volume(self, volume):
25         self._music_volume = volume
26
27         pygame.mixer.music.set_volume(self._music_volume)
28
29     def pause_sfx(self):
30         pygame.mixer.pause()
31
32     def unpause_sfx(self):
33         pygame.mixer.unpause()
34
35     def stop_sfx(self, fadeout=0):
36         pygame.mixer.fadeout(fadeout)
37
38     def remove_unused_channels(self):
39         unused_channels = []
40         for channel in self._current_channels:
41             if channel.get_busy() is False:
42                 unused_channels.append(channel)
43
44         return unused_channels
45
46     def play_sfx(self, sfx, loop=False):
47         unused_channels = self.remove_unused_channels()
48
49         if len(unused_channels) == 0:
50             channel = pygame.mixer.find_channel()
51         else:
52             channel = unused_channels.pop(0)
53
54         if channel is None:
55             logger.warning('No available channel for SFX')
56             return
57
58         self._current_channels.append(channel)
59         channel.set_volume(self._sfx_volume)
60
61         if loop:
62             channel.play(sfx, loops=-1)
63         else:
64             channel.play(sfx)
65
66     def play_music(self, music_path):
67         if 'menu' in str(music_path) and 'menu' in str(self._current_song):
68             return
69
70         if music_path == self._current_song:
71             return
72
73         pygame.mixer.music.stop()
74         pygame.mixer.music.unload()
75         pygame.mixer.music.load(music_path)
76         pygame.mixer.music.set_volume(self._music_volume)
77         pygame.mixer.music.play(loops=-1)
78
79         self._current_song = music_path

```

```

80
81 audio = AudioManager()

B.7.3 cursor.py

1 import pygame
2 from data.utils.enums import CursorMode
3 from data.utils.assets import GRAPHICS
4
5 # Manager to change mouse cursor icons
6 class CursorManager:
7     def __init__(self):
8         self._mode = CursorMode.ARROW
9         self.set_mode(CursorMode.ARROW)
10
11     def set_mode(self, mode):
12         pygame.mouse.set_visible(True)
13
14         match mode:
15             case CursorMode.ARROW:
16                 pygame.mouse.set_cursor((7, 5), pygame.transform.scale(GRAPHICS['
17 arrow'], (32, 32)))
18             case CursorMode.IBEAM:
19                 pygame.mouse.set_cursor((15, 5), pygame.transform.scale(GRAPHICS['
20 ibeam'], (32, 32)))
21             case CursorMode.OPENGHAND:
22                 pygame.mouse.set_cursor((17, 5), pygame.transform.scale(GRAPHICS['
23 hand_open'], (32, 32)))
24             case CursorMode.CLOSEDHAND:
25                 pygame.mouse.set_cursor((17, 5), pygame.transform.scale(GRAPHICS['
26 hand_closed'], (32, 32)))
27             case CursorMode.NO:
28                 pygame.mouse.set_visible(False)
29
30         self._mode = mode
31
32     def get_mode(self):
33         return self._mode
34
35 cursor = CursorManager()

```

**B.7.4 logs.py**

```

1 import logging.config
2 from data.helpers.data_helpers import load_json
3 from pathlib import Path
4 import logging
5
6 config_path = (Path(__file__).parent / '../app_data/logs_config.json').resolve()
7 config = load_json(config_path)
8 logging.config.dictConfig(config)
9
10 def initialise_logger(file_path):
11     return logging.getLogger(Path(file_path).name)

```

**B.7.5 shader.py**

See Section 3.9.1.

### B.7.6 theme.py

See Section 3.3.4.

### B.7.7 window.py

```

1 import pygame
2 import moderngl
3 from data.utils.constants import ShaderType, SCREEN_SIZE, SHADER_MAP
4 from data.helpers.data_helpers import get_user_settings
5 from data.helpers.asset_helpers import draw_background
6 from data.managers.shader import ShaderManager
7
8 user_settings = get_user_settings()
9 is_opengl = user_settings['opengl']
10 is_fullscreen = user_settings['displayMode'] == 'fullscreen'
11
12 class WindowManager(pygame.Window):
13     def __init__(self, **kwargs):
14         super().__init__(**kwargs)
15         self._native_screen = self.get_surface() # Initialise convert format
16         self.screen = pygame.Surface(self.size, pygame.SRCALPHA)
17
18         # Can only import and initialise graphics after window convert format is
19         # initialised
20         from data.utils.assets import GRAPHICS
21         self.set_icon(GRAPHICS['icon'])
22
23         if is_opengl:
24             self._ctx = moderngl.create_context()
25             self._shader_manager = ShaderManager(self._ctx, screen_size=self.size)
26
27             # Each ShaderType contains a dictionary of kwargs, used as arguments
28             # when running the apply method on the corresponding shader class
29             self.shader_arguments = {
30                 ShaderType.BASE: {},
31                 ShaderType.SHAKE: {},
32                 ShaderType.BLOOM: {},
33                 ShaderType.GRAYSCALE: {},
34                 ShaderType.CRT: {},
35                 ShaderType.RAYS: {}
36             }
37
38             # For the secret settings option in the settings menu, apply shaders
39             # for the selected option
40             if (selected_shader := get_user_settings()['shader']) is not None:
41                 for shader_type in SHADER_MAP[selected_shader]:
42                     self.set_effect(shader_type)
43             else:
44                 # If shaders disabled, use temporary image as background
45                 self._background_image = GRAPHICS['temp_background']
46
47     def set_effect(self, effect, **kwargs):
48         if is_opengl:
49             self._shader_manager.apply_shader(effect, **kwargs)
50
51     def set_apply_arguments(self, effect, **kwargs):
52         if is_opengl:
53             self.shader_arguments[effect] = kwargs
54
55     def clear_apply_arguments(self, effect):

```

```

53     if is_opengl:
54         self.shader_arguments[effect] = {}
55
56     def clear_effect(self, effect):
57         if is_opengl:
58             self._shader_manager.remove_shader(effect)
59             self.clear_apply_arguments(effect)
60
61     def clear_all_effects(self, clear_arguments=False):
62         if is_opengl:
63             self._shader_manager.clear_shaders()
64
65         if clear_arguments:
66             for shader_type in self.shader_arguments:
67                 self.shader_arguments[shader_type] = {}
68
69     def draw(self):
70         if is_opengl:
71             self._shader_manager.draw(self.screen, self.shader_arguments)
72         else:
73             self._native_screen.blit(self.screen, (0, 0))
74
75         self.flip()
76
77         if is_opengl:
78             self.screen.fill((0, 0, 0, 0))
79         else:
80             self.screen.fill((0, 0, 0))
81             draw_background(self.screen, self._background_image)
82
83     def update(self):
84         self.draw()
85
86     def handle_resize(self):
87         self.screen = pygame.Surface(self.size, pygame.SRCALPHA)
88         if is_opengl:
89             self._shader_manager.handle_resize(self.size)
90         else:
91             draw_background(self.screen, self._background_image)
92
93 window = WindowManager(
94     title='Laser Chess',
95     size=SCREEN_SIZE,
96     resizable=True,
97     opengl=is_opengl,
98     fullscreen_desktop=is_fullscreen
99 )

```

## B.8 data\shaders

### B.8.1 protocol.py

```

1 import pygame
2 import moderngl
3 from typing import Protocol, Optional
4 from data.utils.constants import ShaderType
5
6 class SMProtocol(Protocol):
7     def load_shader(self, shader_type: ShaderType, **kwargs) -> None: ...
8     def clear_shaders(self) -> None: ...
9     def create_vao(self, shader_type: ShaderType) -> None: ...

```

```

10     def create_framebuffer(self, shader_type: ShaderType, size: Optional[tuple[int]] = None, filter: Optional[int] = moderngl.NEAREST) -> None: ...
11     def render_to_fbo(self, shader_type: ShaderType, texture: moderngl.Texture, output_fbo: Optional[moderngl.Framebuffer] = None, program_type: Optional[ShaderType] = None, use_image: Optional[bool] = True, **kwargs) -> None: ...
12     def apply_shader(self, shader_type: ShaderType, **kwargs) -> None: ...
13     def remove_shader(self, shader_type: ShaderType) -> None: ...
14     def render_output(self, texture: moderngl.Texture) -> None: ...
15     def get_fbo_texture(self, shader_type: ShaderType) -> moderngl.Texture: ...
16     def calibrate_pygame_surface(self, pygame_surface: pygame.Surface) -> moderngl.Texture: ...
17     def draw(self, surface: pygame.Surface, arguments: dict) -> None: ...
18     def __del__(self) -> None: ...
19     def cleanup(self) -> None: ...
20     def handle_resize(self, new_screen_size: tuple[int]) -> None: ...
21
22     _ctx: moderngl.Context
23     _screen_size: tuple[int]
24     _opengl_buffer: moderngl.Buffer
25     _pygame_buffer: moderngl.Buffer
26     _shader_stack: list[ShaderType]
27
28     _vert_shaders: dict
29     _frag_shaders: dict
30     _programs: dict
31     _vaos: dict
32     _textures: dict
33     _shader_passes: dict
34     framebuffers: dict

```

## B.9 data\shaders\classes

### B.9.1 base.py

```

1 import pygame
2 from data.shaders.protocol import SMProtocol
3 from data.utils.constants import ShaderType
4
5 class Base:
6     def __init__(self, shader_manager: SMProtocol):
7         self._shader_manager = shader_manager
8
9         self._shader_manager.create_framebuffer(ShaderType.BASE)
10        self._shader_manager.create_vao(ShaderType.BACKGROUND_WAVES)
11        self._shader_manager.create_vao(ShaderType.BACKGROUND_BALATRO)
12        self._shader_manager.create_vao(ShaderType.BACKGROUND_LASERS)
13        self._shader_manager.create_vao(ShaderType.BACKGROUND_GRADIENT)
14        self._shader_manager.create_vao(ShaderType.BACKGROUND_NONE)
15
16    def apply(self, texture, background_type=None):
17        base_texture = self._shader_manager.get_fbo_texture(ShaderType.BASE)
18
19        # Draws background to ShaderType.BASE framebuffer
20        match background_type:
21            case ShaderType.BACKGROUND_WAVES:
22                self._shader_manager.render_to_fbo(
23                    ShaderType.BASE,
24                    texture=base_texture,
25                    program_type=ShaderType.BACKGROUND_WAVES,
26                    use_image=False,
27                    time=pygame.time.get_ticks() / 1000

```

```

28
29         )
30     case ShaderType.BACKGROUND_BALATRO:
31         self._shader_manager.render_to_fbo(
32             ShaderType.BASE,
33             texture=base_texture,
34             program_type=ShaderType.BACKGROUND_BALATRO,
35             use_image=False,
36             time=pygame.time.get_ticks() / 1000,
37             screenSize=base_texture.size
38     )
39     case ShaderType.BACKGROUND_LASERS:
40         self._shader_manager.render_to_fbo(
41             ShaderType.BASE,
42             texture=base_texture,
43             program_type=ShaderType.BACKGROUND_LASERS,
44             use_image=False,
45             time=pygame.time.get_ticks() / 1000,
46             screenSize=base_texture.size
47     )
48     case ShaderType.BACKGROUND_GRADIENT:
49         self._shader_manager.render_to_fbo(
50             ShaderType.BASE,
51             texture=base_texture,
52             program_type=ShaderType.BACKGROUND_GRADIENT,
53             use_image=False,
54             time=pygame.time.get_ticks() / 1000,
55             screenSize=base_texture.size
56     )
57     case None:
58         self._shader_manager.render_to_fbo(
59             ShaderType.BASE,
60             texture=base_texture,
61             program_type=ShaderType.BACKGROUND_NONE,
62             use_image=False,
63         )
64     case _:
65         raise ValueError('(shader.py) Unknown background type:', background_type)
66
67     # Draws background using texture in ShaderType.BASE framebuffer, on pixels
68     # in the Pygame texture that have no alpha
69     self._shader_manager.get_fbo_texture(ShaderType.BASE).use(1)
70     self._shader_manager.render_to_fbo(ShaderType.BASE, texture, background=1)

```

## B.9.2 blend.py

```

1 import moderngl
2 from data.shaders.protocol import SMProtocol
3 from data.utils.constants import ShaderType
4
5 class _Blend:
6     def __init__(self, shader_manager: SMProtocol):
7         self._shader_manager = shader_manager
8
9         self._shader_manager.create_framebuffer(ShaderType._BLEND)
10
11    # Blend two textures, while positioning textures relative to each other if not
12    # the same size
13    def apply(self, texture, texture_2, texture_2_pos):
14        self._shader_manager._ctx.blend_func = (moderngl.SRC_ALPHA, moderngl.ONE)

```

```

15     relative_size = (texture_2.size[0] / texture.size[0], texture_2.size[1] /
16         texture.size[1])
17         # Convert position of smaller texture within big texture into OpenGL
18         coordinates
19         opengl_pos = (texture_2_pos[0], 1 - texture_2_pos[1] - relative_size[1])
20
21         texture_2.use(1)
22         self._shader_manager.render_to_fbo(ShaderType._BLEND, texture, image2=1,
23         image2Pos=opengl_pos, relativeSize=relative_size)
24         self._shader_manager._ctx.blend_func = moderngl.DEFAULT_BLENDING

```

### B.9.3 bloom.py

See Section 3.9.2.

### B.9.4 blur.py

See Section 3.9.2.

### B.9.5 chromatic\_abbreviation.py

```

1 import pygame
2 from data.utils.constants import ShaderType
3 from data.shaders.protocol import SMProtocol
4
5 CHROMATIC_ABBREVIATION_INTENSITY = 2.0
6
7 class ChromaticAbbreviation:
8     def __init__(self, shader_manager: SMProtocol):
9         self._shader_manager = shader_manager
10
11     self._shader_manager.create_framebuffer(ShaderType.CHROMATIC_ABBREVIATION)
12
13     def apply(self, texture):
14         mouse_pos = (pygame.mouse.get_pos()[0] / texture.size[0], pygame.mouse.
15         get_pos()[1] / texture.size[1])
16         self._shader_manager.render_to_fbo(ShaderType.CHROMATIC_ABBREVIATION,
17         texture, mouseFocusPoint=mouse_pos, enabled=pygame.mouse.get_pressed()[0],
18         intensity=CHROMATIC_ABBREVIATION_INTENSITY)

```

### B.9.6 crop.py

```

1 from data.utils.constants import ShaderType
2 from data.shaders.protocol import SMProtocol
3
4 class _Crop:
5     def __init__(self, shader_manager: SMProtocol):
6         self._shader_manager = shader_manager
7
8     def apply(self, texture, relative_pos, relative_size):
9         opengl_pos = (relative_pos[0], 1 - relative_pos[1] - relative_size[1])
10        pixel_size = (int(relative_size[0] * texture.size[0]), int(relative_size
11        [1] * texture.size[1]))
12
13        self._shader_manager.create_framebuffer(ShaderType._CROP, size=pixel_size)
14
15        self._shader_manager.render_to_fbo(ShaderType._CROP, texture, relativePos=
16        opengl_pos, relativeSize=relative_size)

```

**B.9.7 crt.py**

```

1 from data.utils.constants import ShaderType
2 from data.shaders.protocol import SMProtocol
3
4 class CRT:
5     def __init__(self, shader_manager: SMProtocol):
6         self._shader_manager = shader_manager
7
8         shader_manager.create_framebuffer(ShaderType.CRT)
9
10    def apply(self, texture):
11        self._shader_manager.render_to_fbo(ShaderType.CRT, texture)

```

**B.9.8 grayscale.py**

```

1 from data.utils.constants import ShaderType
2 from data.shaders.protocol import SMProtocol
3
4 class Grayscale:
5     def __init__(self, shader_manager: SMProtocol):
6         self._shader_manager = shader_manager
7
8         shader_manager.create_framebuffer(ShaderType.GRAYSCALE)
9
10    def apply(self, texture):
11        self._shader_manager.render_to_fbo(ShaderType.GRAYSCALE, texture)

```

**B.9.9 highlight\_brightness.py**

```

1 from data.utils.constants import ShaderType
2 from data.shaders.protocol import SMProtocol
3
4 HIGHLIGHT_THRESHOLD = 0.9
5
6 class _HighlightBrightness:
7     def __init__(self, shader_manager: SMProtocol):
8         self._shader_manager = shader_manager
9
10        shader_manager.create_framebuffer(ShaderType._HIGHLIGHT_BRIGHTNESS)
11
12    def apply(self, texture, intensity):
13        self._shader_manager.render_to_fbo(ShaderType._HIGHLIGHT_BRIGHTNESS,
14                                         texture, threshold=HIGHLIGHT_THRESHOLD, intensity=intensity)

```

**B.9.10 highlight\_colour.py**

```

1 from data.utils.constants import ShaderType
2 from data.shaders.protocol import SMProtocol
3
4 class _HighlightColour:
5     def __init__(self, shader_manager: SMProtocol):
6         self._shader_manager = shader_manager
7
8         shader_manager.create_framebuffer(ShaderType._HIGHLIGHT_COLOUR)
9
10    def apply(self, texture, old_highlight, colour, intensity):
11        old_highlight.use(1)
12        self._shader_manager.render_to_fbo(ShaderType._HIGHLIGHT_COLOUR, texture,
13                                         highlight=1, colour=colour, threshold=0.1, intensity=intensity)

```

### B.9.11 lightmap.py

```

1 from data.utils.constants import ShaderType
2 from data.shaders.protocol import SMProtocol
3 from data.shaders.classes.shadowmap import _Shadowmap
4
5 LIGHT_RESOLUTION = 256
6
7 class _Lightmap:
8     def __init__(self, shader_manager: SMProtocol):
9         self._shader_manager = shader_manager
10
11     shader_manager.load_shader(ShaderType._SHADOWMAP)
12
13     def apply(self, texture, colour, softShadow, occlusion=None, falloff=0.0,
14               clamp=(-180, 180)):
15         self._shader_manager.create_framebuffer(ShaderType._LIGHTMAP, size=texture.size)
16         self._shader_manager._ctx.enable(self._shader_manager._ctx.BLEND)
17
18         _Shadowmap(self._shader_manager).apply(texture, occlusion)
19         shadow_map = self._shader_manager.get_fbo_texture(ShaderType._SHADOWMAP)
20
21         self._shader_manager.render_to_fbo(ShaderType._LIGHTMAP, shadow_map,
22                                         resolution=LIGHT_RESOLUTION, lightColour=colour, falloff=falloff, angleClamp=clamp,
23                                         softShadow=softShadow)
24
25         self._shader_manager._ctx.disable(self._shader_manager._ctx.BLEND)

```

### B.9.12 occlusion.py

```

1 from data.utils.constants import ShaderType
2 from data.shaders.protocol import SMProtocol
3
4 class _Occlusion:
5     def __init__(self, shader_manager: SMProtocol):
6         self._shader_manager = shader_manager
7
8     def apply(self, texture, occlusion_colour=(255, 0, 0)):
9         self._shader_manager.create_framebuffer(ShaderType._OCCLUSION, size=texture.size)
10        self._shader_manager.render_to_fbo(ShaderType._OCCLUSION, texture,
11                                         checkColour=tuple(num / 255 for num in occlusion_colour))

```

### B.9.13 rays.py

See Section 3.9.3.

### B.9.14 shadowmap.py

```

1 import moderngl
2 from data.utils.constants import ShaderType
3 from data.shaders.protocol import SMProtocol
4 from data.shaders.classes.occlusion import _Occlusion
5
6 LIGHT_RESOLUTION = 256
7
8 class _Shadowmap:
9     def __init__(self, shader_manager: SMProtocol):
10         self._shader_manager = shader_manager

```

```

11     shader_manager.load_shader(ShaderType._OCCLUSION)
12
13     def apply(self, texture, occlusion_texture=None):
14         self._shader_manager.create_framebuffer(ShaderType._SHADOWMAP, size=
15             texture.size[0], 1), filter=moderngl.LINEAR)
16
17         if occlusion_texture is None:
18             _Occlusion(self._shader_manager).apply(texture)
19             occlusion_texture = self._shader_manager.get_fbo_texture(ShaderType.
20             _OCCLUSION)
21
22         self._shader_manager.render_to_fbo(ShaderType._SHADOWMAP,
23             occlusion_texture, resolution=LIGHT_RESOLUTION)

```

**B.9.15 shake.py**

```

1 from data.utils.constants import ShaderType
2 from data.shaders.protocol import SMProtocol
3 from random import randint
4
5 SHAKE_INTENSITY = 3
6
7 class Shake:
8     def __init__(self, shader_manager: SMProtocol):
9         self._shader_manager = shader_manager
10
11         self._shader_manager.create_framebuffer(ShaderType.SHAKE)
12
13     def apply(self, texture, intensity=SHAKE_INTENSITY):
14         displacement = (randint(-intensity, intensity) / 1000, randint(-intensity,
15             intensity) / 1000)
16         self._shader_manager.render_to_fbo(ShaderType.SHAKE, texture, displacement
17             =displacement)

```

**B.9.16 \_\_init\_\_.py**

```

1 from data.shaders.classes.chromatic_abbreviation import ChromaticAbbreviation
2 from data.shaders.classes.highlight_brightness import _HighlightBrightness
3 from data.shaders.classes.highlight_colour import _HighlightColour
4 from data.shaders.classes.shadowmap import _Shadowmap
5 from data.shaders.classes.occlusion import _Occlusion
6 from data.shaders.classes.grayscale import Grayscale
7 from data.shaders.classes.lightmap import _Lightmap
8 from data.shaders.classes.blend import _Blend
9 from data.shaders.classes.shake import Shake
10 from data.shaders.classes.bloom import Bloom
11 from data.shaders.classes.blur import _Blur
12 from data.shaders.classes.crop import _Crop
13 from data.shaders.classes.rays import Rays
14 from data.shaders.classes.base import Base
15 from data.shaders.classes.crt import CRT
16
17 from data.utils.constants import ShaderType
18
19 shader_pass_lookup = {
20     ShaderType.CHROMATIC_ABBREVIATION: ChromaticAbbreviation,
21     ShaderType.GRAYSCALE: Grayscale,
22     ShaderType.SHAKE: Shake,
23     ShaderType.BLOOM: Bloom,
24     ShaderType.BASE: Base,

```

```

25     ShaderType.RAYS: Rays,
26     ShaderType.CRT: CRT,
27
28     ShaderType._HIGHLIGHT_BRIGHTNESS: _HighlightBrightness,
29     ShaderType._HIGHLIGHT_COLOUR: _HighlightColour,
30     ShaderType._CALIBRATE: lambda *args: None,
31     ShaderType._OCCLUSION: _Occlusion,
32     ShaderType._SHADOWMAP: _Shadowmap,
33     ShaderType._LIGHTMAP: _Lightmap,
34     ShaderType._BLEND: _Blend,
35     ShaderType._BLUR: _Blur,
36     ShaderType._CROP: _Crop,
37 }
```

## B.10 data\shaders\fragments

### B.10.1 background\_balatro.frag

```

1 // Original by localthunk (https://www.playbalatro.com)
2 // Modified from https://godotshaders.com/shader/balatro-background-shader/
3
4 # version 330 core
5
6 // Configuration (modify these values to change the effect)
7 #define SPIN_ROTATION -2.0
8 #define SPIN_SPEED 7.0
9 #define OFFSET vec2(0.0)
10 #define COLOUR_2 vec4(0.871, 0.267, 0.231, 1.0)
11 #define COLOUR_1 vec4(0.0, 0.42, 0.706, 1.0)
12 #define COLOUR_3 vec4(0.086, 0.137, 0.145, 1.0)
13 #define CONTRAST 3.5
14 #define LIGHTHING 0.4
15 #define SPIN_AMOUNT 0.25
16 #define PIXEL_FILTER 745.0
17 #define SPIN_EASE 1.0
18 #define PI 3.14159265359
19 #define IS_ROTATE false
20
21 uniform float time;
22 uniform vec2 screenSize;
23
24 in vec2 uvs;
25 out vec4 f_colour;
26
27 vec4 effect(vec2 screenSize, vec2 screen_coords) {
28     float pixel_size = length(screenSize.xy) / PIXEL_FILTER;
29     vec2 uv = (floor(screen_coords.xy*(1./pixel_size))*pixel_size - 0.5*screenSize
30 .xy)/length(screenSize.xy) - OFFSET;
31     float uv_len = length(uv);
32
33     float speed = (SPIN_ROTATION*SPIN_EASE*0.2);
34     if(IS_ROTATE){
35         speed = time * speed;
36     }
37     speed += 302.2;
38     float new_pixel_angle = atan(uv.y, uv.x) + speed - SPIN_EASE*20.*(
39 1.*SPIN_AMOUNT*uv_len + (1. - 1.*SPIN_AMOUNT));
40     vec2 mid = (screenSize.xy/length(screenSize.xy))/2.;
41     uv = (vec2((uv_len * cos(new_pixel_angle) + mid.x), (uv_len * sin(
42 new_pixel_angle) + mid.y)) - mid);
```

```

41     uv *= 30.;
42     speed = time*(SPIN_SPEED);
43     vec2 uv2 = vec2(uv.x+uv.y);
44
45     for(int i=0; i < 5; i++) {
46         uv2 += sin(max(uv.x, uv.y)) + uv;
47         uv += 0.5*vec2(cos(5.1123314 + 0.353*uv2.y + speed*0.131121),sin(uv2.x -
48             0.113*speed));
49         uv -= 1.0*cos(uv.x + uv.y) - 1.0*sin(uv.x*0.711 - uv.y);
50     }
51
52     float contrast_mod = (0.25*CONTRAST + 0.5*SPIN_AMOUNT + 1.2);
53     float paint_res = min(2., max(0., length(uv)*(0.035)*contrast_mod));
54     float c1p = max(0.,1. - contrast_mod*abs(1.-paint_res));
55     float c2p = max(0.,1. - contrast_mod*abs(paint_res));
56     float c3p = 1. - min(1., c1p + c2p);
57     float light = (LIGHTHING - 0.2)*max(c1p*5. - 4., 0.) + LIGHTHING*max(c2p*5. -
58        4., 0.);
59     return (0.3/CONTRAST)*COLOUR_1 + (1. - 0.3/CONTRAST)*(COLOUR_1*c1p + COLOUR_2*
60     c2p + vec4(c3p*COLOUR_3.rgb, c3p*COLOUR_1.a)) + light;
61 }
62 }
```

## B.10.2 background\_gradient.frag

```

1 // Modified from https://www.shadertoy.com/view/wdyczG
2
3 #version 330 core
4
5 uniform float time;
6 uniform vec2 screenSize;
7
8 in vec2 uvs;
9 out vec4 f_colour;
10
11 #define S(a,b,t) smoothstep(a,b,t)
12
13 mat2 Rot(float a)
14 {
15     float s = sin(a);
16     float c = cos(a);
17     return mat2(c, -s, s, c);
18 }
19
20 // Created by inigo quilez - iq/2014
21 // License Creative Commons Attribution-NonCommercial-ShareAlike 3.0 Unported
22 // License.
22 vec2 hash( vec2 p )
23 {
24     p = vec2( dot(p,vec2(2127.1,81.17)), dot(p,vec2(1269.5,283.37)) );
25     return fract(sin(p)*43758.5453);
26 }
27
28 float noise( in vec2 p )
29 {
30     vec2 i = floor( p );
31     vec2 f = fract( p );
32     vec2 u = f*f*(3.0-2.0*f);

```

```

34
35     float n = mix( mix( dot( -1.0+2.0*hash( i + vec2(0.0,0.0) ), f - vec2(0.0,0.0)
36         ),
37             dot( -1.0+2.0*hash( i + vec2(1.0,0.0) ), f - vec2(1.0,0.0)
38         ),
39             mix( dot( -1.0+2.0*hash( i + vec2(0.0,1.0) ), f - vec2(0.0,1.0)
40         ),
41             dot( -1.0+2.0*hash( i + vec2(1.0,1.0) ), f - vec2(1.0,1.0)
42     ),
43     return 0.5 + 0.5*n;
44 }
45
46 void main() {
47     float ratio = screenSize.x / screenSize.y;
48
49     vec2 tuv = uvs;
50     tuv -= .5;
51
52     // rotate with Noise
53     float degree = noise(vec2(time*.1, tuv.x*tuv.y));
54
55     tuv.y *= 1./ratio;
56     tuv *= Rot(radians((degree-.5)*720.+180.));
57     tuv.y *= ratio;
58
59     // Wave warp with sin
60     float frequency = 5.;
61     float amplitude = 30.;
62     float speed = time * 2.;
63     tuv.x += sin(tuv.y*frequency+speed)/amplitude;
64     tuv.y += sin(tuv.x*frequency*1.5+speed)/(amplitude*.5);
65
66     // draw the image
67     vec3 colorYellow = vec3(.957, .804, .623);
68     vec3 colorDeepBlue = vec3(.192, .384, .933);
69     vec3 layer1 = mix(colorYellow, colorDeepBlue, S(-.3, .2, (tuv*Rot(radians(-5.)).x)));
70
71     vec3 colorRed = vec3(.910, .510, .8);
72     vec3 colorBlue = vec3(0.350, .71, .953);
73     vec3 layer2 = mix(colorRed, colorBlue, S(-.3, .2, (tuv*Rot(radians(-5.))).x));
74
75     vec3 finalComp = mix(layer1, layer2, S(.5, -.3, tuv.y));
76
77     vec3 col = finalComp;
78
79     f_colour = vec4(col,1.0);
80 }

```

### B.10.3 background\_lasers.frag

```

1 // Modified from https://www.shadertoy.com/view/7tBSR1
2 // rand [0,1] https://www.shadertoy.com/view/4djSRW
3
4 #version 330 core
5
6 uniform float time;
7 uniform vec2 screenSize;
8
9 in vec2 uvs;
10 out vec4 f_colour;
11

```

```

12 float rand(vec2 p) {
13     p *= 500.0;
14     vec3 p3 = fract(vec3(p.xy) * .1031);
15     p3 += dot(p3, p3.yzx + 33.33);
16     return fract((p3.x + p3.y) * p3.z);
17 }
18
19 // value noise
20 float noise(vec2 p) {
21     vec2 f = smoothstep(0.0, 1.0, fract(p));
22     vec2 i = floor(p);
23     float a = rand(i);
24     float b = rand(i+vec2(1.0,0.0));
25     float c = rand(i+vec2(0.0,1.0));
26     float d = rand(i+vec2(1.0,1.0));
27     return mix(mix(a, b, f.x), mix(c, d, f.x), f.y);
28 }
29
30 // fractal noise
31 float fbm(vec2 p) {
32     float a = 0.5;
33     float r = 0.0;
34     for (int i = 0; i < 8; i++) {
35         r += a*noise(p);
36         a *= 0.5;
37         p *= 2.0;
38     }
39     return r;
40 }
41
42 // lasers originating from a central point
43 float laser(vec2 p, int num) {
44     float r = atan(p.x, p.y);
45     float sn = sin(r*float(num)+time);
46     float lsr = 0.5+0.5*sn;
47     lsr = lsr*lsr*lsr*lsr*lsr;
48     float glow = pow(clamp(sn, 0.0, 1.0),100.0);
49     return lsr+glow;
50 }
51
52 // mix of fractal noises to simulate fog
53 float clouds(vec2 uv) {
54     vec2 t = vec2(0,time);
55     float c1 = fbm(fbm(uv*3.0)*0.75+uv*3.0+t/3.0);
56     float c2 = fbm(fbm(uv*2.0)*0.5+uv*7.0+t/3.0);
57     float c3 = fbm(fbm(uv*10.0-t)*0.75+uv*5.0+t/6.0);
58     float r = mix(c1, c2, c3*c3);
59     return r*r;
60 }
61
62 void main() {
63     vec2 hs = screenSize.xy/screenSize.y*0.5;
64     vec2 uvc = uvs-hs;
65     float l = (1.0 + 3.0*noise(vec2(15.0-time)))
66     * laser(vec2(uvs.x+0.5, uvs.y*(0.5 + 10.0*noise(vec2(time/5.0)))) + 0.1),
67     15);
68     l += fbm(vec2(2.0*time))
69     * laser(vec2(hs.x-uvc.x-0.2, uvs.y+0.1), 25);
70     l += noise(vec2(time-73.0))
71     * laser(vec2(uvc.x, 1.0-uvs.y+0.5), 30);
72     float c = clouds(uvs);
    vec4 col = vec4(uvs.x, 0.0, 1-uvs.x, 1.0)*(uvs.y*l+uvs.y*uvs.y)*c;

```

```

73     f_colour = pow(col, vec4(0.75));
74 }
75 }
```

#### B.10.4 background\_none.frag

```

1 # version 330 core
2
3 in vec2 uvs;
4 out vec4 f_colour;
5
6 void main() {
7     f_colour = vec4(vec3(0.0 + uvs.x * 0.001), 1.0);
8 }
```

#### B.10.5 background\_waves.frag

```

1 // Modified from https://godotshaders.com/shader/discrete-ocean/
2
3 # version 330 core
4
5 uniform float wave_amp=1.0;
6 uniform float wave_size=4.0;
7 uniform float wave_time_mul=0.2;
8
9 uniform int total_phases=20;
10
11 uniform vec4 bottom_color=vec4(0.608, 0.133, 0.167, 1.0);
12 uniform vec4 top_color=vec4(0.110, 0.149, 0.220, 1.0);
13
14 // uniform vec4 bottom_color=vec4(0.38, 0.04, 0.71, 1.0);
15 // uniform vec4 top_color=vec4(0.15, 0.02, 0.49, 1.0);
16
17 uniform float time;
18
19 in vec2 uvs;
20 out vec4 f_colour;
21
22 #define PI 3.14159
23
24 float rand (float n) {
25     return fract(sin(n) * 43758.5453123);
26 }
27 float noise (float p){
28     float fl = floor(p);
29     float fc = fract(p);
30     return mix(rand(fl), rand(fl + 1.0), fc);
31 }
32 float fmod(float x, float y) {
33     return x - floor(x / y) * y;
34 }
35 vec4 lerp(vec4 a, vec4 b, float w) {
36     return a + w * (b - a);
37 }
38
39 void main() {
40     float t = float(total_phases);
41     float effective_wave_amp = min(wave_amp, 0.5 / t);
42     float d = fmod(uvs.y, 1.0 / t);
43     float i = floor(uvs.y * t);
44     float vi = floor(uvs.y * t + t * effective_wave_amp);
```

```

45     float s = effective_wave_amp * sin((uvs.x + time * max(1.0 / t, noise(vi)) *
46                                         wave_time_mul * vi / t) * 2.0 * PI * wave_size);
47
48     if (d < s) i--;
49     if (d > s + 1.0 / t) i++;
50     i = clamp(i, 0.0, t - 1.0);
51
52     f_colour = lerp(top_color, bottom_color, i / (t - 1.0));
52 }

```

### B.10.6 base.frag

```

1 #version 330 core
2
3 uniform sampler2D image;
4 uniform sampler2D background;
5
6 in vec2 uvs;
7 out vec4 f_colour;
8
9 void main() {
10     vec4 colour = texture(image, uvs);
11
12     if (colour.a == 1.0) {
13         f_colour = colour;
14     } else {
15         f_colour = texture(background, uvs);
16     }
17 }

```

### B.10.7 blend.frag

```

1 #version 330 core
2
3 uniform sampler2D image;
4 uniform sampler2D image2;
5 uniform vec2 relativeSize;
6 uniform vec2 image2Pos;
7
8 in vec2 uvs;
9 out vec4 f_colour;
10
11 void main() {
12     vec3 colour = texture(image, uvs).rgb;
13
14     vec2 image2Coords = vec2((uvs.x - image2Pos.x) / relativeSize.x, (uvs.y -
15                               image2Pos.y) / relativeSize.y);
16
16     float withinBounds = step(image2Pos.x, uvs.x) * step(uvs.x, (image2Pos.x +
17                               relativeSize.x)) * step(image2Pos.y, uvs.y) * step(uvs.y,
18                               (image2Pos.y + relativeSize.y));
19
19     f_colour = vec4(colour + (texture(image2, image2Coords).rgb * withinBounds),
20                      1.0);
19 }

```

### B.10.8 bloom.frag

```

1 #version 330 core
2
3 in vec2 uvs;

```

```

4 out vec4 f_colour;
5
6 uniform sampler2D image;
7 uniform sampler2D blurredImage;
8 uniform float intensity;
9
10 void main() {
11     vec3 baseColour = texture(image, uvs).rgb;
12     vec3 bloomColor = texture(blurredImage, uvs).rgb;
13
14     baseColour += bloomColor * intensity;
15     f_colour = vec4(baseColour, 1.0);
16 }

```

### B.10.9 bloom\_old.frag

```

1 #version 330 core
2
3 in vec2 uvs;
4 out vec4 f_colour;
5
6 uniform sampler2D image;
7 uniform float bloom_spread = 0.1;
8 uniform float bloom_intensity = 0.5;
9
10 void main() {
11     ivec2 size = textureSize(image, 0);
12
13     float uv_x = uvs.x * size.x;
14     float uv_y = uvs.y * size.y;
15
16     vec4 sum = vec4(0.0);
17
18     for (int n = 0; n < 9; ++n) {
19         uv_y = (uvs.y * size.y) + (bloom_spread * float(n - 4));
20         vec4 h_sum = vec4(0.0);
21         h_sum += texelFetch(image, ivec2(uv_x - (4.0 * bloom_spread), uv_y), 0);
22         h_sum += texelFetch(image, ivec2(uv_x - (3.0 * bloom_spread), uv_y), 0);
23         h_sum += texelFetch(image, ivec2(uv_x - (2.0 * bloom_spread), uv_y), 0);
24         h_sum += texelFetch(image, ivec2(uv_x - bloom_spread, uv_y), 0);
25         h_sum += texelFetch(image, ivec2(uv_x, uv_y), 0);
26         h_sum += texelFetch(image, ivec2(uv_x + bloom_spread, uv_y), 0);
27         h_sum += texelFetch(image, ivec2(uv_x + (2.0 * bloom_spread), uv_y), 0);
28         h_sum += texelFetch(image, ivec2(uv_x + (3.0 * bloom_spread), uv_y), 0);
29         h_sum += texelFetch(image, ivec2(uv_x + (4.0 * bloom_spread), uv_y), 0);
30         sum += h_sum / 9.0;
31     }
32
33     f_colour = texture(image, uvs) + ((sum / 9.0) * bloom_intensity);
34 }

```

### B.10.10 blur.frag

See Section 3.9.2.

### B.10.11 box\_blur.frag

```

1 # version 330 core
2
3 uniform sampler2D image;

```

```

4
5 uniform int size=1;
6 uniform int separation=1;
7
8 in vec2 uvs;
9 out vec4 f_colour;
10
11 vec2 textureSize = textureSize(image, 0);
12
13 void main() {
14     if (size <= 0) {
15         return;
16     }
17
18     float count = 0.0;
19
20     for (int i = -size ; i <= size ; ++i) {
21         for (int j = -size ; j <= size ; ++j) {
22             f_colour += texture(image, uvs + (vec2(i, j) * separation) /
23             textureSize).rgba;
24
25             count += 1.0;
26         }
27
28     f_colour.rgb /= count;
29 }
```

### B.10.12 calibrate.frag

```

1 #version 330 core
2
3 uniform sampler2D image;
4
5 in vec2 uvs;
6 out vec4 f_colour;
7
8 void main() {
9     f_colour = vec4(texture(image, uvs).rgba);
10 }
```

### B.10.13 chromatic\_abbreviation.frag

```

1 #version 330 core
2
3 in vec2 uvs;
4 out vec4 f_colour;
5
6 uniform sampler2D image;
7
8 uniform bool enabled;
9 uniform vec2 mouseFocusPoint;
10 uniform float intensity;
11
12 void main() {
13     if (!enabled) {
14         f_colour = texture(image, uvs);
15         return;
16     }
17
18     float redOffset = 0.009 * intensity;
```

```

19     float greenOffset = 0.006 * intensity;
20     float blueOffset = -0.006 * intensity;
21
22     vec2 texSize = textureSize(image, 0).xy;
23     vec2 direction = uvs - mouseFocusPoint;
24
25     f_colour = texture(image, uvs);
26
27     f_colour.r = texture(image, uvs + (direction * vec2(redOffset))).r;
28     f_colour.g = texture(image, uvs + (direction * vec2(greenOffset))).g;
29     f_colour.b = texture(image, uvs + (direction * vec2(blueOffset))).b;
30 }

```

#### B.10.14 crop.frag

```

1 #version 330 core
2
3 uniform sampler2D image;
4 uniform vec2 relativeSize;
5 uniform vec2 relativePos;
6
7 in vec2 uvs;
8 out vec4 f_colour;
9
10 void main() {
11     vec2 sampleCoords = relativeSize.xy * uvs.xy + relativePos.xy;
12
13     float withinBounds = step(0.0, sampleCoords.x) * step(sampleCoords.x, 1.0) *
14         step(0.0, sampleCoords.y) * step(sampleCoords.y, 1.0);
15
16     vec3 colour = texture(image, sampleCoords).rgb * withinBounds;
17     colour.r += (1 - withinBounds);
18
19     f_colour = vec4(colour, 1.0);
}

```

#### B.10.15 crt.frag

```

1 #version 330 core
2
3 uniform sampler2D image;
4 uniform int mode = 1;
5
6 in vec2 uvs;
7 out vec4 f_colour;
8
9 void main() {
10     if (mode == 0){
11         f_colour = vec4(texture(image, uvs).rgb, 1.0);
12     } else {
13         float flatness = 1.0;
14
15         if (mode == 1) flatness = 5.0;
16         else if (mode == 2) flatness = 10.0;
17
18         vec2 center = vec2(0.5, 0.5);
19         vec2 off_center = uvs - center;
20
21         // Calculate offset of bulged pixels, increases with distance from center
22         off_center *= 1.0 + 0.8 * pow(abs(off_center.yx), vec2(flatness));
23
}

```

```

24     vec2 uvs_2 = center + off_center;
25
26     if (uvs_2.x > 1.0 || uvs_2.x < 0.0 || uvs_2.y > 1.0 || uvs_2.y < 0.0) {
27         f_colour = vec4(0.0, 0.0, 0.0, 1.0);
28     } else {
29         f_colour = vec4(texture(image, uvs_2).rgb, 1.0);
30
31         // Draw horizontal lines
32         float fv = fract(uvs_2.y * float(textureSize(image, 0).y));
33         fv = min(1.0, 0.8 + 0.5 * min(fv, 1.0 - fv));
34         f_colour.rgb *= fv;
35     }
36 }
37 }
```

### B.10.16 flashlight.frag

```

1 #version 330 core
2
3 uniform sampler2D image;
4 uniform vec2 center;
5
6 in vec2 uvs;
7 out vec4 f_colour;
8
9 vec2 resolution = textureSize(image, 0);
10 float radius = 100.0; // radius in pixel
11
12 float getDistance(vec2 pixelCoord, vec2 playerCoord) {
13     return distance(pixelCoord*resolution, playerCoord);
14 }
15
16 void main() {
17     float distance = getDistance(uvs, center);
18     float a = 0;
19     float b = 1;
20
21     // if (distance < radius)
22     float factor = 1.0 / (pow((distance / 100), 2) + 1);
23     float isLit = step(distance, 10000);
24
25     f_colour = vec4(texture(image, uvs).rgb + factor * isLit, 1.0);
26
27     // if (distance < 10000) {
28     //     float factor = 1.0 / (pow((distance / 100), 2) + 1);
29     //     f_colour = vec4(texture(image, uvs).rgb + factor, 1.0);
30     // }
31     // else {
32     //     f_colour = vec4(texture(image, uvs).rgb, 1.0);
33     // }
34 }
```

### B.10.17 grayscale.frag

```

1 #version 330 core
2
3 uniform sampler2D image;
4
5 in vec2 uvs;
6 out vec4 f_colour;
7
```

```

8 void main() {
9     f_colour = vec4(texture(image, uvs).rgb, 1.0);
10    float gray = dot(f_colour.rgb, vec3(0.299, 0.587, 0.114));
11    f_colour.rgb = vec3(gray, gray, gray);
12 }

```

**B.10.18 highlight\_brightness.frag**

See Section 3.9.2.

**B.10.19 highlight\_colour.frag**

```

1 # version 330 core
2
3 uniform sampler2D image;
4 uniform sampler2D highlight;
5
6 uniform vec3 colour;
7 uniform float threshold;
8 uniform float intensity;
9
10 in vec2 uvs;
11 out vec4 f_colour;
12
13 vec3 normColour = colour / 255;
14
15 void main() {
16     vec4 pixel = texture(image, uvs);
17     float isClose = step(abs(pixel.r - normColour.r), threshold) * step(abs(pixel.g - normColour.g), threshold) * step(abs(pixel.b - normColour.b), threshold);
18
19     if (isClose == 1.0) {
20         f_colour = vec4(vec3(pixel.rgb * intensity), 1.0);
21     } else {
22         f_colour = vec4(texture(highlight, uvs).rgb, 1.0);
23     }
24 }

```

**B.10.20 lightmap.frag**

See Section 3.9.3.

**B.10.21 occlusion.frag**

See Section 3.9.3.

**B.10.22 rays.frag**

```

1 #version 330 core
2
3 uniform sampler2D image;
4
5 in vec2 uvs;
6 out vec4 f_colour;
7
8 void main() {
9     f_colour = vec4(texture(image, uvs).rgb, 1.0);
10 }

```

**B.10.23 shadowmap.frag**

See Section 3.9.3.

**B.10.24 shake.frag**

```

1 #version 330 core
2
3 uniform sampler2D image;
4 uniform vec2 displacement;
5
6 in vec2 uvs;
7 out vec4 f_colour;
8
9 void main() {
10     f_colour = vec4(texture(image, uvs + displacement).rgb, 1.0);
11 }
```

**B.11 data\shaders\vertex****B.11.1 base.vert**

```

1 #version 330 core
2
3 in vec2 vert;
4 in vec2 texCoords;
5 out vec2 uvs;
6
7 void main() {
8     uvs = texCoords;
9     gl_Position = vec4(vert, 0.0, 1.0);
10 }
```

**B.12 data\states****B.13 data\states\brower****B.13.1 brower.py**

```

1 import pygame
2 import pyperclip
3 from data.helpers.database_helpers import delete_game, get_ordered_games
4 from data.states.browser.widget_dict import BROWSER_WIDGETS
5 from data.utils.event_types import BrowserEventType
6 from data.managers.logs import initialise_logger
7 from data.utils.constants import GAMES_PER_PAGE
8 from data.managers.window import window
9 from data.utils.enums import ShaderType
10 from data.utils.assets import MUSIC
11 from data.control import _State
12 from random import randint
13
14 logger = initialise_logger(__name__)
15
16 class Brower(_State):
17     def __init__(self):
18         super().__init__()
```

```

19
20     self._selected_index = None
21     self._filter_column = 'number_of_ply'
22     self._filter_ascend = False
23     self._games_list = []
24     self._page_number = 1
25
26     def cleanup(self):
27         super().cleanup()
28
29         if self._selected_index is not None:
30             return self._games_list[self._selected_index]
31
32     return None
33
34     def startup(self, persist=None):
35         self.refresh_games_list() # BEFORE RESIZE TO FILL WIDGET BEFORE RESIZING
36         super().startup(BROWSER_WIDGETS, music=MUSIC[f'menu_{randint(1, 3)}'])
37
38         self._filter_column = 'number_of_ply'
39         self._filter_ascend = False
40
41         window.set_apply_arguments(ShaderType.BASE, background_type=ShaderType.
42                                     BACKGROUND_BALATRO)
43
44         BROWSER_WIDGETS['help'].kill()
45         BROWSER_WIDGETS['browser_strip'].kill()
46
47         self.draw()
48
49     def refresh_games_list(self):
50         column_map = {
51             'moves': 'number_of_ply',
52             'winner': 'winner',
53             'time': 'created_dt'
54         }
55
56         ascend_map = {
57             'asc': True,
58             'desc': False
59         }
60
61         filter_column = BROWSER_WIDGETS['filter_column_dropdown'].get_selected_word()
62         filter_ascend = BROWSER_WIDGETS['filter_ascend_dropdown'].get_selected_word()
63
64         self._selected_index = None
65
66         start_row = (self._page_number - 1) * GAMES_PER_PAGE + 1
67         end_row = (self._page_number) * GAMES_PER_PAGE
68         self._games_list = get_ordered_games(column_map[filter_column], ascend_map
69 [filter_ascend], start_row=start_row, end_row=end_row)
70
71         BROWSER_WIDGETS['browser_strip'].initialise_games_list(self._games_list)
72         BROWSER_WIDGETS['browser_strip'].set_surface_size(window.size)
73         BROWSER_WIDGETS['scroll_area'].set_image()
74
75     def get_event(self, event):
76         widget_event = self._widget_group.process_event(event)
77
78         if event.type in [pygame.MOUSEBUTTONUP, pygame.KEYDOWN]:

```

```

77         BROWSER_WIDGETS['help'].kill()
78
79     if widget_event is None:
80         return
81
82     match widget_event.type:
83         case BrowserEventType.MENU_CLICK:
84             self.next = 'menu'
85             self.done = True
86
87         case BrowserEventType.BROWSER_STRIP_CLICK:
88             self._selected_index = widget_event.selected_index
89
90         case BrowserEventType.COPY_CLICK:
91             if self._selected_index is None:
92                 return
93             logger.info(f'COPYING TO CLIPBOARD: {self._games_list[self._selected_index]['final_fen_string']}')
94             pyperclip.copy(self._games_list[self._selected_index]['final_fen_string'])
95
96         case BrowserEventType.DELETE_CLICK:
97             if self._selected_index is None:
98                 return
99             delete_game(self._games_list[self._selected_index]['id'])
100            self.refresh_games_list()
101
102        case BrowserEventType.REVIEW_CLICK:
103            if self._selected_index is None:
104                return
105
106            self.next = 'review'
107            self.done = True
108
109        case BrowserEventType.FILTER_COLUMN_CLICK:
110            selected_word = BROWSER_WIDGETS['filter_column_dropdown'].get_selected_word()
111
112            if selected_word is None:
113                return
114
115            self.refresh_games_list()
116
117        case BrowserEventType.FILTER_ASCEND_CLICK:
118            selected_word = BROWSER_WIDGETS['filter_ascend_dropdown'].get_selected_word()
119
120            if selected_word is None:
121                return
122
123            self.refresh_games_list()
124
125        case BrowserEventType.PAGE_CLICK:
126            self._page_number = widget_event.data
127
128            self.refresh_games_list()
129
130        case BrowserEventType.HELP_CLICK:
131            self._widget_group.add(BROWSER_WIDGETS['help'])
132            self._widget_group.handle_resize(window.size)
133
134    def draw(self):

```

```

135         self._widget_group.draw()

```

### B.13.2 widget\_dict.py

```

1  from data.helpers.database_helpers import get_number_of_games
2  from data.components.custom_event import CustomEvent
3  from data.utils.event_types import BrowserEventType
4  from data.utils.constants import GAMES_PER_PAGE
5  from data.utils.assets import GRAPHICS
6  from data.widgets import *
7
8  BROWSER_HEIGHT = 0.6
9
10 browser_strip = BrowserStrip(
11     relative_position=(0.0, 0.0),
12     relative_height=BROWSER_HEIGHT,
13     games_list=[]
14 )
15
16 number_of_pages = get_number_of_games() // GAMES_PER_PAGE + 1
17
18 carousel_widgets = {
19     i: Text(
20         relative_position=(0, 0),
21         relative_size=(0.3, 0.1),
22         text=f"PAGE {i} OF {number_of_pages}",
23         fill_colour=(0, 0, 0, 0),
24         fit_vertical=False,
25         border_width=0,
26     )
27     for i in range(1, number_of_pages + 1)
28 }
29
30 sort_by_container = Rectangle(
31     relative_size=(0.5, 0.1),
32     relative_position=(0.01, 0.77),
33     anchor_x='right',
34     visible=True
35 )
36
37 buttons_container = Rectangle(
38     relative_position=(0, 0.025),
39     relative_size=(0.5, 0.1),
40     scale_mode='height',
41     anchor_x='center'
42 )
43
44 top_right_container = Rectangle(
45     relative_position=(0, 0),
46     relative_size=(0.15, 0.075),
47     fixed_position=(5, 5),
48     anchor_x='right',
49     scale_mode='height'
50 )
51
52 BROWSER_WIDGETS = {
53     'help':
54     Icon(
55         relative_position=(0, 0),
56         relative_size=(1.02, 1.02),
57         icon=GRAPHICS['browser_help'],
58         anchor_x='center',

```

```

59         anchor_y='center',
60         border_width=0,
61         fill_colour=(0, 0, 0, 0)
62     ),
63     'default': [
64         buttons_container,
65         sort_by_container,
66         top_right_container,
67         ReactiveIconButton(
68             parent=top_right_container,
69             relative_position=(0, 0),
70             relative_size=(1, 1),
71             anchor_x='right',
72             scale_mode='height',
73             base_icon=GRAPHICS['home_base'],
74             hover_icon=GRAPHICS['home_hover'],
75             press_icon=GRAPHICS['home_press'],
76             event=CustomEvent(BrowserEventType.MENU_CLICK)
77         ),
78         ReactiveIconButton(
79             parent=top_right_container,
80             relative_position=(0, 0),
81             relative_size=(1, 1),
82             scale_mode='height',
83             base_icon=GRAPHICS['help_base'],
84             hover_icon=GRAPHICS['help_hover'],
85             press_icon=GRAPHICS['help_press'],
86             event=CustomEvent(BrowserEventType.HELP_CLICK)
87         ),
88         ReactiveIconButton(
89             parent=buttons_container,
90             relative_position=(0, 0),
91             relative_size=(1, 1),
92             scale_mode='height',
93             base_icon=GRAPHICS['copy_base'],
94             hover_icon=GRAPHICS['copy_hover'],
95             press_icon=GRAPHICS['copy_press'],
96             event=CustomEvent(BrowserEventType.COPY_CLICK),
97         ),
98         ReactiveIconButton(
99             parent=buttons_container,
100            relative_position=(0, 0),
101            relative_size=(1, 1),
102            scale_mode='height',
103            anchor_x='center',
104            base_icon=GRAPHICS['delete_base'],
105            hover_icon=GRAPHICS['delete_hover'],
106            press_icon=GRAPHICS['delete_press'],
107            event=CustomEvent(BrowserEventType.DELETE_CLICK),
108        ),
109        ReactiveIconButton(
110            parent=buttons_container,
111            relative_position=(0, 0),
112            relative_size=(1, 1),
113            scale_mode='height',
114            anchor_x='right',
115            base_icon=GRAPHICS['review_base'],
116            hover_icon=GRAPHICS['review_hover'],
117            press_icon=GRAPHICS['review_press'],
118            event=CustomEvent(BrowserEventType.REVIEW_CLICK),
119        ),
120        Text(

```

```

121         parent=sort_by_container,
122         relative_position=(0, 0),
123         relative_size=(0.3, 1),
124         fit_vertical=False,
125         text='SORT BY:',
126         border_width=0,
127         fill_colour=(0, 0, 0, 0)
128     )
129 ],
130 'browser_strip':
131     browser_strip,
132 'scroll_area':
133 ScrollArea(
134     relative_position=(0.0, 0.15),
135     relative_size=(1, BROWSER_HEIGHT),
136     vertical=False,
137     widget=browser_strip
138 ),
139 'filter_column_dropdown':
140 Dropdown(
141     parent=sort_by_container,
142     relative_position=(0.3, 0),
143     relative_height=0.75,
144     anchor_x='right',
145     word_list=['time', 'moves', 'winner'],
146     fill_colour=(255, 100, 100),
147     event=CustomEvent(BrowserEventType.FILTER_COLUMN_CLICK)
148 ),
149 'filter_ascend_dropdown':
150 Dropdown(
151     parent=sort_by_container,
152     relative_position=(0, 0),
153     relative_height=0.75,
154     anchor_x='right',
155     word_list=['desc', 'asc'],
156     fill_colour=(255, 100, 100),
157     event=CustomEvent(BrowserEventType.FILTER_ASCEND_CLICK)
158 ),
159 'page_carousel':
160 Carousel(
161     relative_position=(0.01, 0.77),
162     margin=5,
163     widgets_dict=carousel_widgets,
164     event=CustomEvent(BrowserEventType.PAGE_CLICK),
165   )
166 }

```

## B.14 data\states\config

### B.14.1 config.py

```

1 import pygame
2 from data.states.config.default_config import default_config
3 from data.states.config.widget_dict import CONFIG_WIDGETS
4 from data.utils.event_types import ConfigEventType
5 from data.managers.logs import initialise_logger
6 from data.managers.animation import animation
7 from data.utils.constants import ShaderType
8 from data.utils.assets import MUSIC, SFX
9 from data.managers.window import window
10 from data.managers.audio import audio

```

```

11 from data.managers.theme import theme
12 from data.utils.enums import Colour
13 from data.control import _State
14 from random import randint
15
16 logger = initialise_logger(__name__)
17
18 class Config(_State):
19     def __init__(self):
20         super().__init__()
21
22         self._config = None
23         self._valid_fen = True
24         self._selected_preset = None
25
26     def cleanup(self):
27         super().cleanup()
28
29         window.clear_apply_arguments(ShaderType.BLOOM)
30
31         return self._config
32
33     def startup(self, persist=None):
34         super().startup(CONFIG_WIDGETS, music=MUSIC[f'menu_{randint(1, 3)}'])
35         window.set_apply_arguments(ShaderType.BLOOM, highlight_colours=[(pygame.Color('0x95e0cc')).rgb, pygame.Color('0xf14e52').rgb], colour_intensity=0.9)
36
37         CONFIG_WIDGETS['invalid_fen_string'].kill()
38         CONFIG_WIDGETS['help'].kill()
39
40         self._config = default_config
41
42         if persist:
43             self._config['FEN_STRING'] = persist
44
45         self.set_fen_string(self._config['FEN_STRING'])
46         self.toggle_pvc(self._config['CPU_ENABLED'])
47         self.set_active_colour(self._config['COLOUR'])
48
49         CONFIG_WIDGETS['cpu_depth_carousel'].set_to_key(self._config['CPU_DEPTH'])
50         if self._config['CPU_ENABLED']:
51             self.create_depth_picker()
52         else:
53             self.remove_depth_picker()
54
55         self.draw()
56
57     def create_depth_picker(self):
58         # CONFIG_WIDGETS['start_button'].update_relative_position((0.5, 0.8))
59         # CONFIG_WIDGETS['start_button'].set_image()
60         CONFIG_WIDGETS['cpu_depth_carousel'].set_surface_size(window.size)
61         CONFIG_WIDGETS['cpu_depth_carousel'].set_image()
62         CONFIG_WIDGETS['cpu_depth_carousel'].set_geometry()
63         self._widget_group.add(CONFIG_WIDGETS['cpu_depth_carousel'])
64
65     def remove_depth_picker(self):
66         # CONFIG_WIDGETS['start_button'].update_relative_position((0.5, 0.7))
67         # CONFIG_WIDGETS['start_button'].set_image()
68
69         CONFIG_WIDGETS['cpu_depth_carousel'].kill()
70
71     def toggle_pvc(self, pvc_enabled):

```

```

72         if pvc_enabled:
73             CONFIG_WIDGETS['pvc_button'].set_locked(True)
74             CONFIG_WIDGETS['pvp_button'].set_locked(False)
75         else:
76             CONFIG_WIDGETS['pvp_button'].set_locked(True)
77             CONFIG_WIDGETS['pvc_button'].set_locked(False)
78
79         self._config['CPU_ENABLED'] = pvc_enabled
80
81         if self._config['CPU_ENABLED']:
82             self.create_depth_picker()
83         else:
84             self.remove_depth_picker()
85
86     def set_fen_string(self, new_fen_string):
87         CONFIG_WIDGETS['fen_string_input'].set_text(new_fen_string)
88         self._config['FEN_STRING'] = new_fen_string
89
90         self.set_preset_overlay(new_fen_string)
91
92     try:
93         CONFIG_WIDGETS['board_thumbnail'].initialise_board(new_fen_string)
94         CONFIG_WIDGETS['invalid_fen_string'].kill()
95
96         if new_fen_string[-1].lower() == 'r':
97             self.set_active_colour(Colour.RED)
98         else:
99             self.set_active_colour(Colour.BLUE)
100
101         self._valid_fen = True
102     except:
103         CONFIG_WIDGETS['board_thumbnail'].initialise_board('')
104         self._widget_group.add(CONFIG_WIDGETS['invalid_fen_string'])
105
106         window.set_effect(ShaderType.SHAKE)
107         animation.set_timer(500, lambda: window.clear_effect(ShaderType.SHAKE))
108     )
109
110     audio.play_sfx(SFX['error_1'])
111     audio.play_sfx(SFX['error_2'])
112
113     self._valid_fen = False
114
115     def get_event(self, event):
116         widget_event = self._widget_group.process_event(event)
117
118         if event.type in [pygame.MOUSEBUTTONUP, pygame.KEYDOWN]:
119             CONFIG_WIDGETS['help'].kill()
120
121         if widget_event is None:
122             return
123
124         match widget_event.type:
125             case ConfigEventType.GAME_CLICK:
126                 if self._valid_fen:
127                     self.next = 'game'
128                     self.done = True
129
130             case ConfigEventType.MENU_CLICK:
131                 self.next = 'menu'
132                 self.done = True

```

```

133         case ConfigEventType.TIME_CLICK:
134             self._config['TIME_ENABLED'] = not(widget_event.data)
135             CONFIG_WIDGETS['timer_button'].set_next_icon()
136
137         case ConfigEventType.PVP_CLICK:
138             self.toggle_pvc(False)
139
140         case ConfigEventType.PVC_CLICK:
141             self.toggle_pvc(True)
142
143         case ConfigEventType.FEN_STRING_TYPE:
144             self.set_fen_string(widget_event.text)
145
146         case ConfigEventType.TIME_TYPE:
147             if widget_event.text == '':
148                 self._config['TIME'] = 5
149             else:
150                 self._config['TIME'] = float(widget_event.text)
151
152         case ConfigEventType.CPU_DEPTH_CLICK:
153             self._config['CPU_DEPTH'] = int(widget_event.data)
154
155         case ConfigEventType.PRESET_CLICK:
156             self.set_fen_string(widget_event.fen_string)
157
158         case ConfigEventType.SETUP_CLICK:
159             if self.valid_fen:
160                 self.next = 'editor'
161                 self.done = True
162
163         case ConfigEventType.COLOUR_CLICK:
164             self.set_active_colour(widget_event.data.get_flipped_colour())
165
166         case ConfigEventType.HELP_CLICK:
167             self._widget_group.add(CONFIG_WIDGETS['help'])
168             self._widget_group.handle_resize(window.size)
169
170     def set_preset_overlay(self, fen_string):
171         fen_string_widget_map = {
172             'sc3ncfcnspb2/2pc7/3Pd6/pa1Pc1rbra1pb1Pd/pb1Pd1RaRb1pa1Pc/6pb3/7Pa2/2
173             PdNaFaNa3Sa b': 'preset_1',
174             'sc3ncfcncrast/10/3Pd2pa3/paPc2Pbra2pbPd/pbPd2Rapd2paPc/3Pc2pb3/10/2
175             RaNaFaNa3Sa b': 'preset_2',
176             'sc3pcnspb3/5fc4/pa3pcncrast/pb1rd1Pd1Pb3/3pd1pb1Rd1Pd/3RaNaPa3Pc/4Fa5
177             /3PdNaPa3Sa b': 'preset_3'
178         }
179
180         if fen_string in fen_string_widget_map:
181             self._selected_preset = CONFIG_WIDGETS[fen_string_widget_map[fen_string]]
182         else:
183             self._selected_preset = None
184
185     def set_active_colour(self, colour):
186         if self._config['COLOUR'] != colour:
187             CONFIG_WIDGETS['to_move_button'].set_next_icon()
188
189         self._config['COLOUR'] = colour
190
191         if colour == Colour.BLUE:
192             CONFIG_WIDGETS['to_move_text'].set_text('BLUE TO MOVE')
193         elif colour == Colour.RED:

```

```

191         CONFIG_WIDGETS['to_move_text'].set_text('RED TO MOVE')
192
193     if self._valid_fen:
194         self._config['FEN_STRING'] = self._config['FEN_STRING'][:-1] + colour.
195         name[0].lower()
196         CONFIG_WIDGETS['fen_string_input'].set_text(self._config['FEN_STRING']
197     ])
198
199     def draw(self):
200         self._widget_group.draw()
201
202         if self._selected_preset:
203             pygame.draw.rect(window.screen, theme['borderPrimary'], (*self.
204             _selected_preset.position, *self._selected_preset.size), width=int(theme['
205             borderWidth']))
206
207     def update(self, **kwargs):
208         self._widget_group.update()
209         super().update(**kwargs)

```

### B.14.2 default\_config.py

```

1 from data.utils.enums import Colour
2
3 default_config = {
4     'FEN_STRING': 'sc3ncfcn cpb2/2pc7/3Pd6/pa1Pc1rbra1pb1Pd/pb1Pd1RaRb1pa1Pc/6pb3/7
5     Pa2/2PdNaFa3Sa b',
6     'COLOUR': Colour.BLUE,
7     'TIME_ENABLED': True,
8     'CPU_ENABLED': False,
9     'CPU_DEPTH': 2,
10    'TIME': 5,
11 }

```

### B.14.3 widget\_dict.py

```

1 from data.widgets import *
2 from data.states.config.default_config import default_config
3 from data.helpers.asset_helpers import get_highlighted_icon
4 from data.components.custom_event import CustomEvent
5 from data.utils.event_types import ConfigEventType
6 from data.utils.assets import GRAPHICS
7 from data.managers.theme import theme
8 from data.utils.enums import Colour
9
10 def float_validator(num_string):
11     try:
12         float(num_string)
13         return True
14     except:
15         return False
16
17 if default_config['CPU_ENABLED']:
18     pvp_icons = {False: GRAPHICS['swords'], True: GRAPHICS['swords']}
19     pvc_icons = {True: GRAPHICS['robot'], False: GRAPHICS['robot']}
20     pvc_locked = True
21     pvp_locked = False
22 else:
23     pvp_icons = {True: GRAPHICS['swords'], False: GRAPHICS['swords']}
24     pvc_icons = {False: GRAPHICS['robot'], True: GRAPHICS['robot']}
25     pvc_locked = False

```

```

26     pvp_locked = True
27
28 if default_config['TIME_ENABLED']:
29     time_enabled_icons = {True: GRAPHICS['timer'], False: get_highlighted_icon(
30         GRAPHICS['timer'])}
31 else:
32     time_enabled_icons = {False: get_highlighted_icon(GRAPHICS['timer']), True:
33         GRAPHICS['timer']}
34
35 if default_config['COLOUR'] == Colour.BLUE:
36     colour_icons = {Colour.BLUE: GRAPHICS['pharaoh_0_a'], Colour.RED: GRAPHICS['
37         pharaoh_1_a']}
38 else:
39     colour_icons = {Colour.RED: GRAPHICS['pharaoh_1_a'], Colour.BLUE: GRAPHICS['
40         pharaoh_0_a']}
41
42 preview_container = Rectangle(
43     relative_position=(-0.15, 0),
44     relative_size=(0.65, 0.9),
45     anchor_x='center',
46     anchor_y='center',
47 )
48
49 config_container = Rectangle(
50     relative_position=(0.325, 0),
51     relative_size=(0.3, 0.9),
52     anchor_x='center',
53     anchor_y='center',
54 )
55
56 to_move_container = Rectangle(
57     parent=config_container,
58     relative_size=(0.9, 0.15),
59     relative_position=(0, 0.1),
60     anchor_x='center'
61 )
62
63 board_thumbnail = BoardThumbnail(
64     parent=preview_container,
65     relative_position=(0, 0),
66     relative_width=0.7,
67     scale_mode='width',
68     anchor_x='right',
69 )
70
71 top_right_container = Rectangle(
72     relative_position=(0, 0),
73     relative_size=(0.15, 0.075),
74     fixed_position=(5, 5),
75     anchor_x='right',
76     scale_mode='height'
77 )
78
79 CONFIG_WIDGETS = {
80     'help':
81         Icon(
82             relative_position=(0, 0),
83             relative_size=(1.02, 1.02),
84             icon=GRAPHICS['config_help'],
85             anchor_x='center',
86             anchor_y='center',
87             border_width=0,
88

```

```

84         fill_colour=(0, 0, 0, 0)
85     ),
86     'default': [
87         preview_container,
88         config_container,
89         to_move_container,
90         top_right_container,
91         ReactiveIconButton(
92             parent=top_right_container,
93             relative_position=(0, 0),
94             relative_size=(1, 1),
95             anchor_x='right',
96             scale_mode='height',
97             base_icon=GRAPHICS['home_base'],
98             hover_icon=GRAPHICS['home_hover'],
99             press_icon=GRAPHICS['home_press'],
100            event=CustomEvent(ConfigEventType.MENU_CLICK)
101        ),
102        ReactiveIconButton(
103            parent=top_right_container,
104            relative_position=(0, 0),
105            relative_size=(1, 1),
106            scale_mode='height',
107            base_icon=GRAPHICS['help_base'],
108            hover_icon=GRAPHICS['help_hover'],
109            press_icon=GRAPHICS['help_press'],
110            event=CustomEvent(ConfigEventType.HELP_CLICK)
111        ),
112        TextInput(
113            parent=config_container,
114            relative_position=(0.3, 0.3),
115            relative_size=(0.65, 0.15),
116            fit_vertical=True,
117            placeholder='TIME CONTROL (DEFAULT 5)',
118            default=str(default_config['TIME']),
119            border_width=5,
120            margin=20,
121            validator=float_validator,
122            event=CustomEvent(ConfigEventType.TIME_TYPE)
123        ),
124        Text(
125            parent=config_container,
126            fit_vertical=False,
127            relative_position=(0.75, 0.3),
128            relative_size=(0.2, 0.15),
129            text='MINS',
130            border_width=0,
131            fill_colour=(0, 0, 0, 0)
132        ),
133        TextButton(
134            parent=preview_container,
135            relative_position=(0.3, 0),
136            relative_size=(0.15, 0.15),
137            text='CUSTOM',
138            anchor_y='bottom',
139            fit_vertical=False,
140            margin=10,
141            event=CustomEvent(ConfigEventType.SETUP_CLICK)
142        )
143    ],
144    'board_thumbnail':
145        board_thumbnail,

```

```

146     'fen_string_input':
147         TextInput(
148             parent=preview_container,
149             relative_position=(0, 0),
150             relative_size=(0.55, 0.15),
151             fit_vertical=False,
152             placeholder='ENTER FEN STRING',
153             default='sc3ncfcn cpb2/2pc7/3Pd7/pa1Pc1rb1pb1Pd/pb1Pd1RaRb1pa1Pc/6pb3/7
Pa2/2PdNaFaNa3Sa b',
154             border_width=5,
155             anchor_y='bottom',
156             anchor_x='right',
157             margin=20,
158             event=CustomEvent(ConfigEventType.FEN_STRING_TYPE)
159         ),
160     'start_button':
161         TextButton(
162             parent=config_container,
163             relative_position=(0, 0),
164             relative_size=(0.9, 0.3),
165             anchor_y='bottom',
166             anchor_x='center',
167             text='START NEW GAME',
168             strength=0.1,
169             text_colour=theme['textSecondary'],
170             margin=20,
171             fit_vertical=False,
172             event=CustomEvent(ConfigEventType.GAME_CLICK)
173         ),
174     'timer_button':
175         MultipleIconButton(
176             parent=config_container,
177             scale_mode='height',
178             relative_position=(0.05, 0.3),
179             relative_size=(0.15, 0.15),
180             margin=10,
181             border_width=5,
182             border_radius=5,
183             icons_dict=time_enabled_icons,
184             event=CustomEvent(ConfigEventType.TIME_CLICK)
185         ),
186     'pvp_button':
187         MultipleIconButton(
188             parent=config_container,
189             relative_position=(-0.225, 0.5),
190             relative_size=(0.45, 0.15),
191             margin=15,
192             anchor_x='center',
193             icons_dict=pvp_icons,
194             stretch=False,
195             event=CustomEvent(ConfigEventType.PVP_CLICK)
196         ),
197     'pvc_button':
198         MultipleIconButton(
199             parent=config_container,
200             relative_position=(0.225, 0.5),
201             relative_size=(0.45, 0.15),
202             anchor_x='center',
203             margin=15,
204             icons_dict=pvc_icons,
205             stretch=False,
206             event=CustomEvent(ConfigEventType.PVC_CLICK)

```

```

207 ),
208 'invalid_fen_string':
209 Text(
210     parent=board_thumbnail,
211     relative_position=(0, 0),
212     relative_size=(0.9, 0.1),
213     fit_vertical=False,
214     anchor_x='center',
215     anchor_y='center',
216     text='INVALID FEN STRING!',
217     margin=10,
218     fill_colour=theme['fillError'],
219     text_colour=theme['textError'],
220 ),
221 'preset_1':
222 BoardThumbnailButton(
223     parent=preview_container,
224     relative_width=0.25,
225     relative_position=(0, 0),
226     scale_mode='width',
227     fen_string="sc3ncfcnspb2/2pc7/3Pd6/pa1Pc1rbrailpb1Pd/pb1Pd1RaRb1pa1Pc/6pb3
/7Pa2/2PdNaFaNa3Sa b",
228     event=CustomEvent(ConfigEventType.PRESET_CLICK)
229 ),
230 'preset_2':
231 BoardThumbnailButton(
232     parent=preview_container,
233     relative_width=0.25,
234     relative_position=(0, 0.35),
235     scale_mode='width',
236     fen_string="sc3ncfcnrcra2/10/3Pd2pa3/paPc2Pbra2pbPd/pbPd2Rapd2paPc/3Pc2pb3
/10/2RaNaFaNa3Sa b",
237     event=CustomEvent(ConfigEventType.PRESET_CLICK)
238 ),
239 'preset_3':
240 BoardThumbnailButton(
241     parent=preview_container,
242     relative_width=0.25,
243     relative_position=(0, 0.7),
244     scale_mode='width',
245     fen_string="sc3pcnspb3/5fc4/pa3pcnrcra3/pb1rd1Pd1Pb3/3pd1pb1Rd1Pd/3
RaNaPa3Pc/4Fa5/3PdNaPa3Sa b",
246     event=CustomEvent(ConfigEventType.PRESET_CLICK)
247 ),
248 'to_move_button':
249 MultipleIconButton(
250     parent=to_move_container,
251     scale_mode='height',
252     relative_position=(0, 0),
253     relative_size=(1, 1),
254     icons_dict=colour_icons,
255     anchor_x='left',
256     event=CustomEvent(ConfigEventType.COLOUR_CLICK)
257 ),
258 'to_move_text':
259 Text(
260     parent=to_move_container,
261     relative_position=(0, 0),
262     relative_size=(0.75, 1),
263     fit_vertical=False,
264     text='TO MOVE',
265     anchor_x='right'

```

```

266 ),
267 'cpu_depth_carousel':
268 Carousel(
269     parent=config_container,
270     relative_position=(0, 0.65),
271     event=CustomEvent(ConfigEventType.CPU_DEPTH_CLICK),
272     anchor_x='center',
273     border_width=0,
274     fill_colour=(0, 0, 0, 0),
275     widgets_dict={
276         2: Text(
277             parent=config_container,
278             relative_position=(0, 0),
279             relative_size=(0.8, 0.075),
280             text="EASY",
281             margin=0,
282             border_width=0,
283             fill_colour=(0, 0, 0, 0)
284         ),
285         3: Text(
286             parent=config_container,
287             relative_position=(0, 0),
288             relative_size=(0.8, 0.075),
289             text="MEDIUM",
290             margin=0,
291             border_width=0,
292             fill_colour=(0, 0, 0, 0)
293         ),
294         4: Text(
295             parent=config_container,
296             relative_position=(0, 0),
297             relative_size=(0.8, 0.075),
298             text="HARD",
299             margin=0,
300             border_width=0,
301             fill_colour=(0, 0, 0, 0)
302         ),
303     }
304 )
305 }

```

## B.15 data\states\editor

### B.15.1 editor.py

```

1 import pygame
2 import pyperclip
3 from data.states.game.components.bitboard_collection import BitboardCollection
4 from data.utils.enums import Colour, RotationDirection, Piece, Rotation
5 from data.states.game.components.fen_parser import encode_fen_string
6 from data.states.game.components.overlay_draw import OverlayDraw
7 from data.states.game.components.piece_group import PieceGroup
8 from data.helpers.bitboard_helpers import coords_to_bitboard
9 from data.helpers.board_helpers import screen_pos_to_coords
10 from data.states.game.components.father import DragAndDrop
11 from data.states.editor.widget_dict import EDITOR_WIDGETS
12 from data.utils.event_types import EditorEventType
13 from data.managers.logs import initialise_logger
14 from data.managers.window import window
15 from data.control import _State
16

```

```

17 logger = initialise_logger(__name__)
18
19 class Editor(_State):
20     def __init__(self):
21         super().__init__()
22
23         self._bitboards = None
24         self._piece_group = None
25         self._selected_coords = None
26         self._selected_tool = None
27         self._selected_tool.colour = None
28         self._initial_fen_string = None
29         self._starting.colour = None
30
31         self._drag_and_drop = None
32         self._overlay_draw = None
33
34     def cleanup(self):
35         super().cleanup()
36
37         self.deselect_tool()
38
39         return encode_fen_string(self._bitboards)
40
41     def startup(self, persist):
42         super().startup(EDITOR_WIDGETS)
43         EDITOR_WIDGETS['help'].kill()
44
45         self._drag_and_drop = DragAndDrop(EDITOR_WIDGETS['chessboard'].position,
46                                         EDITOR_WIDGETS['chessboard'].size)
46         self._overlay_draw = OverlayDraw(EDITOR_WIDGETS['chessboard'].position,
47                                         EDITOR_WIDGETS['chessboard'].size)
47         self._bitboards = BitboardCollection(persist['FEN_STRING'])
48         self._piece_group = PieceGroup()
49
50         self._selected_coords = None
51         self._selected_tool = None
52         self._selected_tool.colour = None
53         self._initial_fen_string = persist['FEN_STRING']
54         self._starting.colour = Colour.BLUE
55
56         self.refresh_pieces()
57         self.set_starting.colour(Colour.BLUE if persist['FEN_STRING'][-1].lower()
58 == 'b' else Colour.RED)
59         self.draw()
60
61     @property
62     def selected_coords(self):
63         return self._selected_coords
64
65     @selected_coords.setter
66     def selected_coords(self, new_coords):
67         self._overlay_draw.set_selected_coords(new_coords)
68         self._selected_coords = new_coords
69
70     def get_event(self, event):
71         widget_event = self._widget_group.process_event(event)
72
73         if event.type in [pygame.MOUSEBUTTONUP, pygame.KEYDOWN]:
74             EDITOR_WIDGETS['help'].kill()
75
76         if event.type == pygame.MOUSEBUTTONDOWN:

```

```

76     clicked_coords = screen_pos_to_coords(event.pos, EDITOR_WIDGETS['chessboard'].position, EDITOR_WIDGETS['chessboard'].size)
77
78     if clicked_coords:
79         self.selected_coords = clicked_coords
80
81     if self._selected_tool is None:
82         return
83
84     if self._selected_tool == 'MOVE':
85         self.set_dragged_piece(clicked_coords)
86
87     elif self._selected_tool == 'ERASE':
88         self.remove_piece()
89     else:
90         self.set_piece(self._selected_tool, self._selected_tool.colour
91             , Rotation.UP)
92
93     return
94
95     if event.type == pygame.MOUSEBUTTONUP:
96         clicked_coords = screen_pos_to_coords(event.pos, EDITOR_WIDGETS['chessboard'].position, EDITOR_WIDGETS['chessboard'].size)
97
98         if self._drag_and_drop.dragged_sprite:
99             self.remove_dragged_piece(clicked_coords)
100
101    if widget_event is None:
102        if event.type == pygame.MOUSEBUTTONDOWN and self._widget_group.on_widget(event.pos) is False:
103            self.selected_coords = None
104
105    return
106
107    match widget_event.type:
108        case None:
109            return
110
111        case EditorEventType.MENU_CLICK:
112            self.next = 'menu'
113            self.done = True
114
115        case EditorEventType.PICK_PIECE_CLICK:
116            if widget_event.piece == self._selected_tool and widget_event.active.colour == self._selected_tool.colour:
117                self.deselect_tool()
118            else:
119                self.select_tool(widget_event.piece, widget_event.active.colour)
120
121        case EditorEventType.ROTATE_PIECE_CLICK:
122            self.rotate_piece(widget_event.rotation_direction)
123
124        case EditorEventType.EMPTY_CLICK:
125            self._bitboards = BitboardCollection(fen_string='sc9
126 /10/10/10/10/10/10/9Sa b')
127            self.refresh_pieces()
128
129        case EditorEventType.RESET_CLICK:
130            self.reset_board()

```

```

131         case EditorEventType.COPY_CLICK:
132             logger.info(f'COPYING TO CLIPBOARD: {encode_fen_string(self._bitboards)}')
133             pyperclip.copy(encode_fen_string(self._bitboards))
134
135         case EditorEventType.BLUE_START_CLICK:
136             self.set_starting_colour(Colour.BLUE)
137
138         case EditorEventType.RED_START_CLICK:
139             self.set_starting_colour(Colour.RED)
140
141         case EditorEventType.START_CLICK:
142             self.next = 'config'
143             self.done = True
144
145         case EditorEventType.CONFIG_CLICK:
146             self.reset_board()
147             self.next = 'config'
148             self.done = True
149
150         case EditorEventType.ERASE_CLICK:
151             if self._selected_tool == 'ERASE':
152                 self.deselect_tool()
153             else:
154                 self.select_tool('ERASE', None)
155
156         case EditorEventType.MOVE_CLICK:
157             if self._selected_tool == 'MOVE':
158                 self.deselect_tool()
159             else:
160                 self.select_tool('MOVE', None)
161
162         case EditorEventType.HELP_CLICK:
163             self._widget_group.add(EDITOR_WIDGETS['help'])
164             self._widget_group.handle_resize(window.size)
165
166     def reset_board(self):
167         self._bitboards = BitboardCollection(self._initial_fen_string)
168         self.refresh_pieces()
169
170     def refresh_pieces(self):
171         self._piece_group.initialise_pieces(self._bitboards.convert_to_piece_list(),
172                                             EDITOR_WIDGETS['chessboard'].position,
173                                             EDITOR_WIDGETS['chessboard'].size)
174
175     def set_starting_colour(self, new_colour):
176         if new_colour == Colour.BLUE:
177             EDITOR_WIDGETS['blue_start_button'].set_locked(True)
178             EDITOR_WIDGETS['red_start_button'].set_locked(False)
179         elif new_colour == Colour.RED:
180             EDITOR_WIDGETS['blue_start_button'].set_locked(False)
181             EDITOR_WIDGETS['red_start_button'].set_locked(True)
182
183         if new_colour != self._starting_colour:
184             EDITOR_WIDGETS['blue_start_button'].set_next_icon()
185             EDITOR_WIDGETS['red_start_button'].set_next_icon()
186
187         self._starting_colour = new_colour
188         self._bitboards.active_colour = new_colour
189
190     def set_dragged_piece(self, coords):
191         bitboard_under_mouse = coords_to_bitboard(coords)
192         dragged_piece = self._bitboards.get_piece_on(bitboard_under_mouse, Colour.

```

```

        BLUE) or self._bitboards.get_piece_on(bitboard_under_mouse, Colour.RED)
191
192     if dragged_piece is None:
193         return
194
195     dragged_colour = self._bitboards.get_colour_on(bitboard_under_mouse)
196     dragged_rotation = self._bitboards.get_rotation_on(bitboard_under_mouse)
197
198     self._drag_and_drop.set_dragged_piece(dragged_piece, dragged_colour,
199     dragged_rotation)
200     self._overlay_draw.set_hover_limit(False)
201
202     def remove_dragged_piece(self, coords):
203         piece, colour, rotation = self._drag_and_drop.get_dragged_info()
204
205         if coords and coords != self._selected_coords and piece != Piece.SPHINX:
206             self.remove_piece()
207             self.selected_coords = coords
208             self.set_piece(piece, colour, rotation)
209             self.selected_coords = None
210
211             self._drag_and_drop.remove_dragged_piece()
212             self._overlay_draw.set_hover_limit(True)
213
214     def set_piece(self, piece, colour, rotation):
215         if self.selected_coords is None or self.selected_coords == (0, 7) or self.
216         selected_coords == (9, 0):
217             return
218
219             self.remove_piece()
220
221             selected_bitboard = coords_to_bitboard(self.selected_coords)
222             self._bitboards.set_square(selected_bitboard, piece, colour)
223             self._bitboards.set_rotation(selected_bitboard, rotation)
224
225             self.refresh_pieces()
226
227     def remove_piece(self):
228         if self.selected_coords is None or self.selected_coords == (0, 7) or self.
229         selected_coords == (9, 0):
230             return
231
232             selected_bitboard = coords_to_bitboard(self.selected_coords)
233             self._bitboards.clear_square(selected_bitboard, Colour.BLUE)
234             self._bitboards.clear_square(selected_bitboard, Colour.RED)
235             self._bitboards.clear_rotation(selected_bitboard)
236
237             self.refresh_pieces()
238
239     def rotate_piece(self, rotation_direction):
240         if self.selected_coords is None or self.selected_coords == (0, 7) or self.
241         selected_coords == (9, 0):
242             return
243
244             selected_bitboard = coords_to_bitboard(self.selected_coords)
245
246             if self._bitboards.get_piece_on(selected_bitboard, Colour.BLUE) is None
247             and self._bitboards.get_piece_on(selected_bitboard, Colour.RED) is None:
248                 return
249
250             current_rotation = self._bitboards.get_rotation_on(selected_bitboard)
251
252

```

```

247         if rotation_direction == RotationDirection.CLOCKWISE:
248             self._bitboards.update_rotation(selected_bitboard, selected_bitboard,
249                 current_rotation.get_clockwise())
250             elif rotation_direction == RotationDirection.ANTICLOCKWISE:
251                 self._bitboards.update_rotation(selected_bitboard, selected_bitboard,
252                     current_rotation.get_anticlockwise())
253
254     self.refresh_pieces()
255
256     def select_tool(self, piece, colour):
257         dict_name_map = { Colour.BLUE: 'blue_piece_buttons', Colour.RED: 'red_piece_buttons' }
258
259         self.deselect_tool()
260
261         if piece == 'ERASE':
262             EDITOR_WIDGETS['erase_button'].set_locked(True)
263             EDITOR_WIDGETS['erase_button'].set_next_icon()
264         elif piece == 'MOVE':
265             EDITOR_WIDGETS['move_button'].set_locked(True)
266             EDITOR_WIDGETS['move_button'].set_next_icon()
267         else:
268             EDITOR_WIDGETS[dict_name_map[colour]][piece].set_locked(True)
269             EDITOR_WIDGETS[dict_name_map[colour]][piece].set_next_icon()
270
271         self._selected_tool = piece
272         self._selected_tool_colour = colour
273
274     def deselect_tool(self):
275         dict_name_map = { Colour.BLUE: 'blue_piece_buttons', Colour.RED: 'red_piece_buttons' }
276
277         if self._selected_tool:
278             if self._selected_tool == 'ERASE':
279                 EDITOR_WIDGETS['erase_button'].set_locked(False)
280                 EDITOR_WIDGETS['erase_button'].set_next_icon()
281             elif self._selected_tool == 'MOVE':
282                 EDITOR_WIDGETS['move_button'].set_locked(False)
283                 EDITOR_WIDGETS['move_button'].set_next_icon()
284             else:
285                 EDITOR_WIDGETS[dict_name_map[self._selected_tool_colour]][self._selected_tool].set_locked(False)
286                 EDITOR_WIDGETS[dict_name_map[self._selected_tool_colour]][self._selected_tool].set_next_icon()
287
288         self._selected_tool = None
289         self._selected_tool_colour = None
290
291     def handle_resize(self):
292         super().handle_resize()
293         self._piece_group.handle_resize(EDITOR_WIDGETS['chessboard'].position,
294             EDITOR_WIDGETS['chessboard'].size)
295         self._drag_and_drop.handle_resize(EDITOR_WIDGETS['chessboard'].position,
296             EDITOR_WIDGETS['chessboard'].size)
297         self._overlay_draw.handle_resize(EDITOR_WIDGETS['chessboard'].position,
298             EDITOR_WIDGETS['chessboard'].size)
299
300     def draw(self):
301         self._widget_group.draw()
302         self._overlay_draw.draw(window.screen)
303         self._piece_group.draw(window.screen)
304         self._drag_and_drop.draw(window.screen)

```

### B.15.2 widget\_dict.py

```

1 from data.utils.enums import Piece, Colour, RotationDirection
2 from data.helpers.asset_helpers import get_highlighted_icon
3 from data.components.custom_event import CustomEvent
4 from data.utils.constants import BLUE_BUTTON_COLOURS
5 from data.utils.event_types import EditorEventType
6 from data.utils.assets import GRAPHICS
7 from data.widgets import *
8
9 blue_pieces_container = Rectangle(
10     relative_position=(0.25, 0),
11     relative_size=(0.13, 0.65),
12     scale_mode='height',
13     anchor_y='center',
14     anchor_x='center'
15 )
16
17 red_pieces_container = Rectangle(
18     relative_position=(-0.25, 0),
19     relative_size=(0.13, 0.65),
20     scale_mode='height',
21     anchor_y='center',
22     anchor_x='center'
23 )
24
25 bottom_actions_container = Rectangle(
26     relative_position=(0, 0.05),
27     relative_size=(0.4, 0.1),
28     anchor_x='center',
29     anchor_y='bottom'
30 )
31
32 top_actions_container = Rectangle(
33     relative_position=(0, 0.05),
34     relative_size=(0.3, 0.1),
35     anchor_x='center',
36     scale_mode='height'
37 )
38
39 top_right_container = Rectangle(
40     relative_position=(0, 0),
41     relative_size=(0.15, 0.075),
42     fixed_position=(5, 5),
43     anchor_x='right',
44     scale_mode='height'
45 )
46
47 EDITOR_WIDGETS = {
48     'help':
49     Icon(
50         relative_position=(0, 0),
51         relative_size=(1.02, 1.02),
52         icon=GRAPHICS['editor_help'],
53         anchor_x='center',
54         anchor_y='center',
55         border_width=0,
56         fill_colour=(0, 0, 0, 0)
57     ),
58     'default': [
59         red_pieces_container,

```

```

60         blue_pieces_container,
61         bottom_actions_container,
62         top_actions_container,
63         top_right_container,
64         ReactiveIconButton(
65             parent=top_right_container,
66             relative_position=(0, 0),
67             relative_size=(1, 1),
68             anchor_x='right',
69             scale_mode='height',
70             base_icon=GRAPHICS['home_base'],
71             hover_icon=GRAPHICS['home_hover'],
72             press_icon=GRAPHICS['home_press'],
73             event=CustomEvent(EditorEventType.MENU_CLICK)
74         ),
75         ReactiveIconButton(
76             parent=top_right_container,
77             relative_position=(0, 0),
78             relative_size=(1, 1),
79             scale_mode='height',
80             base_icon=GRAPHICS['help_base'],
81             hover_icon=GRAPHICS['help_hover'],
82             press_icon=GRAPHICS['help_press'],
83             event=CustomEvent(EditorEventType.HELP_CLICK)
84         ),
85         ReactiveIconButton(
86             parent=bottom_actions_container,
87             relative_position=(0.06, 0),
88             relative_size=(1, 1),
89             anchor_x='center',
90             scale_mode='height',
91             base_icon=GRAPHICS['clockwise_arrow_base'],
92             hover_icon=GRAPHICS['clockwise_arrow_hover'],
93             press_icon=GRAPHICS['clockwise_arrow_press'],
94             event=CustomEvent(EditorEventType.ROTATE_PIECE_CLICK,
95             rotation_direction=RotationDirection.CLOCKWISE)
96         ),
97         ReactiveIconButton(
98             parent=bottom_actions_container,
99             relative_position=(-0.06, 0),
100            relative_size=(1, 1),
101            anchor_x='center',
102            scale_mode='height',
103            base_icon=GRAPHICS['anticlockwise_arrow_base'],
104            hover_icon=GRAPHICS['anticlockwise_arrow_hover'],
105            press_icon=GRAPHICS['anticlockwise_arrow_press'],
106            event=CustomEvent(EditorEventType.ROTATE_PIECE_CLICK,
107            rotation_direction=RotationDirection.ANTICLOCKWISE)
108        ),
109        ReactiveIconButton(
110            parent=top_actions_container,
111            relative_position=(0, 0),
112            relative_size=(1, 1),
113            scale_mode='height',
114            anchor_x='right',
115            base_icon=GRAPHICS['copy_base'],
116            hover_icon=GRAPHICS['copy_hover'],
117            press_icon=GRAPHICS['copy_press'],
118            event=CustomEvent(EditorEventType.COPY_CLICK),
119        ),
120        ReactiveIconButton(
121            parent=top_actions_container,

```

```

120         relative_position=(0, 0),
121         relative_size=(1, 1),
122         scale_mode='height',
123         base_icon=GRAPHICS['delete_base'],
124         hover_icon=GRAPHICS['delete_hover'],
125         press_icon=GRAPHICS['delete_press'],
126         event=CustomEvent(EditorEventType.EMPTY_CLICK),
127     ),
128     ReactiveIconButton(
129         parent=top_actions_container,
130         relative_position=(0, 0),
131         relative_size=(1, 1),
132         scale_mode='height',
133         anchor_x='center',
134         base_icon=GRAPHICS['discard_arrow_base'],
135         hover_icon=GRAPHICS['discard_arrow_hover'],
136         press_icon=GRAPHICS['discard_arrow_press'],
137         event=CustomEvent(EditorEventType.RESET_CLICK),
138     ),
139     ReactiveIconButton(
140         relative_position=(0, 0),
141         fixed_position=(10, 0),
142         relative_size=(0.1, 0.1),
143         anchor_x='right',
144         anchor_y='center',
145         scale_mode='height',
146         base_icon=GRAPHICS['play_arrow_base'],
147         hover_icon=GRAPHICS['play_arrow_hover'],
148         press_icon=GRAPHICS['play_arrow_press'],
149         event=CustomEvent(EditorEventType.START_CLICK),
150     ),
151     ReactiveIconButton(
152         relative_position=(0, 0),
153         fixed_position=(10, 0),
154         relative_size=(0.1, 0.1),
155         anchor_y='center',
156         scale_mode='height',
157         base_icon=GRAPHICS['return_arrow_base'],
158         hover_icon=GRAPHICS['return_arrow_hover'],
159         press_icon=GRAPHICS['return_arrow_press'],
160         event=CustomEvent(EditorEventType.CONFIG_CLICK),
161     )
162 ],
163 'blue_piece_buttons': {},
164 'red_piece_buttons': {},
165 'erase_button':
166     MultipleIconButton(
167         parent=red_pieces_container,
168         relative_position=(0, 0),
169         relative_size=(0.2, 0.2),
170         scale_mode='height',
171         margin=10,
172         icons_dict={True: GRAPHICS['eraser'], False: get_highlighted_icon(GRAPHICS['eraser'])},
173         event=CustomEvent(EditorEventType.ERASE_CLICK),
174     ),
175     'move_button':
176     MultipleIconButton(
177         parent=blue_pieces_container,
178         relative_position=(0, 0),
179         relative_size=(0.2, 0.2),
180         scale_mode='height',

```

```

181     box_colours=BLUE_BUTTON_COLOURS,
182     icons_dict={True: GRAPHICS['finger'], False: get_highlighted_icon(GRAPHICS
183 ['finger'])}),
184     event=CustomEvent(EditorEventType.MOVE_CLICK),
185 ),
186     'chessboard':
187     Chessboard(
188         relative_position=(0, 0),
189         relative_width=0.4,
190         scale_mode='width',
191         anchor_x='center',
192         anchor_y='center'
193     ),
194     'blue_start_button':
195     MultipleIconButton(
196         parent=bottom_actions_container,
197         relative_position=(0, 0),
198         relative_size=(1, 1),
199         scale_mode='height',
200         anchor_x='right',
201         box_colours=BLUE_BUTTON_COLOURS,
202         icons_dict={False: get_highlighted_icon(GRAPHICS['pharaoh_0_a']), True:
203 GRAPHICS['pharaoh_0_a']},
204         event=CustomEvent(EditorEventType.BLUE_START_CLICK)
205     ),
206     'red_start_button':
207     MultipleIconButton(
208         parent=bottom_actions_container,
209         relative_position=(0, 0),
210         relative_size=(1, 1),
211         scale_mode='height',
212         icons_dict={True: GRAPHICS['pharaoh_1_a'], False: get_highlighted_icon(
213 GRAPHICS['pharaoh_1_a'])},
214         event=CustomEvent(EditorEventType.RED_START_CLICK)
215     )
216 }
217
218 for index, piece in enumerate([piece for piece in Piece if piece != Piece.SPHINX]):
219     :
220     blue_icon = GRAPHICS[f'{piece.name.lower()}_0_a']
221     dimmed_blue_icon = get_highlighted_icon(blue_icon)
222
223     EDITOR_WIDGETS['blue_piece_buttons'][piece] = MultipleIconButton(
224         parent=blue_pieces_container,
225         relative_position=(0, (index + 1) / 5),
226         relative_size=(0.2, 0.2),
227         scale_mode='height',
228         box_colours=BLUE_BUTTON_COLOURS,
229         icons_dict={True: blue_icon, False: dimmed_blue_icon},
230         event=CustomEvent(EditorEventType.PICK_PIECE_CLICK, piece=piece,
231 active_colour=Colour.BLUE)
232     )
233
234     red_icon = GRAPHICS[f'{piece.name.lower()}_1_a']
235
236     dimmed_red_icon = get_highlighted_icon(red_icon)
237
238     EDITOR_WIDGETS['red_piece_buttons'][piece] = MultipleIconButton(
239         parent=red_pieces_container,
240         relative_position=(0, (index + 1) / 5),
241         relative_size=(0.2, 0.2),
242         scale_mode='height',

```

```

238         icons_dict={True: red_icon, False: dimmed_red_icon},
239         event=CustomEvent(EditorEventType.PICK_PIECE_CLICK, piece=piece,
240             active_colour=Colour.RED)
240     )

```

## B.16 data\states\game

### B.16.1 game.py

```

1 import pygame
2 from functools import partial
3 from data.states.game.mvc.game_controller import GameController
4 from data.helpers.database_helpers import insert_into_games
5 from data.states.game.mvc.game_model import GameModel
6 from data.states.game.mvc.pause_view import PauseView
7 from data.states.game.mvc.game_view import GameView
8 from data.states.game.mvc.win_view import WinView
9 from data.components.game_entry import GameEntry
10 from data.managers.logs import initialise_logger
11 from data.managers.window import window
12 from data.managers.audio import audio
13 from data.utils.constants import ShaderType
14 from data.utils.assets import MUSIC, SFX
15 from data.control import _State
16
17 logger = initialise_logger(__name__)
18
19 class Game(_State):
20     def __init__(self):
21         super().__init__()
22
23     def cleanup(self):
24         super().cleanup()
25
26         window.clear_apply_arguments(ShaderType.BLOOM)
27         window.clear_effect(ShaderType.RAYS)
28
29         game_entry = GameEntry(self.model.states, final_fen_string=self.model.
30             get_fen_string())
31         inserted_game = insert_into_games(game_entry.convert_to_row())
32
33         return inserted_game
34
35     def switch_to_menu(self):
36         self.next = 'menu'
37         self.done = True
38
39     def switch_to_review(self):
40         self.next = 'review'
41         self.done = True
42
43     def startup(self, persist):
44         music = MUSIC[['cpu_easy', 'cpu_medium', 'cpu_hard'][persist['CPU_DEPTH']
45 - 2]] if persist['CPU_ENABLED'] else MUSIC['pvp']
46         super().startup(music=music)
47
48         window.set_apply_arguments(ShaderType.BASE, background_type=ShaderType.
49             BACKGROUND_LASERS)
50         window.set_apply_arguments(ShaderType.BLOOM, highlight_colours=[(pygame.
51             Color('0x95e0cc')).rgb, pygame.Color('0xf14e52').rgb], colour_intensity=0.8)
52         binded_startup = partial(self.startup, persist)

```

```

49
50         self.model = GameModel(persist)
51         self.view = GameView(self.model)
52         self.pause_view = PauseView(self.model)
53         self.win_view = WinView(self.model)
54         self.controller = GameController(self.model, self.view, self.win_view,
55                                         self.pause_view, self.switch_to_menu, self.switch_to_review, binded_startup)
56
57         self.view.draw()
58
59         audio.play_sfx(SFX['game_start_1'])
60         audio.play_sfx(SFX['game_start_2'])
61
62     def get_event(self, event):
63         self.controller.handle_event(event)
64
65     def handle_resize(self):
66         self.view.handle_resize()
67         self.win_view.handle_resize()
68         self.pause_view.handle_resize()
69
70     def draw(self):
71         self.view.draw()
72         self.win_view.draw()
73         self.pause_view.draw()
74
75     def update(self):
76         self.controller.check_cpu()
77         super().update()

```

## B.16.2 widget\_dict.py

```

1 from data.widgets import *
2 from data.utils.enums import RotationDirection, Colour
3 from data.components.custom_event import CustomEvent
4 from data.utils.event_types import GameEventType
5 from data.utils.assets import GRAPHICS
6
7 right_container = Rectangle(
8     relative_position=(0.05, 0),
9     relative_size=(0.2, 0.5),
10    anchor_y='center',
11    anchor_x='right',
12 )
13
14 rotate_container = Rectangle(
15     relative_position=(0, 0.05),
16     relative_size=(0.2, 0.1),
17    anchor_x='center',
18    anchor_y='bottom',
19 )
20
21 move_list = MoveList(
22     parent=right_container,
23     relative_position=(0, 0),
24     relative_width=1,
25     minimum_height=300,
26     move_list=[]
27 )
28
29 resign_button = TextButton(
30     parent=right_container,

```

```

31     relative_position=(0, 0),
32     relative_size=(0.5, 0.2),
33     fit_vertical=False,
34     anchor_y='bottom',
35     text="    Resign",
36     margin=5,
37     event=CustomEvent(GameEventType.RESIGN_CLICK)
38 )
39
40 draw_button = TextButton(
41     parent=right_container,
42     relative_position=(0, 0),
43     relative_size=(0.5, 0.2),
44     fit_vertical=False,
45     anchor_x='right',
46     anchor_y='bottom',
47     text="    Draw",
48     margin=5,
49     event=CustomEvent(GameEventType.DRAW_CLICK)
50 )
51
52 top_right_container = Rectangle(
53     relative_position=(0, 0),
54     relative_size=(0.225, 0.075),
55     fixed_position=(5, 5),
56     anchor_x='right',
57     scale_mode='height'
58 )
59
60 GAME_WIDGETS = {
61     'help':
62     Icon(
63         relative_position=(0, 0),
64         relative_size=(1.02, 1.02),
65         icon=GRAPHICS['game_help'],
66         anchor_x='center',
67         anchor_y='center',
68         border_width=0,
69         fill_colour=(0, 0, 0, 0)
70     ),
71     'tutorial':
72     Icon(
73         relative_position=(0, 0),
74         relative_size=(0.9, 0.9),
75         icon=GRAPHICS['game_tutorial'],
76         anchor_x='center',
77         anchor_y='center',
78     ),
79     'default': [
80         right_container,
81         rotate_container,
82         top_right_container,
83         ReactiveIconButton(
84             parent=top_right_container,
85             relative_position=(0, 0),
86             relative_size=(1, 1),
87             anchor_x='right',
88             scale_mode='height',
89             base_icon=GRAPHICS['home_base'],
90             hover_icon=GRAPHICS['home_hover'],
91             press_icon=GRAPHICS['home_press'],
92             event=CustomEvent(GameEventType.MENU_CLICK)

```

```

93     ),
94     ReactiveIconButton(
95         parent=top_right_container,
96         relative_position=(0, 0),
97         relative_size=(1, 1),
98         scale_mode='height',
99         base_icon=GRAPHICS['tutorial_base'],
100        hover_icon=GRAPHICS['tutorial_hover'],
101        press_icon=GRAPHICS['tutorial_press'],
102        event=CustomEvent(GameEventType.TUTORIAL_CLICK)
103    ),
104    ReactiveIconButton(
105        parent=top_right_container,
106        relative_position=(0.33, 0),
107        relative_size=(1, 1),
108        scale_mode='height',
109        base_icon=GRAPHICS['help_base'],
110        hover_icon=GRAPHICS['help_hover'],
111        press_icon=GRAPHICS['help_press'],
112        event=CustomEvent(GameEventType.HELP_CLICK)
113    ),
114    ReactiveIconButton(
115        parent=rotate_container,
116        relative_position=(0, 0),
117        relative_size=(1, 1),
118        scale_mode='height',
119        anchor_x='right',
120        base_icon=GRAPHICS['clockwise_arrow_base'],
121        hover_icon=GRAPHICS['clockwise_arrow_hover'],
122        press_icon=GRAPHICS['clockwise_arrow_press'],
123        event=CustomEvent(GameEventType.ROTATE_PIECE, rotation_direction=
RotationDirection.CLOCKWISE)
124    ),
125    ReactiveIconButton(
126        parent=rotate_container,
127        relative_position=(0, 0),
128        relative_size=(1, 1),
129        scale_mode='height',
130        base_icon=GRAPHICS['anticlockwise_arrow_base'],
131        hover_icon=GRAPHICS['anticlockwise_arrow_hover'],
132        press_icon=GRAPHICS['anticlockwise_arrow_press'],
133        event=CustomEvent(GameEventType.ROTATE_PIECE, rotation_direction=
RotationDirection.ANTICLOCKWISE)
134    ),
135    resign_button,
136    draw_button,
137    Icon(
138        parent=resign_button,
139        relative_position=(0, 0),
140        relative_size=(0.75, 0.75),
141        fill_colour=(0, 0, 0, 0),
142        scale_mode='height',
143        anchor_y='center',
144        border_radius=0,
145        border_width=0,
146        margin=5,
147        icon=GRAPHICS['resign']
148    ),
149    Icon(
150        parent=draw_button,
151        relative_position=(0, 0),
152        relative_size=(0.75, 0.75),

```

```

153         fill_colour=(0, 0, 0, 0),
154         scale_mode='height',
155         anchor_y='center',
156         border_radius=0,
157         border_width=0,
158         margin=5,
159         icon=GRAPHICS['draw']
160     ),
161 ],
162 'scroll_area': # REMEMBER SCROLL AREA AFTER CONTAINER FOR RESIZING
163 ScrollArea(
164     parent=right_container,
165     relative_position=(0, 0),
166     relative_size=(1, 0.8),
167     vertical=True,
168     widget=move_list
169 ),
170 'move_list':
171     move_list,
172 'blue_timer':
173 Timer(
174     relative_position=(0.05, 0.05),
175     anchor_y='center',
176     relative_size=(0.1, 0.1),
177     active_colour=Colour.BLUE,
178     event=CustomEvent(GameEventType.TIMER_END),
179 ),
180 'red_timer':
181 Timer(
182     relative_position=(0.05, -0.05),
183     anchor_y='center',
184     relative_size=(0.1, 0.1),
185     active_colour=Colour.RED,
186     event=CustomEvent(GameEventType.TIMER_END),
187 ),
188 'status_text':
189 Text(
190     relative_position=(0, 0.05),
191     relative_size=(0.4, 0.1),
192     anchor_x='center',
193     fit_vertical=False,
194     margin=10,
195     text="g",
196     minimum_width=400
197 ),
198 'chessboard':
199 Chessboard(
200     relative_position=(0, 0),
201     anchor_x='center',
202     anchor_y='center',
203     scale_mode='width',
204     relative_width=0.4
205 ),
206 'blue_piece_display':
207 PieceDisplay(
208     relative_position=(0.05, 0.05),
209     relative_size=(0.2, 0.1),
210     anchor_y='bottom',
211     active_colour=Colour.BLUE
212 ),
213 'red_piece_display':
214 PieceDisplay(

```

```

215         relative_position=(0.05, 0.05),
216         relative_size=(0.2, 0.1),
217         active_colour=Colour.RED
218     )
219 }
220
221 PAUSE_WIDGETS = {
222     'default': [
223         TextButton(
224             relative_position=(0, -0.125),
225             relative_size=(0.3, 0.2),
226             anchor_x='center',
227             anchor_y='center',
228             text='GO TO MENU',
229             fit_vertical=False,
230             event=CustomEvent(GameEventType.MENU_CLICK)
231         ),
232         TextButton(
233             relative_position=(0, 0.125),
234             relative_size=(0.3, 0.2),
235             anchor_x='center',
236             anchor_y='center',
237             text='RESUME GAME',
238             fit_vertical=False,
239             event=CustomEvent(GameEventType.PAUSE_CLICK)
240         )
241     ]
242 }
243
244 win_container = Rectangle(
245     relative_position=(0, 0),
246     relative_size=(0.4, 0.8),
247     scale_mode='height',
248     anchor_x='center',
249     anchor_y='center',
250     fill_colour=(128, 128, 128, 200),
251     visible=True
252 )
253
254 WIN_WIDGETS = {
255     'default': [
256         win_container,
257         TextButton(
258             parent=win_container,
259             relative_position=(0, 0.5),
260             relative_size=(0.8, 0.15),
261             text='GO TO MENU',
262             anchor_x='center',
263             fit_vertical=False,
264             event=CustomEvent(GameEventType.MENU_CLICK)
265         ),
266         TextButton(
267             parent=win_container,
268             relative_position=(0, 0.65),
269             relative_size=(0.8, 0.15),
270             text='REVIEW GAME',
271             anchor_x='center',
272             fit_vertical=False,
273             event=CustomEvent(GameEventType.REVIEW_CLICK)
274         ),
275         TextButton(
276             parent=win_container,

```

```

277         relative_position=(0, 0.8),
278         relative_size=(0.8, 0.15),
279         text='NEW GAME',
280         anchor_x='center',
281         fit_vertical=False,
282         event=CustomEvent(GameEventType.GAME_CLICK)
283     ),
284 ],
285 'blue_won':
286 Icon(
287     parent=win_container,
288     relative_position=(0, 0.05),
289     relative_size=(0.8, 0.3),
290     anchor_x='center',
291     border_width=0,
292     margin=0,
293     icon=GRAPHICS['blue_won'],
294     fill_colour=(0, 0, 0, 0),
295 ),
296 'red_won':
297 Icon(
298     parent=win_container,
299     relative_position=(0, 0.05),
300     relative_size=(0.8, 0.3),
301     anchor_x='center',
302     border_width=0,
303     margin=0,
304     icon=GRAPHICS['red_won'],
305     fill_colour=(0, 0, 0, 0),
306     fit_icon=True,
307 ),
308 'draw_won':
309 Icon(
310     parent=win_container,
311     relative_position=(0, 0.05),
312     relative_size=(0.8, 0.3),
313     anchor_x='center',
314     border_width=0,
315     margin=0,
316     icon=GRAPHICS['draw_won'],
317     fill_colour=(0, 0, 0, 0),
318 ),
319 'by_checkmate':
320 Icon(
321     parent=win_container,
322     relative_position=(0, 0.375),
323     relative_size=(0.8, 0.1),
324     anchor_x='center',
325     border_width=0,
326     margin=0,
327     icon=GRAPHICS['by_checkmate'],
328     fill_colour=(0, 0, 0, 0),
329 ),
330 'by_resignation':
331 Icon(
332     parent=win_container,
333     relative_position=(0, 0.375),
334     relative_size=(0.8, 0.1),
335     anchor_x='center',
336     border_width=0,
337     margin=0,
338     icon=GRAPHICS['by_resignation'],

```

```

339         fill_colour=(0, 0, 0, 0),
340     ),
341     'by_draw':
342     Icon(
343         parent=win_container,
344         relative_position=(0, 0.375),
345         relative_size=(0.8, 0.1),
346         anchor_x='center',
347         border_width=0,
348         margin=0,
349         icon=GRAPHICS['by_draw'],
350         fill_colour=(0, 0, 0, 0),
351     ),
352     'by_timeout':
353     Icon(
354         parent=win_container,
355         relative_position=(0, 0.375),
356         relative_size=(0.8, 0.1),
357         anchor_x='center',
358         border_width=0,
359         margin=0,
360         icon=GRAPHICS['by_timeout'],
361         fill_colour=(0, 0, 0, 0),
362     )
363 }
```

## B.17 data\states\game\components

### B.17.1 bitboard\_collection.py

See Section 3.5.5.

### B.17.2 board.py

See Section 3.5.4.

### B.17.3 capture\_draw.py

```

1 from data.states.game.components.particles_draw import ParticlesDraw
2 from data.helpers.board_helpers import coords_to_screen_pos
3 from data.managers.animation import animation
4 from data.utils.constants import ShaderType
5 from data.managers.window import window
6 from data.utils.enums import Colour
7
8 class CaptureDraw:
9     def __init__(self, board_position, board_size):
10         self._board_position = board_position
11         self._square_size = board_size[0] / 10
12         self._particles_draw = ParticlesDraw()
13
14     def add_capture(self, piece, colour, rotation, piece_coords, sphinx_coords,
15                     active_colour, particles=True, shake=True):
16         if particles:
17             self._particles_draw.add_captured_piece(
18                 piece,
19                 colour,
```

```

20         coords_to_screen_pos(piece_coords, self._board_position, self.
21             _square_size),
22             self._square_size
23         )
24         self._particles_draw.add_sparks(
25             3,
26             (255, 0, 0) if active_colour == Colour.RED else (0, 0, 255),
27             coords_to_screen_pos(sphinx_coords, self._board_position, self.
28             _square_size)
29         )
30
31     if shake:
32         window.set_effect(ShaderType.SHAKE)
33         animation.set_timer(500, lambda: window.clear_effect(ShaderType.SHAKE)
34     )
35
36     def draw(self, screen):
37         self._particles_draw.draw(screen)
38
39     def update(self):
40         self._particles_draw.update()
41
42     def handle_resize(self, board_position, board_size):
43         self._board_position = board_position
44         self._square_size = board_size[0] / 10

```

#### B.17.4 father.py

```

1 import pygame
2 from data.states.game.components.piece_sprite import PieceSprite
3 from data.utils.enums import CursorMode
4 from data.managers.cursor import cursor
5
6 DRAG_THRESHOLD = 500
7
8 class DragAndDrop:
9     def __init__(self, board_position, board_size, change_cursor=True):
10         self._board_position = board_position
11         self._board_size = board_size
12         self._change_cursor = change_cursor
13         self._ticks_since_drag = 0
14
15         self.dragged_sprite = None
16
17     def set_dragged_piece(self, piece, colour, rotation):
18         sprite = PieceSprite(piece=piece, colour=colour, rotation=rotation)
19         sprite.set_geometry((0, 0), self._board_size[0] / 10)
20         sprite.set_image()
21
22         self.dragged_sprite = sprite
23         self._ticks_since_drag = pygame.time.get_ticks()
24
25         if self._change_cursor:
26             cursor.set_mode(CursorMode.CLOSEDHAND)
27
28     def remove_dragged_piece(self):
29         self.dragged_sprite = None
30         time_dragged = pygame.time.get_ticks() - self._ticks_since_drag
31         self._ticks_since_drag = 0
32
33         if self._change_cursor:
34             cursor.set_mode(CursorMode.OPENGHAND)

```

```

35         return time_dragged > DRAG_THRESHOLD
36
37     def get_dragged_info(self):
38         return self.dragged_sprite.type, self.dragged_sprite.colour, self.
39             dragged_sprite.rotation
40
41     def draw(self, screen):
42         if self.dragged_sprite is None:
43             return
44
45         self.dragged_sprite.rect.center = pygame.mouse.get_pos()
46         screen.blit(self.dragged_sprite.image, self.dragged_sprite.rect.topleft)
47
48     def handle_resize(self, board_position, board_size):
49         if self.dragged_sprite:
50             self.dragged_sprite.set_geometry(board_position, board_size[0] / 10)
51
52         self._board_position = board_position
53         self._board_size = board_size

```

### B.17.5 fen\_parser.py

```

1  from data.helpers.bitboard_helpers import occupied_squares, bitboard_to_index
2  from data.utils.enums import Colour, RotationIndex, Rotation, Piece
3  from data.utils.constants import EMPTY_BB
4
5  def parse_fen_string(fen_string):
6      #sc3ncfcnlpb2/2pc7/3Pd6/pa1Pcirbra1pb1Pd/pb1Pd1RaRbipa1Pc/6pb3/7Pa2/2
7      #PdNaFaNa3Sa b
8      piece_bitboards = {char: EMPTY_BB for char in Piece}, {char: EMPTY_BB for
9          char in Piece}
10     rotation_bitboards = [EMPTY_BB, EMPTY_BB]
11     combined_colour_bitboards = [EMPTY_BB, EMPTY_BB]
12     combined_all_bitboard = 0
13     part_1, part_2 = fen_string.split(' ')
14
15     rank = 7
16     file = 0
17
18     piece_count = {char.lower(): 0 for char in Piece} | {char.upper(): 0 for char
19          in Piece}
20
21     for index, character in enumerate(part_1):
22         square = rank * 10 + file
23
24         if character.lower() in Piece:
25             piece_count[character] += 1
26             if character.isupper():
27                 piece_bitboards[Colour.BLUE][character.lower()] |= 1 << square
28
29             else:
30                 piece_bitboards[Colour.RED][character.lower()] |= 1 << square
31
32         rotation = part_1[index + 1]
33         match rotation:
34             case Rotation.UP:
35                 pass
36             case Rotation.RIGHT:
37                 rotation_bitboards[RotationIndex.FIRSTBIT] |= 1 << square
38             case Rotation.DOWN:
39                 rotation_bitboards[RotationIndex.SECONDBIT] |= 1 << square

```

```

37         case Rotation.LEFT:
38             rotation_bitboards[RotationIndex.SECONDBIT] |= 1 << square
39             rotation_bitboards[RotationIndex.FIRSTBIT] |= 1 << square
40         case _:
41             raise ValueError('Invalid FEN String - piece character not
42 followed by rotational character')
43
44     file += 1
45     elif character in '0123456789':
46         if character == '1' and fen_string[index + 1] == '0':
47             file += 10
48             continue
49
50         file += int(character)
51     elif character == '/':
52         rank = rank - 1
53         file = 0
54     elif character in Rotation:
55         continue
56     else:
57         raise ValueError('Invalid FEN String - invalid character found:', character)
58
59     if piece_count['s'] != 1 or piece_count['S'] != 1:
60         raise ValueError('Invalid FEN string - invalid number of Sphinx pieces')
61     # COMMENTED OUT AS NO PHARAOH PIECES IS OKAY IF PARSING FEN STRING FOR
62     FINISHED GAME BOARD THUMBNAIL
63     elif piece_count['f'] > 1 or piece_count['F'] > 1:
64         raise ValueError('Invalid FEN string - invalid number of Pharaoh pieces')
65
66     if part_2 == 'b':
67         colour = Colour.BLUE
68     elif part_2 == 'r':
69         colour = Colour.RED
70     else:
71         raise ValueError('Invalid FEN string - invalid active colour')
72
73     for piece in Piece:
74         combined_colour_bitboards[Colour.BLUE] |= piece_bitboards[Colour.BLUE][piece]
75         combined_colour_bitboards[Colour.RED] |= piece_bitboards[Colour.RED][piece]
76
77     combined_all_bitboard = combined_colour_bitboards[Colour.BLUE] |
78     combined_colour_bitboards[Colour.RED]
79     return (piece_bitboards, combined_colour_bitboards, combined_all_bitboard,
80             rotation_bitboards, colour)
81
82 def encode_fen_string(bitboard_collection):
83     blue_bitboards = bitboard_collection.piece_bitboards[Colour.BLUE]
84     red_bitboards = bitboard_collection.piece_bitboards[Colour.RED]
85
86     fen_string_list = [''] * 80
87
88     for piece, bitboard in blue_bitboards.items():
89         for individual_bitboard in occupied_squares(bitboard):
90             index = bitboard_to_index(individual_bitboard)
91             rotation = bitboard_collection.get_rotation_on(individual_bitboard)
92             fen_string_list[index] = piece.upper() + rotation
93
94     for piece, bitboard in red_bitboards.items():
95         for individual_bitboard in occupied_squares(bitboard):
96

```

```

92         index = bitboard_to_index(individual_bitboard)
93         rotation = bitboard_collection.get_rotation_on(individual_bitboard)
94         fen_string_list[index] = piece.lower() + rotation
95
96         fen_string = ''
97         row_string = ''
98         empty_count = 0
99         for index, square in enumerate(fen_string_list):
100             if square == '':
101                 empty_count += 1
102             else:
103                 if empty_count > 0:
104                     row_string += str(empty_count)
105                     empty_count = 0
106
107             row_string += square
108
109             if index % 10 == 9:
110                 if empty_count > 0:
111                     fen_string = '/' + row_string + str(empty_count) + fen_string
112                 else:
113                     fen_string = '/' + row_string + fen_string
114
115             row_string = ''
116             empty_count = 0
117
118         fen_string = fen_string[1:]
119
120         if bitboard_collection.active_colour == Colour.BLUE:
121             colour = 'b'
122         else:
123             colour = 'r'
124
125     return fen_string + ' ' + colour

```

### B.17.6 laser.py

```

1  from data.utils.constants import A_FILE_MASK, J_FILE_MASK, ONE_RANK_MASK,
2   EIGHT_RANK_MASK, EMPTY_BB
3  from data.helpers import bitboard_helpers as bb_helpers
4  from data.utils.enums import Piece, Colour, Rotation
5
5  class Laser:
6      def __init__(self, bitboards):
7          self._bitboards = bitboards
8          self.hit_square_bitboard, self.piece_hit, self.laser_path, self.
9          path_bitboard, self.pieces_on_trajectory, self.end_cap = self.
10         calculate_trajectory()
11
12         if (self.hit_square_bitboard != EMPTY_BB):
13             self.piece_rotation = self._bitboards.get_rotation_on(self.
14             hit_square_bitboard)
15             self.piece_colour = self._bitboards.get_colour_on(self.
16             hit_square_bitboard)
17
18     def calculate_trajectory(self):
19         current_square = self._bitboards.get_piece_bitboard(Piece.SPHINX, self.
20         _bitboards.active_colour)
21         previous_direction = self._bitboards.get_rotation_on(current_square)
22         trajectory_bitboard = 0b0
23         trajectory_list = []
24         square_animation_states = []

```

```

20         pieces_on_trajectory = []
21
22     while current_square:
23         current_piece = self._bitboards.get_piece_on(current_square, Colour.
24             BLUE) or self._bitboards.get_piece_on(current_square, Colour.RED)
25         current_rotation = self._bitboards.get_rotation_on(current_square)
26
27         next_square, direction, piece_hit = self.calculate_next_square(
28             current_square, current_piece, current_rotation, previous_direction)
29
30         trajectory_bitboard |= current_square
31         trajectory_list.append(bb_helpers.bitboard_to_coords(current_square))
32         square_animation_states.append(direction)
33
34         if previous_direction != direction or (current_piece == Piece.ANUBIS
35             and not piece_hit):
36             pieces_on_trajectory.append(current_square)
37
38         if next_square == EMPTY_BB:
39             hit_square_bitboard = 0b0
40
41         if piece_hit:
42             hit_square_bitboard = current_square
43
44         if piece_hit or current_piece == Piece.ANUBIS:
45             end_cap = True
46         else:
47             end_cap = False
48
49         return hit_square_bitboard, piece_hit, list(zip(trajectory_list,
50             square_animation_states)), trajectory_bitboard, pieces_on_trajectory, end_cap
51
52     current_square = next_square
53     previous_direction = direction
54
55 def calculate_next_square(self, square, piece, rotation, previous_direction):
56     match piece:
57         case Piece.SPHINX:
58             if previous_direction != rotation:
59                 return EMPTY_BB, previous_direction, None
60
61             next_square = self.next_square_bitboard(square, rotation)
62             return next_square, previous_direction, Piece.SPHINX
63
64         case Piece.PYRAMID:
65             if previous_direction in [rotation, rotation.get_clockwise()]:
66                 return EMPTY_BB, previous_direction, Piece.PYRAMID
67
68             if previous_direction == rotation.get_anticlockwise():
69                 new_direction = previous_direction.get_clockwise()
70             else:
71                 new_direction = previous_direction.get_anticlockwise()
72
73             next_square = self.next_square_bitboard(square, new_direction)
74
75             return next_square, new_direction, None
76
77         case Piece.ANUBIS:
78             if previous_direction == rotation.get_clockwise().get_clockwise():
79                 return EMPTY_BB, previous_direction, None
80
81             return EMPTY_BB, previous_direction, Piece.ANUBIS

```

```

78
79         case Piece.SCARAB:
80             if previous_direction in [rotation.get_clockwise(), rotation.
81             get_anticlockwise()]:
81                 new_direction = previous_direction.get_anticlockwise()
82             else:
83                 new_direction = previous_direction.get_clockwise()
84
85             next_square = self.next_square_bitboard(square, new_direction)
86
87             return next_square, new_direction, None
88
89         case Piece.PHARAOH:
90             return EMPTY_BB, previous_direction, Piece.PHARAOH
91
92         case None:
93             next_square = self.next_square_bitboard(square, previous_direction)
94
95             return next_square, previous_direction, None
96
97     def next_square_bitboard(self, src_bitboard, previous_direction):
98         match previous_direction:
99             case Rotation.UP:
100                 masked_src_bitboard = src_bitboard & EIGHT_RANK_MASK
101                 return masked_src_bitboard << 10
102             case Rotation.RIGHT:
103                 masked_src_bitboard = src_bitboard & J_FILE_MASK
104                 return masked_src_bitboard << 1
105             case Rotation.DOWN:
106                 masked_src_bitboard = src_bitboard & ONE_RANK_MASK
107                 return masked_src_bitboard >> 10
108             case Rotation.LEFT:
109                 masked_src_bitboard = src_bitboard & A_FILE_MASK
110                 return masked_src_bitboard >> 1

```

### B.17.7 laser\_draw.py

See Section 3.4.1.

### B.17.8 move.py

```

1 import re
2 from data.helpers.bitboard_helpers import notation_to_bitboard, coords_to_bitboard
3             , bitboard_to_coords, bitboard_to_notation
4 from data.utils.enums import MoveType, Colour, RotationDirection
5 from data.managers.logs import initialise_logger
6
7 logger = initialise_logger(__name__)
8
9 class Move():
10     def __init__(self, move_type, src, dest=None, rotation_direction=None):
11         self.move_type = move_type
12         self.src = src
13         self.dest = dest
14         self.rotation_direction = rotation_direction
15
16     def to_notation(self, colour, piece, hit_square_bitboard):
17         hit_square = ''
18         if colour == Colour.BLUE:
19             piece = piece.upper()

```

```
19
20     if hit_square_bitboard:
21         hit_square = 'x' + bitboard_to_notation(hit_square_bitboard)
22
23     if self.move_type == MoveType.MOVE:
24         return 'M' + piece + bitboard_to_notation(self.src) +
25     bitboard_to_notation(self.dest) + hit_square
26     else:
27         return 'R' + piece + bitboard_to_notation(self.src) + self.
28     rotation_direction + hit_square
29
30     def __str__(self):
31         rotate_text = ''
32         coords_1 = '(' + chr(bitboard_to_coords(self.src)[0] + 65) + ', ' + str(
33         bitboard_to_coords(self.src)[1] + 1) + ')'
34
35         if self.move_type == MoveType.ROTATE:
36             rotate_text = ' ' + self.rotation_direction.name
37             return f'{self.move_type.name}{rotate_text}: ON {coords_1}'
38
39         elif self.move_type == MoveType.MOVE:
40             coords_2 = '(' + chr(bitboard_to_coords(self.dest)[0] + 65) + ', ' +
41             str(bitboard_to_coords(self.dest)[1] + 1) + ')'
42             return f'{self.move_type.name}{rotate_text}: FROM {coords_1} TO {coords_2}'
43
44         # (Rotation: {self.rotation_direction})
45
46     @classmethod
47     def instance_from_notation(move_cls, notation):
48         try:
49             notation = notation.split('x')[0]
50             move_type = notation[0].lower()
51
52             moves = notation[2:]
53             letters = re.findall(r'[A-Za-z]+', moves)
54             numbers = re.findall(r'\d+', moves)
55
56             if move_type == MoveType.MOVE:
57                 src_bitboard = notation_to_bitboard(letters[0] + numbers[0])
58                 dest_bitboard = notation_to_bitboard(letters[1] + numbers[1])
59
60                 return move_cls(move_type, src_bitboard, dest_bitboard)
61
62             elif move_type == MoveType.ROTATE:
63                 src_bitboard = notation_to_bitboard(letters[0] + numbers[0])
64                 rotation_direction = RotationDirection(letters[1])
65
66                 return move_cls(move_type, src_bitboard, src_bitboard,
67             rotation_direction)
68             else:
69                 raise ValueError('(Move.instance_from_notation) Invalid move type:',
70             move_type)
71
72         except Exception as error:
73             logger.info('(Move.instance_from_notation) Error occurred while parsing',
74             ':', error)
75             raise error
76
77     @classmethod
78     def instance_from_input(move_cls, move_type, src, dest=None, rotation=None):
79         try:
```

```

73         if move_type == MoveType.MOVE:
74             src_bitboard = notation_to_bitboard(src)
75             dest_bitboard = notation_to_bitboard(dest)
76
77         elif move_type == MoveType.ROTATE:
78             src_bitboard = notation_to_bitboard(src)
79             dest_bitboard = src_bitboard
80
81         return move_cls(move_type, src_bitboard, dest_bitboard, rotation)
82     except Exception as error:
83         logger.info('Error (Move.instance_from):', error)
84         raise error
85
86     @classmethod
87     def instance_from_coords(move_cls, move_type, src_coords, dest_coords=None,
88                             rotation_direction=None):
89         try:
90             src_bitboard = coords_to_bitboard(src_coords)
91             dest_bitboard = coords_to_bitboard(dest_coords)
92
93             return move_cls(move_type, src_bitboard, dest_bitboard,
94                             rotation_direction)
95         except Exception as error:
96             logger.info('Error (Move.instance_from_coords):', error)
97             raise error
98
99     @classmethod
100    def instance_from_bitboards(move_cls, move_type, src_bitboard, dest_bitboard=
101                                None, rotation_direction=None):
102        try:
103            return move_cls(move_type, src_bitboard, dest_bitboard,
104                            rotation_direction)
105        except Exception as error:
106            logger.info('Error (Move.instance_from_bitboards):', error)
107            raise error

```

### B.17.9 overlay\_draw.py

```

1  import pygame
2  from data.utils.constants import OVERLAY_COLOUR_LIGHT, OVERLAY_COLOUR_DARK
3  from data.helpers.board_helpers import coords_to_screen_pos, screen_pos_to_coords,
4      create_square_overlay, create_circle_overlay
5
6  class OverlayDraw:
7      def __init__(self, board_position, board_size, limit_hover=True):
8          self._board_position = board_position
9          self._board_size = board_size
10
11         self._hovered_coords = None
12         self._selected_coords = None
13         self._available_coords = None
14
15         self._limit_hover = limit_hover
16
17         self._selected_overlay = None
18         self._hovered_overlay = None
19         self._available_overlay = None
20
21         self.initialise_overlay_surfaces()
22
23     @property
24     def square_size(self):

```

```

24         return self._board_size[0] / 10
25
26     def initialise_overlay_surfaces(self):
27         self._selected_overlay = create_square_overlay(self.square_size,
28             OVERLAY_COLOUR_DARK)
29         self._hovered_overlay = create_square_overlay(self.square_size,
30             OVERLAY_COLOUR_LIGHT)
31         self._available_overlay = create_circle_overlay(self.square_size,
32             OVERLAY_COLOUR_LIGHT)
33
34     def set_hovered_coords(self, mouse_pos):
35         self._hovered_coords = screen_pos_to_coords(mouse_pos, self.
36             _board_position, self._board_size)
37
38     def set_selected_coords(self, coords):
39         self._selected_coords = coords
40
41     def set_available_coords(self, coords_list):
42         self._available_coords = coords_list
43
44     def set_hover_limit(self, new_limit):
45         self._limit_hover = new_limit
46
47     def draw(self, screen):
48         self.set_hovered_coords(pygame.mouse.get_pos())
49
50         if self._selected_coords:
51             screen.blit(self._selected_overlay, coords_to_screen_pos(self.
52                 _selected_coords, self._board_position, self.square_size))
53
54         if self._available_coords:
55             for coords in self._available_coords:
56                 screen.blit(self._available_overlay, coords_to_screen_pos(coords,
57                     self._board_position, self.square_size))
58
59         if self._hovered_coords:
60             if self._hovered_coords is None:
61                 return
62
63             if self._limit_hover and ((self._available_coords is None) or (self.
64                 _hovered_coords not in self._available_coords)):
65                 return
66
67             screen.blit(self._hovered_overlay, coords_to_screen_pos(self.
68                 _hovered_coords, self._board_position, self.square_size))
69
70     def handle_resize(self, board_position, board_size):
71         self._board_position = board_position
72         self._board_size = board_size
73
74         self.initialise_overlay_surfaces()

```

### B.17.10 particles\_draw.py

See Section 3.4.2.

### B.17.11 piece\_group.py

```

1 import pygame
2 from data.states.game.components.piece_sprite import PieceSprite

```

```

3  from data.utils.enums import Colour, Piece
4
5  class PieceGroup(pygame.sprite.Group):
6      def __init__(self):
7          super().__init__()
8
9      def initialise_pieces(self, piece_list, board_position, board_size):
10         self.empty()
11
12         for index, piece_and_rotation in enumerate(piece_list):
13             x = index % 10
14             y = index // 10
15
16             if piece_and_rotation:
17                 if piece_and_rotation[0].isupper():
18                     colour = Colour.BLUE
19                 else:
20                     colour = Colour.RED
21
22                 piece = PieceSprite(piece=Piece(piece_and_rotation[0].lower()),
23                                     colour=colour, rotation=piece_and_rotation[1])
24                 piece.set_coords((x, y))
25                 piece.set_geometry(board_position, board_size[0] / 10)
26                 piece.set_image()
27                 self.add(piece)
28
29         def set_geometry(self, board_position, board_size):
30             for sprite in self.sprites():
31                 sprite.set_geometry(board_position, board_size[0] / 10)
32
33         def handle_resize(self, board_position, board_size):
34             self.set_geometry(board_position, board_size)
35
36             for sprite in self.sprites():
37                 sprite.set_image()
38
39         def remove_piece(self, coords):
40             for sprite in self.sprites():
41                 if sprite.coords == coords:
42                     sprite.kill()

```

### B.17.12 piece\_sprite.py

```

1  import pygame
2  from data.helpers.board_helpers import coords_to_screen_pos
3  from data.helpers.asset_helpers import scale_and_cache
4  from data.utils.assets import GRAPHICS
5  from data.utils.enums import Piece
6
7  class PieceSprite(pygame.sprite.Sprite):
8      def __init__(self, piece, colour, rotation):
9          super().__init__()
10         self.colour = colour
11         self.rotation = rotation
12
13         self.type = piece
14         self.coords = None
15         self.size = None
16
17     @property
18     def image_name(self):

```

```

19         return Piece(self.type).name.lower() + '_' + str(self.colour) + '_' + self
20         .rotation
21
22     def set_image(self):
23         self.image = scale_and_cache(GRAPHICS[self.image_name], (self.size, self.
24         size))
25
26     def set_geometry(self, new_position, square_size):
27         self.size = square_size
28         self.rect = pygame.FRect((0, 0, square_size, square_size))
29
30         if self.coords:
31             self.rect.topleft = coords_to_screen_pos(self.coords, new_position,
32             square_size)
33         else:
34             self.rect.topleft = new_position
35
36     def set_coords(self, new_coords):
37         self.coords = new_coords

```

### B.17.13 psqt.py

```

1 from data.utils.enums import Piece
2
3 FLIP = [
4     70, 71, 72, 73, 74, 75, 76, 77, 78, 79,
5     60, 61, 62, 63, 64, 65, 66, 67, 68, 69,
6     50, 51, 52, 53, 54, 55, 56, 57, 58, 59,
7     40, 41, 42, 43, 44, 45, 46, 47, 48, 49,
8     6, 31, 32, 33, 34, 35, 36, 37, 38, 39,
9     4, 21, 22, 23, 24, 25, 26, 27, 28, 29,
10    2, 11, 12, 13, 14, 3, 16, 17, 18, 19,
11    0, 1, 2, 3, 4, 5, 6, 7, 8, 9,
12 ]
13
14 PSQT = {
15     Piece.PYRAMID: [
16         0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
17         0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
18         0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
19         0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
20         0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
21         0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
22         0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
23         0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
24     ],
25     Piece.ANUBIS: [
26         0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
27         0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
28         0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
29         0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
30         0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
31         6, 6, 6, 6, 6, 6, 6, 6, 6, 6,
32         4, 4, 4, 4, 4, 4, 4, 4, 4, 4,
33         2, 2, 2, 2, 2, 2, 2, 2, 2, 2,
34     ],
35     Piece.SCARAB: [
36         0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
37         0, 0, 1, 1, 1, 1, 1, 0, 0,
38         0, 0, 1, 2, 2, 2, 2, 1, 0, 0,
39         0, 0, 1, 2, 3, 3, 2, 1, 0, 0,
40         0, 0, 1, 2, 3, 3, 2, 1, 0, 0,

```

```

41      0, 0, 1, 2, 2, 2, 2, 1, 0, 0,
42      0, 0, 1, 1, 1, 1, 1, 0, 0,
43      0, 0, 0, 0, 0, 0, 0, 0, 0,
44  ],
45 Piece.PHARAOH: [
46      0, 0, 0, 0, 0, 0, 0, 0, 0,
47      0, 0, 0, 0, 0, 0, 0, 0, 0,
48      0, 0, 0, 0, 0, 0, 0, 0, 0,
49      0, 0, 0, 0, 0, 0, 0, 0, 0,
50      0, 0, 0, 0, 0, 0, 0, 0, 0,
51      0, 0, 0, 0, 0, 0, 0, 0, 0,
52      0, 0, 0, 2, 2, 2, 2, 0, 0,
53      0, 0, 0, 2, 4, 4, 2, 0, 0,
54  ],
55 }

```

## B.18 data\states\game\cpu

### B.18.1 base.py

```

1 import time
2 from pprint import PrettyPrinter
3 from data.utils.enums import Colour, Score, Miscellaneous
4 from data.states.game.cpu.evaluator import Evaluator
5 from data.managers.logs import initialise_logger
6
7 logger = initialise_logger(__name__)
8 printer = PrettyPrinter(indent=2, sort_dicts=False)
9
10 class BaseCPU:
11     def __init__(self, callback, verbose=True):
12         self._evaluator = Evaluator(verbose=False)
13         self._verbose = verbose
14         self._callback = callback
15         self._stats = {}
16
17     def initialise_stats(self):
18         self._stats = {
19             'nodes': 0,
20             'leaf_nodes': 0,
21             'draws': 0,
22             'mates': 0,
23             'ms_per_node': 0,
24             'time_taken': time.time()
25         }
26
27     def print_stats(self, score, move):
28         """
29             Prints statistics after traversing tree.
30
31             Args:
32                 score (int): Final score obtained after traversal.
33                 move (Move): Best move obtained after traversal.
34
35             if self._verbose is False:
36                 return
37
38             self._stats['time_taken'] = round(1000 * (time.time() - self._stats['
39             time_taken']), 3)
40             self._stats['ms_per_node'] = round(self._stats['time_taken'] / self._stats
41             ['nodes'], 3)

```

```

40
41     # Prints stats across multiple lines
42     if self._verbose is True:
43         logger.info(f'\n\n'
44                     f'{self.__str__()} Search Results:\n'
45                     f'{printer.pformat(self._stats)}\n'
46                     f'Best score: {score} Best move: {move}\n'
47                     )
48
49     # Prints stats in a compacted format
50     elif self._verbose.lower() == 'compact':
51         logger.info(self._stats)
52         logger.info(f'Best score: {score} Best move: {move}')
53
54     def find_move(self, board, stop_event=None):
55         raise NotImplementedError
56
57     def search(self, board, depth, stop_event, absolute=False, **kwargs):
58         if stop_event and stop_event.is_set():
59             raise TimeoutError(f'Thread killed - stopping minimax function ({self.__str__().search()})')
60
61         self._stats['nodes'] += 1
62
63         if (winner := board.check_win()) is not None:
64             self._stats['leaf_nodes'] += 1
65             return self.process_win(winner, depth, absolute)
66
67         if depth == 0:
68             self._stats['leaf_nodes'] += 1
69             return self.evaluator.evaluate(board, absolute), None
70
71     def process_win(self, winner, depth, absolute):
72         self._stats['leaf_nodes'] += 1
73
74         if winner == Miscellaneous.DRAW:
75             self._stats['draws'] += 1
76             return 0, None
77         elif winner == Colour.BLUE or absolute:
78             self._stats['mates'] += 1
79             return Score.CHECKMATE + depth, None
80         elif winner == Colour.RED:
81             self._stats['mates'] += 1
82             return -Score.CHECKMATE - depth, None
83
84     def __str__(self):
85         return self.__class__.__name__

```

### B.18.2 cpu\_thread.py

See Section 3.6.6.

### B.18.3 evaluator.py

See Section 3.6.5.

### B.18.4 move\_orderer.py

```

1 from data.states.game.cpu.evaluator import Evaluator
2

```

```

3  class SimpleEvaluator:
4      def __init__(self):
5          self._evaluator = Evaluator(verbose=False)
6          self._cache = {}
7
8      def evaluate(self, board):
9          if (hashed := board.to_hash()) in self._cache:
10              return self._cache[hashed]
11
12          score = self._evaluator.evaluate_material(board, board.get_active_colour())
13      )
14          self._cache[hashed] = score
15
16      return score
17
18  class MoveOrderer:
19      def __init__(self):
20          self._evaluator = SimpleEvaluator()
21
22      # def get_eval(self, board, move):
23      #     laser_result = board.apply_move(move)
24      #     score = self._evaluator.evaluate(board)
25      #     board.undo_move(move, laser_result)
26      #     return score
27
28      # def score_moves(self, board, moves):
29      #     for i in range(len(moves)):
30      #         score = self.get_eval(board, moves[i])
31      #         moves[i] = (moves[i], score)
32
33      #     return moves
34
35      def best_move_to_front(self, moves, start_idx, laser_coords):
36          for i in range(start_idx + 1, len(moves)):
37              if moves[i].src in laser_coords:
38                  moves[i], moves[start_idx] = moves[start_idx], moves[i]
39          return
40
41      def get_moves(self, board, hint=None, laser_coords=None):
42          if hint:
43              yield hint
44
45          colour = board.get_active_colour()
46          moves = list(board.generate_all_moves(colour))
47
48          for i in range(len(moves)):
49              if laser_coords:
50                  self.best_move_to_front(moves, i, laser_coords)
51
52          yield moves[i]

```

### B.18.5 temp.py

```

1  from data.utils.constants import Score, Colour
2  from data.states.game.cpu.base import BaseCPU
3  from pprint import pprint
4
5  class MinimaxCPU(BaseCPU):
6      def __init__(self, max_depth, callback, verbose):
7          super().__init__(callback, verbose)
8          self._max_depth = max_depth
9

```

```

10     def find_move(self, board, stop_event):
11         # No bit_length bug as None type returned, so Move __str__ called on
12         # NoneType I think (just deal with None being returned)
13         try:
14             best_move = self.search(board, self._max_depth, -Score.INFINITE, Score
15             .INFINITE, stop_event)
16
17             if self._verbose:
18                 print('\nCPU Search Results:')
19                 pprint(self._stats)
20                 print('Best move:', best_move, '\n')
21
22             self._callback(self._best_move)
23         except Exception as error:
24             print('(MinimaxBase.find_move) Error has occurred: ')
25             raise error
26
27     def search(self, board, depth, alpha, beta, stop_event):
28         if stop_event.is_set():
29             raise Exception('Thread killed - stopping minimax function (CPU.
30                         minimax)')
31
32         # cached_move, cached_score = self._transposition_table.get_entry(hash_key
33         # =board.bitboards.get_hash(), depth=depth, alpha=alpha, beta=beta)
34         # if cached_move or cached_score:
35         #     if depth == self._max_depth:
36         #         self._best_move = cached_move
37         #     return cached_score
38
39         if depth == 0:
40             return self.evaluate(board)
41
42         if is_maximiser:
43             score = -Score.INFINITE
44
45             for move in board.generate_all_moves(board.get_active_colour()):
46                 before, before_score = board.bitboards.get_rotation_string(), self
47                 .evaluate(board)
48
49                 laser_result = board.apply_move(move)
50                 new_score = self.minimax(board, depth - 1, alpha, beta, False,
51                 stop_event)
52
53                 if new_score >= score:
54                     score = new_score
55
56                     board.undo_move(move, laser_result)
57
58                     alpha = max(alpha, score)
59                     if depth == self._max_depth: # https://stackoverflow.com/questions
60                     /31429974/alphabeta-pruning-alpha-equals-or-greater-than-beta-why-equals
61                     if beta < alpha:
62                         break
63                     else:
64                         if beta <= alpha:
65                             break

```

```

65
66         after, after_score = board.bitboards.get_rotation_string(), self.
67     evaluate(board)
68     if (before != after or before_score != after_score):
69         print('shit\n\n')
70
71     return score
72
73 else:
74     score = Score.INFINITE
75
76 for move in board.generate_all_moves(board.get_active_colour()):
77     bef, before_score = board.bitboards.get_rotation_string(), self.
78     evaluate(board)
79
80     laser_result = board.apply_move(move)
81     new_score = self.minimax(board, depth - 1, alpha, beta, False,
82     stop_event)
83
84     if new_score <= score:
85         score = new_score
86         if depth == self._max_depth:
87             self._best_move = move
88
89         board.undo_move(move, laser_result)
90
91         beta = min(beta, score)
92         if depth == self._max_depth:
93             if beta < alpha:
94                 break
95
96         after, after_score = board.bitboards.get_rotation_string(), self.
97     evaluate(board)
98     if (bef != after or before_score != after_score):
99         print('shit\n\n')
100        raise ValueError
101
102 return score

```

### B.18.6 transposition\_table.py

See Section 3.6.8.

### B.18.7 zobrist\_hasher.py

See Section 3.6.7.

## B.19 data\states\game\cpu\engines

### B.19.1 alpha\_beta.py

See Section 3.6.2.

## B.19.2 iterative\_deepening.py

See Section 3.6.4.

### B.19.3 minimax.py

See Section 3.6.1.

## B.19.4 negamax.py

```
1 from random import choice
2 from data.states.game.cpu.engines.transposition_table import
    TranspositionTableMixin
3 from data.states.game.cpu.engines.iterative_deepening import
    IterativeDeepeningMixin
4 from data.states.game.cpu.base import BaseCPU
5 from data.utils.enums import Score
6
7 class NegamaxCPU(BaseCPU):
8     def __init__(self, max_depth, callback, verbose=False):
9         super().__init__(callback, verbose)
10        self._max_depth = max_depth
11
12    def find_move(self, board, stop_event):
13        self.initialise_stats()
14        best_score, best_move = self.search(board, self._max_depth, stop_event)
15
16        if self._verbose:
17            self.print_stats(best_score, best_move)
18
19        self._callback(best_move)
20
21    def search(self, board, depth, stop_event, moves=None):
22        if (base_case := super().search(board, depth, stop_event, absolute=True)):
23            return base_case
24
25        best_move = None
26        best_score = -Score.INFINITE
27
28        for move in board.generate_all_moves(board.get_active_colour()):
29            laser_result = board.apply_move(move)
30
31            new_score = self.search(board, depth - 1, stop_event)[0]
32            new_score = -new_score
33
34            if new_score > best_score:
35                best_score = new_score
36                best_move = move
37            elif new_score == best_score:
38                best_move = choice([best_move, move])
39
40            board.undo_move(move, laser_result)
41
42        return best_score, best_move
43
44 class ABNegamaxCPU(BaseCPU):
45     def __init__(self, max_depth, callback, verbose=True):
46         super().__init__(callback, verbose)
47         self._max_depth = max_depth
```

```

49     def initialise_stats(self):
50         """Initialises the statistics for the search."""
51         super().initialise_stats()
52         self._stats['beta_prunes'] = 0
53
54     def find_move(self, board, stop_event):
55         """Finds the best move for the current board state.
56
57         Args:
58             board (Board): The current board state.
59             stop_event (threading.Event): The event to signal stopping the search.
60
61         """
62         self.initialise_stats()
63         best_score, best_move = self.search(board, self._max_depth, -Score.INFINITE, Score.INFINITE, stop_event)
64
65         if self._verbose:
66             self.print_stats(best_score, best_move)
67
68         self._callback(best_move)
69
70     def search(self, board, depth, alpha, beta, stop_event):
71         """Searches for the best move using the Alpha-Beta Negamax algorithm.
72
73         Args:
74             board (Board): The current board state.
75             depth (int): The current depth in the game tree.
76             alpha (int): The alpha value for pruning.
77             beta (int): The beta value for pruning.
78             stop_event (threading.Event): The event to signal stopping the search.
79
80         Returns:
81             tuple: The best score and the best move found.
82
83         """
84         if (base_case := super().search(board, depth, stop_event, absolute=True)):
85             return base_case
86
87         best_move = None
88         best_score = alpha
89
90         for move in board.generate_all_moves(board.get_active_colour()):
91             laser_result = board.apply_move(move)
92
93             new_score = self.search(board, depth - 1, -beta, -best_score,
94             stop_event)[0]
95             new_score = -new_score
96
97             if new_score > best_score:
98                 best_score = new_score
99                 best_move = move
100            elif new_score == best_score:
101                best_move = choice([best_move, move])
102
103            board.undo_move(move, laser_result)
104
105            if best_score >= beta:
106                self._stats['beta_prunes'] += 1
107                break
108
109        return best_score, best_move
110
111
112 class TTNegamaxCPU(TranspositionTableMixin, ABNegamaxCPU):

```

```

109     def initialise_stats(self):
110         """Initialises the statistics for the search."""
111         super().initialise_stats()
112         self._stats['cache_hits'] = 0
113
114     def print_stats(self, score, move):
115         """Prints the statistics for the search.
116
117         Args:
118             score (int): The best score found.
119             move (Move): The best move found.
120
121             self._stats['cache_hits_percentage'] = round(self._stats['cache_hits']) /
122             self._stats['nodes'], 3)
123             self._stats['cache_entries'] = len(self._table._table)
124             super().print_stats(score, move)
125
126 class IDNegamaxCPU(TranspositionTableMixin, IterativeDeepeningMixin, ABNegamaxCPU):
127     :
128     def initialise_stats(self):
129         """Initialises the statistics for the search."""
130         super().initialise_stats()
131         self._stats['cache_hits'] = 0
132
133     def print_stats(self, score, move):
134         """Prints the statistics for the search.
135
136         Args:
137             score (int): The best score found.
138             move (Move): The best move found.
139
140             self._stats['cache_hits_percentage'] = self._stats['cache_hits'] / self.
141             _stats['nodes']
142             self._stats['cache_entries'] = len(self._table._table)
143             super().print_stats(score, move)

```

### B.19.5 simple.py

```

1 from data.states.game.cpu.base import BaseCPU
2 from data.utils.enums import Colour, Score
3
4 class SimpleCPU(BaseCPU):
5     def __init__(self, callback, verbose=True):
6         super().__init__(callback, verbose)
7
8     def find_move(self, board, stop_event=None):
9         self.initialise_stats()
10        best_score, best_move = self.search(board, stop_event)
11
12        if self._verbose:
13            self.print_stats(best_score, best_move)
14
15        self._callback(best_move)
16
17    def search(self, board, stop_event):
18        if stop_event and stop_event.is_set():
19            raise Exception('Thread killed - stopping simple function (SimpleCPU.
20            search)')
21
22        active_colour = board.bitboards.active_colour
23        best_score = -Score.INFINITE if active_colour == Colour.BLUE else Score.
24        INFINITE

```

```

23         best_move = None
24
25     for move in board.generate_all_moves(active_colour):
26         laser_result = board.apply_move(move)
27
28         self._stats['nodes'] += 1
29
30         if winner := board.check_win() is not None:
31             self.process_win(winner)
32         else:
33             self._stats['leaf_nodes'] += 1
34
35         score = self._evaluator.evaluate(board)
36
37         if (active_colour == Colour.BLUE and score > best_score) or (
38             active_colour == Colour.RED and score < best_score):
39             best_move = move
40             best_score = score
41
42         board.undo_move(move, laser_result)
43
44     return best_score, best_move

```

### B.19.6 transposition\_table.py

See Section 3.6.3.

### B.19.7 \_\_init\_\_.py

```

1 from data.states.game.cpu.engines.simple import SimpleCPU
2 from data.states.game.cpu.engines.negamax import NegamaxCPU
3 from data.states.game.cpu.engines.minimax import MinimaxCPU
4 from data.states.game.cpu.engines.alpha_beta import ABMinimaxCPU
5 from data.states.game.cpu.engines.iterative_deepening import IDMMinimaxCPU
6 from data.states.game.cpu.engines.transposition_table import TTMinimaxCPU

```

## B.20 data\states\game\mvc

### B.20.1 game\_controller.py

See Section 3.5.3.

### B.20.2 game\_model.py

See Section 3.5.1.

### B.20.3 game\_view.py

See Section 3.5.2.

### B.20.4 pause\_view.py

```

1 import pygame
2 from data.states.game.widget_dict import PAUSE_WIDGETS
3 from data.components.widget_group import WidgetGroup
4 from data.utils.event_types import GameEventType

```

```

5  from data.utils.constants import PAUSE_COLOUR
6  from data.managers.window import window
7  from data.managers.audio import audio
8
9  class PauseView:
10     def __init__(self, model):
11         self._model = model
12
13         self._screen_overlay = pygame.Surface(window.size, pygame.SRCALPHA)
14         self._screen_overlay.fill(PAUSE_COLOUR)
15
16         self._widget_group = WidgetGroup(PAUSE_WIDGETS)
17         self._widget_group.handle_resize(window.size)
18
19         self._model.register_listener(self.process_model_event, 'pause')
20
21         self._event_to_func_map = {
22             GameEventType.PAUSE_CLICK: self.handle_pause_click
23         }
24
25         self.states = {
26             'PAUSED': False
27         }
28
29     def handle_pause_click(self, event):
30         self.states['PAUSED'] = not self.states['PAUSED']
31
32         if self.states['PAUSED']:
33             audio.pause_sfx()
34         else:
35             audio.unpause_sfx()
36
37     def handle_resize(self):
38         self._screen_overlay = pygame.Surface(window.size, pygame.SRCALPHA)
39         self._screen_overlay.fill(PAUSE_COLOUR)
40         self._widget_group.handle_resize(window.size)
41
42     def draw(self):
43         if self.states['PAUSED']:
44             window.screen.blit(self._screen_overlay, (0, 0))
45             self._widget_group.draw()
46
47     def process_model_event(self, event):
48         try:
49             self._event_to_func_map.get(event.type)(event)
50         except:
51             raise KeyError('Event type not recognized in Paused View (PauseView.\nprocess_model_event)', event)
52
53     def convert_mouse_pos(self, event):
54         return self._widget_group.process_event(event)

```

### B.20.5 win\_view.py

```

1  from data.utils.enums import Colour, Miscellaneous, CursorMode
2  from data.components.widget_group import WidgetGroup
3  from data.states.game.widget_dict import WIN_WIDGETS
4  from data.managers.window import window
5  from data.managers.cursor import cursor
6
7  class WinView:
8      def __init__(self, model):

```

```

9         self._model = model
10
11     self._widget_group = WidgetGroup(WIN_WIDGETS)
12     self._widget_group.handle_resize(window.size)
13
14     def handle_resize(self):
15         self._widget_group.handle_resize(window.size)
16
17     def draw(self):
18         if self._model.states['WINNER'] is not None:
19             if cursor.get_mode() != CursorMode.ARROW:
20                 cursor.set_mode(CursorMode.ARROW)
21
22         if self._model.states['WINNER'] == Colour.BLUE:
23             WIN_WIDGETS['red_won'].kill()
24             WIN_WIDGETS['draw_won'].kill()
25         elif self._model.states['WINNER'] == Colour.RED:
26             WIN_WIDGETS['blue_won'].kill()
27             WIN_WIDGETS['draw_won'].kill()
28         elif self._model.states['WINNER'] == Miscellaneous.DRAW:
29             WIN_WIDGETS['red_won'].kill()
30             WIN_WIDGETS['blue_won'].kill()
31
32         self._widget_group.draw()
33
34     def set_win_type(self, win_type):
35         WIN_WIDGETS['by_draw'].kill()
36         WIN_WIDGETS['by_timeout'].kill()
37         WIN_WIDGETS['by_resignation'].kill()
38         WIN_WIDGETS['by_checkmate'].kill()
39
40         match win_type:
41             case 'CAPTURE':
42                 self._widget_group.add(WIN_WIDGETS['by_checkmate'])
43             case 'DRAW':
44                 self._widget_group.add(WIN_WIDGETS['by_draw'])
45             case 'RESIGN':
46                 self._widget_group.add(WIN_WIDGETS['by_resignation'])
47             case 'TIME':
48                 self._widget_group.add(WIN_WIDGETS['by_timeout'])
49
50     def convert_mouse_pos(self, event):
51         return self._widget_group.process_event(event)

```

## B.21 data\states\menu

### B.21.1 menu.py

```

1 import pygame
2 import sys
3 from random import randint
4 from data.helpers.asset_helpers import get_rotational_angle
5 from data.helpers.asset_helpers import scale_and_cache
6 from data.states.menu.widget_dict import MENU_WIDGETS
7 from data.utils.assets import GRAPHICS, MUSIC, SFX
8 from data.managers.logs import initialise_logger
9 from data.utils.event_types import MenuEventType
10 from data.managers.animation import animation
11 from data.utils.constants import ShaderType
12 from data.managers.window import window
13 from data.managers.audio import audio

```

```

14 from data.control import _State
15
16 logger = initialise_logger(__file__)
17
18 class Menu(_State):
19     def __init__(self):
20         super().__init__()
21         self._fire_laser = False
22         self._bloom_mask = None
23         self._laser_mask = None
24
25     def cleanup(self):
26         super().cleanup()
27
28         window.clear_apply_arguments(ShaderType.BLOOM)
29         window.clear_apply_arguments(ShaderType.SHAKE)
30         window.clear_effect(ShaderType.CHROMATIC_ABBREVIATION)
31
32         return None
33
34     def startup(self, persist=None):
35         super().startup(MENU_WIDGETS, music=MUSIC[f'menu_{randint(1, 3)}'])
36         window.set_apply_arguments(ShaderType.BASE, background_type=ShaderType.
37 BACKGROUND_BALATRO)
38         window.set_effect(ShaderType.CHROMATIC_ABBREVIATION)
39
40         MENU_WIDGETS['credits'].kill()
41
42         self._fire_laser = False
43         self._bloom_mask = None
44         self._laser_mask = None
45
46         self.draw()
47         self.update_masks()
48
49     @property
50     def sphinx_center(self):
51         return (window.size[0] - self.sphinx_size[0] / 2, window.size[1] - self.
52 sphinx_size[1] / 2)
53
54     @property
55     def sphinx_size(self):
56         return (min(window.size) * 0.1, min(window.size) * 0.1)
57
58     @property
59     def sphinx_rotation(self):
60         mouse_pos = (pygame.mouse.get_pos()[0], pygame.mouse.get_pos()[1] + 0.01)
61         return -get_rotational_angle(mouse_pos, self.sphinx_center)
62
63     def get_event(self, event):
64         if event.type in [pygame.MOUSEBUTTONDOWN, pygame.KEYDOWN]:
65             MENU_WIDGETS['credits'].kill()
66
67             if event.type == pygame.MOUSEBUTTONDOWN:
68                 self._fire_laser = True
69                 audio.play_sfx(SFX['menu_laser_windup'])
70                 audio.play_sfx(SFX['menu_laser_loop'], loop=True)
71                 animation.set_timer(SFX['menu_laser_loop'].get_length() * 1000 / 2,
72 lambda: audio.play_sfx(SFX['menu_laser_loop'], loop=True) if self._fire_laser
73 else ...) # Overlap two loops of sfx to hide transition
74
75         elif event.type == pygame.MOUSEBUTTONUP:

```

```

72         self._fire_laser = False
73
74     window.clear_effect(ShaderType.RAYS)
75     animation.set_timer(300, lambda: window.clear_effect(ShaderType.SHAKE))
76
77     audio.stop_sfx(1000)
78
79     widget_event = self._widget_group.process_event(event)
80
81     if widget_event is None:
82         return
83
84     match widget_event.type:
85         case None:
86             return
87
88         case MenuEventType.CONFIG_CLICK:
89             self.next = 'config'
90             self.done = True
91
92         case MenuEventType.SETTINGS_CLICK:
93             self.next = 'settings'
94             self.done = True
95
96         case MenuEventType.BROWSER_CLICK:
97             self.next = 'browser'
98             self.done = True
99
100        case MenuEventType.QUIT_CLICK:
101            pygame.quit()
102            sys.exit()
103            logger.info('quitting...')
104
105        case MenuEventType.CREDITS_CLICK:
106            self._widget_group.add(MENU_WIDGETS['credits'])
107
108    def draw_sphinx(self):
109        sphinx_surface = scale_and_cache(GRAPHICS['sphinx_0_b'], self.sphinx_size)
110        sphinx_surface = pygame.transform.rotate(sphinx_surface, self.sphinx_rotation)
111        sphinx_rect = pygame.FRect(0, 0, *self.sphinx_size)
112        sphinx_rect.center = self.sphinx_center
113
114        window.screen.blit(sphinx_surface, sphinx_rect)
115
116    def update_masks(self):
117        self.draw()
118
119        widget_mask = window.screen.copy()
120        laser_mask = pygame.mask.from_surface(widget_mask)
121        laser_mask = laser_mask.to_surface(setcolor=(255, 0, 0, 255), unsetcolor=(0, 0, 0, 255))
122        pygame.draw.rect(laser_mask, (0, 0, 0), (window.screen.width - self.sphinx_size[0], window.screen.height - self.sphinx_size[1], *self.sphinx_size))
123
124        pygame.draw.rect(widget_mask, (0, 0, 0, 255), (window.screen.width - 50, 0, 50, 50))
125
126        self._bloom_mask = widget_mask
127        self._laser_mask = laser_mask
128
129    def draw(self):
130        self._widget_group.draw()
131        self.draw_sphinx()
132
133        if self._fire_laser:

```

```

128         window.set_apply_arguments(ShaderType.RAYS, occlusion=self._laser_mask
129         , softShadow=0.1)
130
130         window.set_apply_arguments(ShaderType.BLOOM, highlight_surface=self.
131         _bloom_mask, surface_intensity=0.3, brightness_intensity=0.6)
132
132     def update(self, **kwargs):
133         random_offset = lambda: randint(-5, 5) / 40
134         if self._fire_laser:
135             window.clear_effect(ShaderType.RAYS)
136             window.set_effect(ShaderType.RAYS, lights=[[[
137                 (self.sphinx_center[0] / window.size[0], self.sphinx_center[1] /
window.size[1]),
138                 2.2,
139                 (190, 190, 255),
140                 0.99,
141                 (self.sphinx_rotation - 2 + random_offset(), self.sphinx_rotation
+ 2 + random_offset())
142                 ]])
143
144             window.set_effect(ShaderType.SHAKE)
145             window.set_apply_arguments(ShaderType.SHAKE, intensity=1)
146             pygame.mouse.set_pos(pygame.mouse.get_pos()[0] + random_offset(),
pygame.mouse.get_pos()[1] + random_offset())
147
148         super().update(**kwargs)
149
150     def handle_resize(self):
151         super().handle_resize()
152         self.update_masks()

```

## B.21.2 widget\_dict.py

```

1 from data.components.custom_event import CustomEvent
2 from data.utils.event_types import MenuEventType
3 from data.utils.assets import GRAPHICS
4 from data.managers.theme import theme
5 from data.widgets import *
6
7 top_right_container = Rectangle(
8     relative_position=(0, 0),
9     relative_size=(0.15, 0.075),
10    fixed_position=(5, 5),
11    anchor_x='right',
12    scale_mode='height'
13 )
14
15 MENU_WIDGETS = {
16     'credits':
17     Icon(
18         relative_position=(0, 0),
19         relative_size=(0.7, 0.7),
20         icon=GRAPHICS['credits'],
21         anchor_x='center',
22         anchor_y='center',
23         margin=50
24     ),
25     'default': [
26         top_right_container,
27         Rectangle(
28             relative_position=(0.65, 0.15),
29             relative_size=(0.15, 0.15),

```

```

30         scale_mode='height',
31         border_width=0,
32         border_radius=50,
33         fill_colour=theme['fillSecondary'],
34         visible=True
35     ),
36     Rectangle(
37         relative_position=(0.8, 0.1),
38         relative_size=(0.10, 0.10),
39         scale_mode='height',
40         border_width=0,
41         border_radius=100,
42         fill_colour=theme['fillSecondary'],
43         visible=True
44     ),
45     Rectangle(
46         relative_position=(0.5, 0.1),
47         relative_size=(0.20, 0.20),
48         scale_mode='height',
49         border_width=0,
50         border_radius=10,
51         fill_colour=theme['fillSecondary'],
52         visible=True
53     ),
54     Rectangle(
55         relative_position=(0.9, 0.2),
56         relative_size=(0.15, 0.15),
57         scale_mode='height',
58         border_width=0,
59         border_radius=20,
60         fill_colour=theme['fillSecondary'],
61         visible=True
62     ),
63     Rectangle(
64         relative_position=(0.85, 0.4),
65         relative_size=(0.20, 0.20),
66         scale_mode='height',
67         border_width=0,
68         border_radius=30,
69         fill_colour=theme['fillSecondary'],
70         visible=True
71     ),
72     Rectangle(
73         relative_position=(0.7, 0.4),
74         relative_size=(0.10, 0.10),
75         scale_mode='height',
76         border_width=0,
77         border_radius=50,
78         fill_colour=theme['fillSecondary'],
79         visible=True
80     ),
81     ReactiveIconButton(
82         parent=top_right_container,
83         relative_position=(0, 0),
84         relative_size=(1, 1),
85         anchor_x='right',
86         scale_mode='height',
87         base_icon=GRAPHICS['quit_base'],
88         hover_icon=GRAPHICS['quit_hover'],
89         press_icon=GRAPHICS['quit_press'],
90         event=CustomEvent(MenuEventType.QUIT_CLICK)
91     ),

```

```

92     ReactiveIconButton(
93         parent=top_right_container,
94         relative_position=(0, 0),
95         relative_size=(1, 1),
96         scale_mode='height',
97         base_icon=GRAPHICS['credits_base'],
98         hover_icon=GRAPHICS['credits_hover'],
99         press_icon=GRAPHICS['credits_press'],
100        event=CustomEvent(MenuEventType.CREDITS_CLICK)
101    ),
102    ReactiveIconButton(
103        relative_position=(0.05, -0.2),
104        relative_size=(0, 0.15),
105        anchor_y='center',
106        base_icon=GRAPHICS['play_text_base'],
107        hover_icon=GRAPHICS['play_text_hover'],
108        press_icon=GRAPHICS['play_text_press'],
109        event=CustomEvent(MenuEventType.CONFIG_CLICK)
110    ),
111    ReactiveIconButton(
112        relative_position=(0.05, 0),
113        relative_size=(0, 0.15),
114        anchor_y='center',
115        base_icon=GRAPHICS['review_text_base'],
116        hover_icon=GRAPHICS['review_text_hover'],
117        press_icon=GRAPHICS['review_text_press'],
118        event=CustomEvent(MenuEventType.BROWSER_CLICK)
119    ),
120    ReactiveIconButton(
121        relative_position=(0.05, 0.2),
122        relative_size=(0, 0.15),
123        anchor_y='center',
124        base_icon=GRAPHICS['settings_text_base'],
125        hover_icon=GRAPHICS['settings_text_hover'],
126        press_icon=GRAPHICS['settings_text_press'],
127        event=CustomEvent(MenuEventType.SETTINGS_CLICK)
128    ),
129    # Icon(
130    #     relative_position=(0.0, 0.1),
131    #     relative_size=(0.3, 0.2),
132    #     anchor_x='center',
133    #     fill_colour=theme['fillSecondary'],
134    #     icon=GRAPHICS['title_screen_art'],
135    #     stretch=False
136    # ),
137 ]
138 }
139
140 # Widgets used for testing light rays effect
141 TEST_WIDGETS = {
142     'default': [
143         Rectangle(
144             relative_position=(0.4, 0.2),
145             relative_size=(0.1, 0.1),
146             scale_mode='height',
147             visible=True,
148             border_width=0,
149             fill_colour=(255, 0, 0),
150             border_radius=1000
151         ),
152         Rectangle(
153             relative_position=(0.5, 0.7),

```

```

154         relative_size=(0.1, 0.1),
155         scale_mode='height',
156         visible=True,
157         border_width=0,
158         fill_colour=(255, 0, 0),
159         border_radius=1000
160     ),
161     Rectangle(
162         relative_position=(0.6, 0.6),
163         relative_size=(0.2, 0.2),
164         scale_mode='height',
165         visible=True,
166         border_width=0,
167         fill_colour=(255, 0, 0),
168         border_radius=1000
169     ),
170     Rectangle(
171         relative_position=(0.4, 0.6),
172         relative_size=(0.1, 0.1),
173         scale_mode='height',
174         visible=True,
175         border_width=0,
176         fill_colour=(255, 0, 0),
177         border_radius=1000
178     ),
179     Rectangle(
180         relative_position=(0.6, 0.4),
181         relative_size=(0.1, 0.1),
182         scale_mode='height',
183         visible=True,
184         border_width=0,
185         fill_colour=(255, 0, 0),
186         border_radius=1000
187     ),
188     Rectangle(
189         relative_position=(0.3, 0.4),
190         relative_size=(0.1, 0.1),
191         scale_mode='height',
192         visible=True,
193         border_width=0,
194         fill_colour=(255, 0, 0),
195         border_radius=1000
196     ),
197     Rectangle(
198         relative_position=(0.475, 0.15),
199         relative_size=(0.2, 0.2),
200         scale_mode='height',
201         visible=True,
202         border_width=0,
203         fill_colour=(255, 0, 0),
204         border_radius=1000
205     ),
206     Rectangle(
207         relative_position=(0.6, 0.2),
208         relative_size=(0.1, 0.1),
209         scale_mode='height',
210         visible=True,
211         border_width=0,
212         fill_colour=(255, 0, 0),
213         border_radius=1000
214     )
215 ]

```

216 }

## B.22 data\states\review

### B.22.1 review.py

See Section 3.7.1.

### B.22.2 widget\_dict.py

```

1  from data.widgets import *
2  from data.components.custom_event import CustomEvent
3  from data.utils.event_types import ReviewEventType
4  from data.utils.assets import GRAPHICS
5  from data.utils.enums import Colour
6
7  MOVE_LIST_WIDTH = 0.2
8
9  right_container = Rectangle(
10     relative_position=(0.05, 0),
11     relative_size=(0.2, 0.7),
12     anchor_y='center',
13     anchor_x='right'
14 )
15
16 info_container = Rectangle(
17     parent=right_container,
18     relative_position=(0, 0.5),
19     relative_size=(1, 0.5),
20     visible=True
21 )
22
23 arrow_container = Rectangle(
24     relative_position=(0, 0.05),
25     relative_size=(0.4, 0.1),
26     anchor_x='center',
27     anchor_y='bottom'
28 )
29
30 move_list = MoveList(
31     parent=right_container,
32     relative_position=(0, 0),
33     relative_width=1,
34     minimum_height=300,
35     move_list=[]
36 )
37
38 top_right_container = Rectangle(
39     relative_position=(0, 0),
40     relative_size=(0.15, 0.075),
41     fixed_position=(5, 5),
42     anchor_x='right',
43     scale_mode='height'
44 )
45
46 REVIEW_WIDGETS = {
47     'help':
48     Icon(
49         relative_position=(0, 0),
50         relative_size=(1.02, 1.02),

```

```

51         icon=GRAPHICS['review_help'],
52         anchor_x='center',
53         anchor_y='center',
54         border_width=0,
55         fill_colour=(0, 0, 0, 0)
56     ),
57     'default': [
58         arrow_container,
59         right_container,
60         info_container,
61         top_right_container,
62         ReactiveIconButton(
63             parent=top_right_container,
64             relative_position=(0, 0),
65             relative_size=(1, 1),
66             anchor_x='right',
67             scale_mode='height',
68             base_icon=GRAPHICS['home_base'],
69             hover_icon=GRAPHICS['home_hover'],
70             press_icon=GRAPHICS['home_press'],
71             event=CustomEvent(ReviewEventType.MENU_CLICK)
72         ),
73         ReactiveIconButton(
74             parent=top_right_container,
75             relative_position=(0, 0),
76             relative_size=(1, 1),
77             scale_mode='height',
78             base_icon=GRAPHICS['help_base'],
79             hover_icon=GRAPHICS['help_hover'],
80             press_icon=GRAPHICS['help_press'],
81             event=CustomEvent(ReviewEventType.HELP_CLICK)
82         ),
83         ReactiveIconButton(
84             parent=arrow_container,
85             relative_position=(0, 0),
86             relative_size=(1, 1),
87             scale_mode='height',
88             base_icon=GRAPHICS['left_arrow_filled_base'],
89             hover_icon=GRAPHICS['left_arrow_filled_hover'],
90             press_icon=GRAPHICS['left_arrow_filled_press'],
91             event=CustomEvent(ReviewEventType.PREVIOUS_CLICK)
92         ),
93         ReactiveIconButton(
94             parent=arrow_container,
95             relative_position=(0, 0),
96             relative_size=(1, 1),
97             scale_mode='height',
98             anchor_x='right',
99             base_icon=GRAPHICS['right_arrow_filled_base'],
100            hover_icon=GRAPHICS['right_arrow_filled_hover'],
101            press_icon=GRAPHICS['right_arrow_filled_press'],
102            event=CustomEvent(ReviewEventType.NEXT_CLICK)
103        ),
104    ],
105    'move_list':
106        move_list,
107    'scroll_area':
108        ScrollArea(
109            parent=right_container,
110            relative_position=(0, 0),
111            relative_size=(1, 0.5),
112            vertical=True,

```

```

113     widget=move_list
114 ),
115 'chessboard':
116 Chessboard(
117     relative_position=(0, 0),
118     relative_width=0.4,
119     scale_mode='width',
120     anchor_x='center',
121     anchor_y='center'
122 ),
123 'move_number_text':
124 Text(
125     parent=info_container,
126     relative_position=(0, 0),
127     relative_size=(1, 0.3),
128     anchor_y='bottom',
129     text='MOVE NO:',
130     fit_vertical=False,
131     margin=10,
132     border_width=0,
133     fill_colour=(0, 0, 0, 0),
134 ),
135 'move_colour_text':
136 Text(
137     parent=info_container,
138     relative_size=(1, 0.3),
139     relative_position=(0, 0),
140     anchor_y='center',
141     text='TO MOVE',
142     fit_vertical=False,
143     margin=10,
144     border_width=0,
145     fill_colour=(0, 0, 0, 0),
146 ),
147 'winner_text':
148 Text(
149     parent=info_container,
150     relative_size=(1, 0.3),
151     relative_position=(0, 0),
152     text='WINNER:',
153     fit_vertical=False,
154     margin=10,
155     border_width=0,
156     fill_colour=(0, 0, 0, 0),
157 ),
158 'blue_timer':
159 Timer(
160     relative_position=(0.05, 0.05),
161     anchor_y='center',
162     relative_size=(0.1, 0.1),
163     active_colour=Colour.BLUE,
164 ),
165 'red_timer':
166 Timer(
167     relative_position=(0.05, -0.05),
168     anchor_y='center',
169     relative_size=(0.1, 0.1),
170     active_colour=Colour.RED
171 ),
172 'timer_disabled_text':
173 Text(
174     relative_size=(0.2, 0.1),

```

```

175         relative_position=(0.05, 0),
176         anchor_y='center',
177         fit_vertical=False,
178         text='TIMER DISABLED',
179     ),
180     'blue_piece_display':
181     PieceDisplay(
182         relative_position=(0.05, 0.05),
183         relative_size=(0.2, 0.1),
184         anchor_y='bottom',
185         active_colour=Colour.BLUE
186     ),
187     'red_piece_display':
188     PieceDisplay(
189         relative_position=(0.05, 0.05),
190         relative_size=(0.2, 0.1),
191         active_colour=Colour.RED
192     ),
193 }
```

## B.23 data\states\settings

### B.23.1 settings.py

```

1 import pygame
2 from random import randint
3 from data.helpers.data_helpers import get_default_settings, get_user_settings,
4     update_user_settings
5 from data.utils.constants import WidgetState, ShaderType, SHADER_MAP
6 from data.states.settings.widget_dict import SETTINGS_WIDGETS
7 from data.utils.event_types import SettingsEventType
8 from data.managers.logs import initialise_logger
9 from data.managers.window import window
10 from data.managers.audio import audio
11 from data.widgets import ColourPicker
12 from data.utils.assets import MUSIC
13 from data.control import _State
14 logger = initialise_logger(__name__)
15
16 class Settings(_State):
17     def __init__(self):
18         super().__init__()
19
20         self._colour_picker = None
21         self._settings = None
22
23     def cleanup(self):
24         super().cleanup()
25
26         update_user_settings(self._settings)
27
28     return None
29
30     def startup(self, persist=None):
31         super().startup(SETTINGS_WIDGETS, music=MUSIC[f'menu_{randint(1, 3)}'])
32
33         window.set_apply_arguments(ShaderType.BASE, background_type=ShaderType.
34             BACKGROUND_BALATRO)
35         self._settings = get_user_settings()
36         self.reload_settings()
```

```

36
37         self.draw()
38
39     def create_colour_picker(self, mouse_pos, button_type):
40         if button_type == SettingsEventType.PRIMARY_COLOUR_BUTTON_CLICK:
41             selected_colour = self._settings['primaryBoardColour']
42             event_type = SettingsEventType.PRIMARY_COLOUR_PICKER_CLICK
43         else:
44             selected_colour = self._settings['secondaryBoardColour']
45             event_type = SettingsEventType.SECONDARY_COLOUR_PICKER_CLICK
46
47         self._colour_picker = ColourPicker(
48             relative_position=(mouse_pos[0] / window.size[0], mouse_pos[1] /
49             window.size[1]),
50             relative_width=0.15,
51             selected_colour=selected_colour,
52             event_type=event_type
53         )
54         self._widget_group.add(self._colour_picker)
55
56     def remove_colour_picker(self):
57         self._colour_picker.kill()
58
59     def reload_display_mode(self):
60         relative_mouse_pos = (pygame.mouse.get_pos()[0] / window.size[0], pygame.
61         mouse.get_pos()[1] / window.size[1])
62
63         if self._settings['displayMode'] == 'fullscreen':
64             window.setFullscreen(desktop=True)
65             window.handle_resize()
66
67         elif self._settings['displayMode'] == 'windowed':
68             window.setWindowed()
69             window.handle_resize()
70             window.restore()
71
72         self._widget_group.handle_resize(window.size)
73
74         new_mouse_pos = (relative_mouse_pos[0] * window.size[0],
75         relative_mouse_pos[1] * window.size[1])
76         pygame.mouse.setPos(new_mouse_pos)
77
78     def reload_shaders(self):
79         window.clear_all_effects()
80
81     for shader_type in SHADER_MAP[self._settings['shader']]:
82         window.set_effect(shader_type)
83
84     def reload_settings(self):
85         SETTINGS_WIDGETS['primary_colour_button'].initialise_new_colours(self.
86         _settings['primaryBoardColour'])
87         SETTINGS_WIDGETS['secondary_colour_button'].initialise_new_colours(self.
88         _settings['secondaryBoardColour'])
89         SETTINGS_WIDGETS['primary_colour_button'].set_state_colour(WidgetState.
90         BASE)
91         SETTINGS_WIDGETS['secondary_colour_button'].set_state_colour(WidgetState.
92         BASE)
93         SETTINGS_WIDGETS['music_volume_slider'].set_volume(self._settings['
94         musicVolume'])
95         SETTINGS_WIDGETS['sfx_volume_slider'].set_volume(self._settings['sfxVolume
96         '])
97         SETTINGS_WIDGETS['display_mode_dropdown'].set_selected_word(self._settings
98

```

```

['displayMode'])
    SETTINGS_WIDGETS['shader_carousel'].set_to_key(self._settings['shader'])
    SETTINGS_WIDGETS['particles_switch'].set_toggle_state(self._settings['particles'])
    SETTINGS_WIDGETS['opengl_switch'].set_toggle_state(self._settings['opengl'])

)
)

self.reload_shaders()
self.reload_display_mode()

def get_event(self, event):
    widget_event = self._widget_group.process_event(event)

    if widget_event is None:
        if event.type == pygame.MOUSEBUTTONDOWN and self._colour_picker:
            self.remove_colour_picker()
        return

    match widget_event.type:
        case SettingsEventType.VOLUME_SLIDER_SLIDE:
            return

        case SettingsEventType.VOLUME_SLIDER_CLICK:
            if widget_event.volume_type == 'music':
                audio.set_music_volume(widget_event.volume)
                self._settings['musicVolume'] = widget_event.volume
            elif widget_event.volume_type == 'sfx':
                audio.set_sfx_volume(widget_event.volume)
                self._settings['sfxVolume'] = widget_event.volume

        case SettingsEventType.DROPDOWN_CLICK:
            selected_word = SETTINGS_WIDGETS['display_mode_dropdown'].get_selected_word()

            if selected_word is None or selected_word == self._settings['displayMode']:
                return

            self._settings['displayMode'] = selected_word

            self.reload_display_mode()

        case SettingsEventType.MENU_CLICK:
            self.next = 'menu'
            self.done = True

        case SettingsEventType.RESET_DEFAULT:
            self._settings = get_default_settings()
            self.reload_settings()

        case SettingsEventType.RESET_USER:
            self._settings = get_user_settings()
            self.reload_settings()

        case SettingsEventType.PRIMARY_COLOUR_BUTTON_CLICK | SettingsEventType.SECONDARY_COLOUR_BUTTON_CLICK:
            if self._colour_picker:
                self.remove_colour_picker()

            self.create_colour_picker(event.pos, widget_event.type)

        case SettingsEventType.PRIMARY_COLOUR_PICKER_CLICK | SettingsEventType.SECONDARY_COLOUR_PICKER_CLICK:
            if self._colour_picker:
                self.remove_colour_picker()

            self.create_colour_picker(event.pos, widget_event.type)

```

```

    .SECONDARY_COLOUR_PICKER_CLICK:
145        if widget_event.colour:
146            r, g, b = widget_event.colour.rgb
147            hex_colour = f'0x{hex(r)[2:]:zfill(2)}{hex(g)[2:]:zfill(2)}{hex(b)[2:]:zfill(2)}'
148
149        if widget_event.type == SettingsEventType.
150            SETTINGS_WIDGETS['primary_colour_button'].initialise_new_colours(widget_event.colour)
151            SETTINGS_WIDGETS['primary_colour_button'].set_state_colour(WidgetState.BASE)
152            self._settings['primaryBoardColour'] = hex_colour
153        elif widget_event.type == SettingsEventType.
154            SETTINGS_WIDGETS['secondary_colour_button'].initialise_new_colours(widget_event.colour)
155            SETTINGS_WIDGETS['secondary_colour_button'].set_state_colour(WidgetState.BASE)
156            self._settings['secondaryBoardColour'] = hex_colour
157
158        case SettingsEventType.SHADER_PICKER_CLICK:
159            self._settings['shader'] = widget_event.data
160            self.reload_shaders()
161
162        case SettingsEventType.OPENGL_CLICK:
163            self._settings['opengl'] = widget_event.toggled
164            self.reload_shaders()
165
166        case SettingsEventType.PARTICLES_CLICK:
167            self._settings['particles'] = widget_event.toggled
168
169    def draw(self):
170        self._widget_group.draw()

```

### B.23.2 widget\_dict.py

```

1 from data.widgets import *
2 from data.helpers.data_helpers import get_user_settings
3 from data.components.custom_event import CustomEvent
4 from data.utils.event_types import SettingsEventType
5 from data.utils.constants import SHADER_MAP
6 from data.utils.assets import GRAPHICS
7 from data.managers.theme import theme
8
9 user_settings = get_user_settings()
10 # font_size = text_width_to_font_size('Shaders (OPENGL GPU REQUIRED)', DEFAULT_FONT, 0.4 * window.screen.width)
11 FONT_SIZE = 21
12
13 carousel_widgets = {
14     key: Text(
15         relative_position=(0, 0),
16         relative_size=(0.25, 0.04),
17         margin=0,
18         text=key.replace('_', ' ').upper(),
19         fit_vertical=True,
20         border_width=0,
21         fill_colour=(0, 0, 0, 0),
22     ) for key in SHADER_MAP.keys()
23 }
24

```

```

25     reset_container = Rectangle(
26         relative_size=(0.2, 0.2),
27         relative_position=(0, 0),
28         fixed_position=(5, 5),
29         anchor_x='right',
30         anchor_y='bottom',
31     )
32
33 SETTINGS_WIDGETS = {
34     'default': [
35         reset_container,
36         ReactiveIconButton(
37             relative_position=(0, 0),
38             relative_size=(0.075, 0.075),
39             anchor_x='right',
40             scale_mode='height',
41             base_icon=GRAPHICS['home_base'],
42             hover_icon=GRAPHICS['home_hover'],
43             press_icon=GRAPHICS['home_press'],
44             fixed_position=(5, 5),
45             event=CustomEvent(SettingsEventType.MENU_CLICK)
46         ),
47         Text(
48             relative_position=(0.01, 0.1),
49             text='Display mode',
50             relative_size=(0.4, 0.04),
51             center=False,
52             border_width=0,
53             margin=0,
54             font_size=21,
55             fill_colour=(0, 0, 0, 0)
56         ),
57         Text(
58             relative_position=(0.01, 0.2),
59             text='Music',
60             relative_size=(0.4, 0.04),
61             center=False,
62             border_width=0,
63             margin=0,
64             font_size=21,
65             fill_colour=(0, 0, 0, 0)
66         ),
67         Text(
68             relative_position=(0.01, 0.3),
69             text='SFX',
70             relative_size=(0.4, 0.04),
71             center=False,
72             border_width=0,
73             margin=0,
74             font_size=21,
75             fill_colour=(0, 0, 0, 0)
76         ),
77         Text(
78             relative_position=(0.01, 0.4),
79             text='Primary board colour',
80             relative_size=(0.4, 0.04),
81             center=False,
82             border_width=0,
83             margin=0,
84             font_size=21,
85             fill_colour=(0, 0, 0, 0)
86         ),

```

```

87     Text(
88         relative_position=(0.01, 0.5),
89         text='Secondary board colour',
90         relative_size=(0.4, 0.04),
91         center=False,
92         border_width=0,
93         margin=0,
94         font_size=21,
95         fill_colour=(0, 0, 0, 0)
96     ),
97     Text(
98         relative_position=(0.01, 0.6),
99         text='Particles',
100        relative_size=(0.4, 0.04),
101        center=False,
102        border_width=0,
103        margin=0,
104        font_size=21,
105        fill_colour=(0, 0, 0, 0)
106    ),
107    Text(
108        relative_position=(0.01, 0.7),
109        text='Shaders (OPENGL GPU REQUIRED)',
110        relative_size=(0.4, 0.04),
111        center=False,
112        border_width=0,
113        margin=0,
114        font_size=21,
115        fill_colour=(0, 0, 0, 0)
116    ),
117    Text(
118        relative_position=(0.01, 0.8),
119        text='Super Secret Settings',
120        relative_size=(0.4, 0.04),
121        center=False,
122        border_width=0,
123        margin=0,
124        font_size=21,
125        fill_colour=(0, 0, 0, 0)
126    ),
127    TextButton(
128        parent=reset_container,
129        relative_position=(0, 0),
130        relative_size=(1, 0.5),
131        fit_vertical=False,
132        margin=10,
133        text='DISCARD CHANGES',
134        text_colour=theme['textSecondary'],
135        event=CustomEvent(SettingsEventType.RESET_USER)
136    ),
137    TextButton(
138        parent=reset_container,
139        relative_position=(0, 0.5),
140        relative_size=(1, 0.5),
141        fit_vertical=False,
142        margin=10,
143        text='RESET TO DEFAULT',
144        text_colour=theme['textSecondary'],
145        event=CustomEvent(SettingsEventType.RESET_DEFAULT)
146    )
147 ],
148 'display_mode_dropdown':

```

```

149     Dropdown(
150         relative_position=(0.4, 0.1),
151         relative_width=0.2,
152         word_list=['fullscreen', 'windowed'],
153         fill_colour=(255, 100, 100),
154         event=CustomEvent(SettingsEventType.DROPODOWN_CLICK)
155     ),
156     'primary_colour_button':
157     ColourButton(
158         relative_position=(0.4, 0.4),
159         relative_size=(0.08, 0.05),
160         fill_colour=user_settings['primaryBoardColour'],
161         border_width=5,
162         event=CustomEvent(SettingsEventType.PRIMARY_COLOUR_BUTTON_CLICK)
163     ),
164     'secondary_colour_button':
165     ColourButton(
166         relative_position=(0.4, 0.5),
167         relative_size=(0.08, 0.05),
168         fill_colour=user_settings['secondaryBoardColour'],
169         border_width=5,
170         event=CustomEvent(SettingsEventType.SECONDARY_COLOUR_BUTTON_CLICK)
171     ),
172     'music_volume_slider':
173     VolumeSlider(
174         relative_position=(0.4, 0.2),
175         relative_length=(0.5),
176         default_volume=user_settings['musicVolume'],
177         border_width=5,
178         volume_type='music'
179     ),
180     'sfx_volume_slider':
181     VolumeSlider(
182         relative_position=(0.4, 0.3),
183         relative_length=(0.5),
184         default_volume=user_settings['sfxVolume'],
185         border_width=5,
186         volume_type='sfx'
187     ),
188     'shader_carousel':
189     Carousel(
190         relative_position = (0.4, 0.8),
191         margin=5,
192         border_width=0,
193         fill_colour=(0, 0, 0, 0),
194         widgets_dict=carousel_widgets,
195         event=CustomEvent(SettingsEventType.SHADER_PICKER_CLICK),
196     ),
197     'particles_switch':
198     Switch(
199         relative_position=(0.4, 0.6),
200         relative_height=0.04,
201         event=CustomEvent(SettingsEventType.PARTICLES_CLICK)
202     ),
203     'opengl_switch':
204     Switch(
205         relative_position=(0.4, 0.7),
206         relative_height=0.04,
207         event=CustomEvent(SettingsEventType.OPENGL_CLICK)
208     ),
209 }
```

## B.24 data\utils

### B.24.1 assets.py

```
1 from pathlib import Path
2 from data.helpers.load_helpers import *
3
4 module_path = Path(__file__).parent
5 GRAPHICS = load_all_gfx((module_path / '../../../../../resources/graphics').resolve())
6 FONTS = load_all_fonts((module_path / '../../../../../resources/fonts').resolve())
7 SFX = load_all_sfx((module_path / '../../../../../resources/sfx').resolve())
8 MUSIC = load_all_music((module_path / '../../../../../resources/music').resolve())
9
10 DEFAULT_FONT = FONTS['vhs-gothic']
11 DEFAULT_FONT.strong = True
12 DEFAULT_FONT.strength = 0.05
```

## B.24.2 constants.py

```

33     WidgetState.BASE: ['0x1c2638', '0x23495d', '0x39707a', '0x95e0cc'],
34     WidgetState.HOVER: ['0xdaf2e9', '0x23495d', '0x39707a', '0x95e0cc'],
35     WidgetState.PRESS: ['0xdaf2e9', '0x1c2638', '0x23495d', '0x39707a']
36 }
37
38 INPUT_COLOURS = {
39     WidgetState.BASE: ['0x1c2638', '0x39707a', '0x23495d', '0x95e0cc'],
40     WidgetState.HOVER: ['0xdaf2e9', '0x39707a', '0x23495d', '0x95e0cc'],
41     WidgetState.PRESS: ['0xdaf2e9', '0x23495d', '0x1c2638', '0x39707a']
42 }
43
44 RED_BUTTON_COLOURS = {
45     WidgetState.BASE: ['0x000000', '0x1c2638', '0x9b222b', '0xf14e52'],
46     WidgetState.HOVER: ['0xdaf2e9', '0x1c2638', '0x9b222b', '0xf14e52'],
47     WidgetState.PRESS: ['0xdaf2e9', '0x23495d', '0xf14e52', '0x95e0cc']
48 }
49
50 LOCKED_RED_BUTTON_COLOURS = {
51     WidgetState.BASE: ['0x000000', '0x000000', '0x1c2638', '0x23495d'],
52     WidgetState.HOVER: ['0xdaf2e9', '0x000000', '0x1c2638', '0x23495d'],
53     WidgetState.PRESS: ['0xdaf2e9', '0x1c2638', '0x23495d', '0xf14e52']
54 }
55
56 LOCKED_BLUE_BUTTON_COLOURS = {
57     WidgetState.BASE: ['0x000000', '0x000000', '0x1c2638', '0x23495d'],
58     WidgetState.HOVER: ['0xdaf2e9', '0x000000', '0x1c2638', '0x23495d'],
59     WidgetState.PRESS: ['0xdaf2e9', '0x1c2638', '0x23495d', '0x39707a']
60 }

```

### B.24.3 enums.py

```

1  from enum import IntEnum, StrEnum, auto
2
3  class CursorMode(IntEnum):
4      ARROW = auto()
5      IBEAM = auto()
6      OPENHAND = auto()
7      CLOSEDHAND = auto()
8      NO = auto()
9
10 class ShaderType(StrEnum):
11     BASE = auto()
12     SHAKE = auto()
13     BLOOM = auto()
14     GRayscale = auto()
15     CRT = auto()
16     RAYS = auto()
17     ChromaticAbbreviation = auto()
18     BackgroundWaves = auto()
19     BackgroundBalatro = auto()
20     BackgroundLasers = auto()
21     BackgroundGradient = auto()
22     BackgroundNone = auto()
23
24     _BLUR = auto()
25     _Highlight_Brightness = auto()
26     _Highlight_Colour = auto()
27     _Calibrate = auto()
28     _Lightmap = auto()
29     _Shadowmap = auto()
30     _Occlusion = auto()
31     _Blend = auto()

```

```

32     _CROP = auto()
33
34 class TranspositionFlag(StrEnum):
35     LOWER = auto()
36     EXACT = auto()
37     UPPER = auto()
38
39 class Miscellaneous(StrEnum):
40     PLACEHOLDER = auto()
41     DRAW = auto()
42
43 class WidgetState(StrEnum):
44     BASE = auto()
45     HOVER = auto()
46     PRESS = auto()
47
48 class StatusText(StrEnum):
49     PLAYER_MOVE = auto()
50     CPU_MOVE = auto()
51     WIN = auto()
52     DRAW = auto()
53
54 class Colour(IntEnum):
55     BLUE = 0
56     RED = 1
57
58     def get_flipped_colour(self):
59         if self == Colour.BLUE:
60             return Colour.RED
61         elif self == Colour.RED:
62             return Colour.BLUE
63
64 class Piece(StrEnum):
65     SPHINX = 's'
66     PYRAMID = 'p'
67     ANUBIS = 'n'
68     SCARAB = 'r'
69     PHARAOH = 'f'
70
71 class Score(IntEnum):
72     PHARAOH = 0
73     SPHINX = 0
74     PYRAMID = 100
75     ANUBIS = 110
76     SCARAB = 200
77
78     MOVE = 4
79     POSITION = 11
80     PHARAOH_SAFETY = 31
81     CHECKMATE = 100000
82     INFINITE = 6969696969
83
84 class Rank(IntEnum):
85     ONE = 0
86     TWO = 1
87     THREE = 2
88     FOUR = 3
89     FIVE = 4
90     SIX = 5
91     SEVEN = 6
92     EIGHT = 7
93

```

```

94  class File(IntEnum):
95      A = 0
96      B = 1
97      C = 2
98      D = 3
99      E = 4
100     F = 5
101     G = 6
102     H = 7
103     I = 8
104     J = 9
105
106    class Rotation(StrEnum):
107        UP = 'a'
108        RIGHT = 'b'
109        DOWN = 'c'
110        LEFT = 'd'
111
112        def to_angle(self):
113            if self == Rotation.UP:
114                return 0
115            elif self == Rotation.RIGHT:
116                return 270
117            elif self == Rotation.DOWN:
118                return 180
119            elif self == Rotation.LEFT:
120                return 90
121
122        def get_clockwise(self):
123            if self == Rotation.UP:
124                return Rotation.RIGHT
125            elif self == Rotation.RIGHT:
126                return Rotation.DOWN
127            elif self == Rotation.DOWN:
128                return Rotation.LEFT
129            elif self == Rotation.LEFT:
130                return Rotation.UP
131
132        def get_anticlockwise(self):
133            if self == Rotation.UP:
134                return Rotation.LEFT
135            elif self == Rotation.RIGHT:
136                return Rotation.UP
137            elif self == Rotation.DOWN:
138                return Rotation.RIGHT
139            elif self == Rotation.LEFT:
140                return Rotation.DOWN
141
142        def get_opposite(self):
143            return self.get_clockwise().get_clockwise()
144
145    class RotationIndex(IntEnum):
146        FIRSTBIT = 0
147        SECONDBIT = 1
148
149    class RotationDirection(StrEnum):
150        CLOCKWISE = 'cw'
151        ANTICLOCKWISE = 'acw'
152
153        def get_opposite(self):
154            if self == RotationDirection.CLOCKWISE:
155                return RotationDirection.ANTICLOCKWISE

```

```

156         elif self == RotationDirection.ANTICLOCKWISE:
157             return RotationDirection.CLOCKWISE
158
159     class MoveType(StrEnum):
160         MOVE = 'm'
161         ROTATE = 'r'
162
163     class LaserType(IntEnum):
164         END = 0
165         STRAIGHT = 1
166         CORNER = 2
167
168     class LaserDirection(IntEnum):
169         FROM_TOP = 1
170         FROM_RIGHT = 2
171         FROM_BOTTOM = 3
172         FROM_LEFT = 4

```

#### B.24.4 event\_types.py

```

1  from enum import StrEnum, auto
2
3  class EditorEventType(StrEnum):
4      MENU_CLICK = auto()
5      PICK_PIECE_CLICK = auto()
6      ROTATE_PIECE_CLICK = auto()
7      COPY_CLICK = auto()
8      EMPTY_CLICK = auto()
9      RESET_CLICK = auto()
10     BLUE_START_CLICK = auto()
11     RED_START_CLICK = auto()
12     START_CLICK = auto()
13     CONFIG_CLICK = auto()
14     ERASE_CLICK = auto()
15     MOVE_CLICK = auto()
16     HELP_CLICK = auto()
17
18 class ReviewEventType(StrEnum):
19     MENU_CLICK = auto()
20     PREVIOUS_CLICK = auto()
21     NEXT_CLICK = auto()
22     HELP_CLICK = auto()
23
24 class BrowserEventType(StrEnum):
25     MENU_CLICK = auto()
26     BROWSER_STRIP_CLICK = auto()
27     COPY_CLICK = auto()
28     DELETE_CLICK = auto()
29     REVIEW_CLICK = auto()
30     FILTER_COLUMN_CLICK = auto()
31     FILTER_ASCEND_CLICK = auto()
32     PAGE_CLICK = auto()
33     HELP_CLICK = auto()
34
35 class GameEventType(StrEnum):
36     BOARD_CLICK = auto()
37     PIECE_CLICK = auto()
38     PAUSE_CLICK = auto()
39     MENU_CLICK = auto()
40     GAME_CLICK = auto()
41     HELP_CLICK = auto()
42     TUTORIAL_CLICK = auto()

```

```

43     RESIGN_CLICK = auto()
44     DRAW_CLICK = auto()
45     REVIEW_CLICK = auto()
46     PIECE_DROP = auto()
47     UPDATE_PIECES = auto()
48     ROTATE_PIECE = auto()
49     SET_LASER = auto()
50     TIMER_END = auto()
51
52 class MenuEventType(StrEnum):
53     CONFIG_CLICK = auto()
54     SETTINGS_CLICK = auto()
55     BROWSER_CLICK = auto()
56     QUIT_CLICK = auto()
57     CREDITS_CLICK = auto()
58
59 class SettingsEventType(StrEnum):
60     RESET_DEFAULT = auto()
61     RESET_USER = auto()
62     MENU_CLICK = auto()
63     COLOUR_SLIDER_SLIDE = auto()
64     COLOUR_SLIDER_CLICK = auto()
65     COLOUR_PICKER_HOVER = auto()
66     PRIMARY_COLOUR_PICKER_CLICK = auto()
67     SECONDARY_COLOUR_PICKER_CLICK = auto()
68     PRIMARY_COLOUR_BUTTON_CLICK = auto()
69     SECONDARY_COLOUR_BUTTON_CLICK = auto()
70     VOLUME_SLIDER_SLIDE = auto()
71     VOLUME_SLIDER_CLICK = auto()
72     SHADER_PICKER_CLICK = auto()
73     OPENGL_CLICK = auto()
74     DROPODOWN_CLICK = auto()
75     PARTICLES_CLICK = auto()
76
77 class ConfigEventType(StrEnum):
78     GAME_CLICK = auto()
79     MENU_CLICK = auto()
80     FEN_STRING_TYPE = auto()
81     TIME_TYPE = auto()
82     TIME_CLICK = auto()
83     PVP_CLICK = auto()
84     PVC_CLICK = auto()
85     CPU_DEPTH_CLICK = auto()
86     PRESET_CLICK = auto()
87     SETUP_CLICK = auto()
88     COLOUR_CLICK = auto()
89     HELP_CLICK = auto()

```

## B.25 data\widgets

### B.25.1 board\_thumbnail.py

```

1 import pygame
2 from data.widgets.bases.widget import _Widget
3 from data.widgets.chessboard import Chessboard
4 from data.states.game.components.piece_group import PieceGroup
5 from data.states.game.components.bitboard_collection import BitboardCollection
6
7 class BoardThumbnail(_Widget):
8     def __init__(self, relative_width, fen_string=' ', **kwargs):

```

```

9      super().__init__(relative_size=(relative_width, relative_width * 0.8), **
10     kwargs)
11
12     self._board = Chessboard(
13         parent=self._parent,
14         relative_position=(0, 0),
15         scale_mode=kwargs.get('scale_mode'),
16         relative_width=relative_width
17     )
18
19     self._empty_surface = pygame.Surface((0, 0), pygame.SRCALPHA)
20
21     self.initialise_board(fen_string)
22     self.set_image()
23     self.set_geometry()
24
25     def initialise_board(self, fen_string):
26         if len(fen_string) == 0:
27             piece_list = []
28         else:
29             piece_list = BitboardCollection(fen_string).convert_to_piece_list()
30
31         self._piece_group = PieceGroup()
32         self._piece_group.initialise_pieces(piece_list, (0, 0), self.size)
33
34         self._board.refresh_board()
35         self.set_image()
36
37     def set_image(self):
38         self.image = pygame.transform.scale(self._empty_surface, self.size)
39
40         self._board.set_image()
41         self.image.blit(self._board.image, (0, 0))
42
43         self._piece_group.draw(self.image)
44
45     def set_geometry(self):
46         super().set_geometry()
47         self._board.set_geometry()
48
49     def set_surface_size(self, new_surface_size):
50         super().set_surface_size(new_surface_size)
51         self._board.set_surface_size(new_surface_size)
52         self._piece_group.handle_resize((0, 0), self.size)
53
54     def process_event(self, event):
55         pass

```

### B.25.2 board\_thumbnail\_button.py

```

1 from data.widgets.bases.pressable import _Pressable
2 from data.widgets.board_thumbnail import BoardThumbnail
3 from data.utils.constants import WidgetState
4 from data.components.custom_event import CustomEvent
5
6 class BoardThumbnailButton(_Pressable, BoardThumbnail):
7     def __init__(self, event, **kwargs):
8         _Pressable.__init__(
9             self,
10             event=CustomEvent(**vars(event), fen_string=kwargs.get('fen_string')),
11             hover_func=lambda: self.set_state_colour(WidgetState.HOVER),
12             down_func=lambda: self.set_state_colour(WidgetState.PRESS),

```

```

13         up_func=lambda: self.set_state_colour(WidgetState.BASE),
14     )
15     BoardThumbnail.__init__(self, **kwargs)
16
17     self.initialise_new_colours(self._fill_colour)
18     self.set_state_colour(WidgetState.BASE)

```

### B.25.3 browser\_item.py

```

1 import pygame
2 from data.helpers.font_helpers import text_width_to_font_size
3 from data.helpers.browser_helpers import get_winner_string
4 from data.widgets.board_thumbnail import BoardThumbnail
5 from data.helpers.asset_helpers import scale_and_cache
6 from data.widgets.bases.widget import _Widget
7
8 FONT_DIVISION = 7
9
10 class BrowserItem(_Widget):
11     def __init__(self, relative_width, game, **kwargs):
12         super().__init__(relative_size=(relative_width, relative_width * 2),
13                         scale_mode='height', **kwargs)
14
15         self._relative_font_size = text_width_to_font_size('YYYY-MM-DD HH:MM:SS',
16                                                          self._font, self.size[0]) / self.surface_size[1]
17
18         self._game = game
19         self._board_thumbnail = BoardThumbnail(
20             relative_position=(0, 0),
21             scale_mode='height',
22             relative_width=relative_width,
23             fen_string=self._game['final_fen_string']
24         )
25
26         self.set_image()
27         self.set_geometry()
28
29     def get_text_to_render(self):
30         depth_to_text = {
31             2: 'EASY',
32             3: 'MEDIUM',
33             4: 'HARD'
34         }
35
36         format_moves = lambda no_of_moves: int(no_of_moves / 2) if (no_of_moves /
37             2 % 1 == 0) else round(no_of_moves / 2, 1)
38
39         if self._game['cpu_enabled'] == 1:
40             depth_text = depth_to_text[self._game['cpu_depth']]
41             cpu_text = f'PVC ({depth_text})'
42         else:
43             cpu_text = 'PVP'
44
45         return [
46             cpu_text,
47             self._game['created_dt'].strftime('%Y-%m-%d %H:%M:%S'),
48             f'WINNER: {get_winner_string(self._game['winner'])}',
49             f'NO. MOVES: {format_moves(self._game['number_of_ply'])}'
50         ]
51
52     def set_image(self):
53         self.image = pygame.Surface(self.size, pygame.SRCALPHA)

```

```

51     resized_board = scale_and_cache(self._board_thumbnail.image, (self.size
52 [0], self.size[0] * 0.8))
53     self.image.blit(resized_board, (0, 0))
54
55     get_line_y = lambda line: (self.size[0] * 0.8) + ((self.size[0] * 0.8) /
56 FONT_DIVISION) * (line + 0.5)
57
58     text_to_render = self.get_text_to_render()
59
60     for index, text in enumerate(text_to_render):
61         self._font.render_to(self.image, (0, get_line_y(index)), text, fgcolor
62 =self._text_colour, size=self.font_size)
63
64     def process_event(self, event):
65         pass

```

#### B.25.4 browser\_strip.py

```

1 import pygame
2 from data.components.custom_event import CustomEvent
3 from data.utils.event_types import BrowserEventType
4 from data.widgets.browser_item import BrowserItem
5 from data.widgets.bases.widget import _Widget
6
7 WIDTH_FACTOR = 0.3
8
9 class BrowserStrip(_Widget):
10     def __init__(self, relative_height, games_list, **kwargs):
11         super().__init__(relative_size=None, **kwargs)
12         self._relative_item_width = relative_height / 2
13         self._get_rect = None
14
15         self._games_list = []
16         self._items_list = []
17         self._selected_index = None
18
19         self.initialise_games_list(games_list)
20
21     @property
22     def item_width(self):
23         return self._relative_item_width * self.surface_size[1]
24
25     @property
26     def size(self):
27         if self._get_rect:
28             height = self._get_rect().height
29         else:
30             height = 0
31         width = max(0, len(self._games_list) * (self.item_width + self.margin) +
32                     self.margin)
33
34         return (width, height)
35
36     def register_get_rect(self, get_rect_func):
37         self._get_rect = get_rect_func
38
39     def initialise_games_list(self, games_list):
40         self._items_list = []
41         self._games_list = games_list
42         self._selected_index = None
43
44         for game in games_list:

```

```

44         browser_item = BrowserItem(relative_position=(0, 0), game=game,
45             relative_width=self._relative_item_width)
46         self._items_list.append(browser_item)
47
48     self.set_image()
49     self.set_geometry()
50
51     def set_image(self):
52         self.image = pygame.Surface(self.size, pygame.SRCALPHA)
53         browser_list = []
54
55         for index, item in enumerate(self._items_list):
56             item.set_image()
57             browser_list.append((item.image, (index * (self.item_width + self.
58 margin) + self.margin, self.margin)))
59
60         self.image.blit(browser_list)
61
62         if self._selected_index is not None:
63             border_position = (self._selected_index * (self.item_width + self.
64 margin), 0)
65             border_size = (self.item_width + 2 * self.margin, self.size[1])
66             pygame.draw.rect(self.image, (255, 255, 255), (*border_position, *
67 border_size), width=int(self.item_width / 20))
68
69     def set_geometry(self):
70         super().set_geometry()
71         for item in self._items_list:
72             item.set_geometry()
73
74     def set_surface_size(self, new_surface_size):
75         super().set_surface_size(new_surface_size)
76
77         for item in self._items_list:
78             item.set_surface_size(new_surface_size)
79
80     def process_event(self, event, scrolled_pos):
81         parent_pos = self._get_rect().topleft
82         self.rect.topleft = parent_pos
83
84         if event.type == pygame.KEYDOWN and event.key == pygame.K_ESCAPE:
85             self._selected_index = None
86             self.set_image()
87             return CustomEvent(BrowserEventType.BROWSER_STRIP_CLICK,
88 selected_index=None)
89
90         if event.type == pygame.MOUSEBUTTONDOWN and self.rect.collidepoint(event.
91 pos):
92             relative_mouse_pos = (event.pos[0] - parent_pos[0], event.pos[1] -
93 parent_pos[1])
94             self._selected_index = int(max(0, (relative_mouse_pos[0] - self.margin
95 ) // (self.item_width + self.margin)))
96             self.set_image()
97             return CustomEvent(BrowserEventType.BROWSER_STRIP_CLICK,
98 selected_index=self._selected_index)

```

### B.25.5 carousel.py

```

1 import pygame
2 from data.widgets.reactive_icon_button import ReactiveIconButton
3 from data.components.custom_event import CustomEvent
4 from data.widgets.bases.circular import _Circular

```

```

5  from data.widgets.bases.widget import _Widget
6  from data.utils.assets import GRAPHICS, SFX
7  from data.utils.enums import Miscellaneous
8
9  class Carousel(_Circular, _Widget):
10     def __init__(self, event, widgets_dict, **kwargs):
11         _Circular.__init__(self, items_dict=widgets_dict)
12         _Widget.__init__(self, relative_size=None, **kwargs)
13
14         max_widget_size = (
15             max([widget.rect.width for widget in widgets_dict.values()]),
16             max([widget.rect.height for widget in widgets_dict.values()])
17         )
18
19         self._relative_max_widget_size = (max_widget_size[0] / self.surface_size
20 [1], max_widget_size[1] / self.surface_size[1])
21         self._relative_size = ((max_widget_size[0] + 2 * (self.margin + self.
22 arrow_size[0])) / self.surface_size[1], (max_widget_size[1]) / self.
23 surface_size[1])
24
25         self._left_arrow = ReactiveIconButton(
26             relative_position=(0, 0),
27             relative_size=(0, self.arrow_size[1] / self.surface_size[1]),
28             scale_mode='height',
29             base_icon=GRAPHICS['left_arrow_base'],
30             hover_icon=GRAPHICS['left_arrow_hover'],
31             press_icon=GRAPHICS['left_arrow_press'],
32             event=CustomEvent(Miscellaneous.PLACEHOLDER),
33             sfx=SFX['carousel_click']
34         )
35         self._right_arrow = ReactiveIconButton(
36             relative_position=(0, 0),
37             relative_size=(0, self.arrow_size[1] / self.surface_size[1]),
38             scale_mode='height',
39             base_icon=GRAPHICS['right_arrow_base'],
40             hover_icon=GRAPHICS['right_arrow_hover'],
41             press_icon=GRAPHICS['right_arrow_press'],
42             event=CustomEvent(Miscellaneous.PLACEHOLDER),
43             sfx=SFX['carousel_click']
44         )
45
46         self._event = event
47         self._empty_surface = pygame.Surface((0, 0), pygame.SRCALPHA)
48
49         self.set_image()
50         self.set_geometry()
51
52     @property
53     def max_widget_size(self):
54         return (self._relative_max_widget_size[0] * self.surface_size[1], self.
55         _relative_max_widget_size[1] * self.surface_size[1])
56
57     @property
58     def arrow_size(self):
59         height = self.max_widget_size[1] * 0.75
60         width = (GRAPHICS['left_arrow_base'].width / GRAPHICS['left_arrow_base'].
61         height) * height
62         return (width, height)
63
64     @property
65     def size(self):
66         return ((self.arrow_size[0] + self.margin) * 2 + self.max_widget_size[0],
67         self.max_widget_size[1])

```

```

    self.max_widget_size[1])

62     @property
63     def left_arrow_position(self):
64         return (0, (self.size[1] - self.arrow_size[1]) / 2)
65
66     @property
67     def right_arrow_position(self):
68         return (self.size[0] - self.arrow_size[0], (self.size[1] - self.arrow_size
69             [1]) / 2)
70
71     def set_image(self):
72         self.image = pygame.transform.scale(self._empty_surface, self.size)
73         self.image.fill(self._fill_colour)
74
75         if self.border_width:
76             pygame.draw.rect(self.image, self._border_colour, (0, 0, *self.size),
77             width=int(self.border_width), border_radius=int(self.border_radius))
78
79         self._left_arrow.set_image()
80         self.image.blit(self._left_arrow.image, self.left_arrow_position)
81
82         self.current_item.set_image()
83         self.image.blit(self.current_item.image, ((self.size[0] - self.
84         current_item.rect.size[0]) / 2, (self.size[1] - self.current_item.rect.size
85             [1]) / 2))
86
86         self._right_arrow.set_image()
87         self.image.blit(self._right_arrow.image, self.right_arrow_position)
88
89     def set_geometry(self):
90         super().set_geometry()
91
92         self.current_item.set_geometry()
93         self._left_arrow.set_geometry()
94         self._right_arrow.set_geometry()
95
95         self.current_item.rect.center = self.rect.center
96         self._left_arrow.rect.topleft = (self.position[0] + self.
97         left_arrow_position[0], self.position[1] + self.left_arrow_position[1])
98         self._right_arrow.rect.topleft = (self.position[0] + self.
99         right_arrow_position[0], self.position[1] + self.right_arrow_position[1])
100
101     def set_surface_size(self, new_surface_size):
102         super().set_surface_size(new_surface_size)
103         self._left_arrow.set_surface_size(new_surface_size)
104         self._right_arrow.set_surface_size(new_surface_size)
105
105         for item in self._items_dict.values():
106             item.set_surface_size(new_surface_size)
107
106     def process_event(self, event):
107         self.current_item.process_event(event)
108         left_arrow_event = self._left_arrow.process_event(event)
109         right_arrow_event = self._right_arrow.process_event(event)
110
111         if left_arrow_event:
112             self.set_previous_item()
113             self.current_item.set_surface_size(self._raw_surface_size)
114
115         elif right_arrow_event:
116             self.set_next_item()

```

```

117         self.current_item.set_surface_size(self._raw_surface_size)
118
119     if left_arrow_event or right_arrow_event:
120         self.set_image()
121         self.set_geometry()
122
123     return CustomEvent(**vars(self._event), data=self.current_key)
124
125 elif event.type in [pygame.MOUSEBUTTONDOWN, pygame.MOUSEBUTTONUP, pygame.
126 MOUSEMOTION]:
127     self.set_image()
128     self.set_geometry()

```

### B.25.6 chessboard.py

```

1 import pygame
2 from data.helpers.data_helpers import get_user_settings
3 from data.helpers.board_helpers import create_board
4 from data.widgets.bases.widget import _Widget
5 from data.utils.enums import CursorMode
6 from data.managers.cursor import cursor
7
8 class Chessboard(_Widget):
9     def __init__(self, relative_width, change_cursor=True, **kwargs):
10         super().__init__(relative_size=(relative_width, relative_width * 0.8), **
11                         kwargs)
12
13         self._board_surface = None
14         self._change_cursor = change_cursor
15         self._cursor_is_hand = False
16
17         self.refresh_board()
18         self.set_image()
19         self.set_geometry()
20
21     def refresh_board(self):
22         user_settings = get_user_settings()
23         self._board_surface = create_board(self.size, user_settings['
24             primaryBoardColour'], user_settings['secondaryBoardColour'])
25
26         self.set_image()
27
28     def set_image(self):
29         self.image = pygame.transform.smoothscale(self._board_surface, self.size)
30
31     def process_event(self, event):
32         if self._change_cursor and event.type in [pygame.MOUSEMOTION, pygame.
33             MOUSEBUTTONUP, pygame.MOUSEBUTTONDOWN]:
34             current_cursor = cursor.get_mode()
35
36             if self.rect.collidepoint(event.pos):
37                 if current_cursor == CursorMode.ARROW:
38                     cursor.set_mode(CursorMode.OPENHAND)
39                 elif current_cursor == CursorMode.OPENHAND and (pygame.mouse.
40                     get_pressed()[0] is True or event.type == pygame.MOUSEBUTTONDOWN):
41                     cursor.set_mode(CursorMode.CLOSEDHAND)
42                 elif current_cursor == CursorMode.CLOSEDHAND and (pygame.mouse.
43                     get_pressed()[0] is False or event.type == pygame.MOUSEBUTTONUP):
44                     cursor.set_mode(CursorMode.OPENHAND)
45             else:
46                 if current_cursor == CursorMode.OPENHAND or (current_cursor ==
47                     CursorMode.CLOSEDHAND and event.type == pygame.MOUSEBUTTONUP):

```

42 cursor.set\_mode(CursorMode.ARROW)

### B.25.7 colour\_button.py

```

1 import pygame
2 from data.widgets.bases.widget import _Widget
3 from data.widgets.bases.pressable import _Pressable
4 from data.utils.constants import WidgetState
5
6 class ColourButton(_Pressable, _Widget):
7     def __init__(self, event, **kwargs):
8         _Pressable.__init__(
9             self,
10            event=event,
11            hover_func=lambda: self.set_state_colour(WidgetState.HOVER),
12            down_func=lambda: self.set_state_colour(WidgetState.PRESS),
13            up_func=lambda: self.set_state_colour(WidgetState.BASE),
14            sfx=None
15        )
16        _Widget.__init__(self, **kwargs)
17
18        self._empty_surface = pygame.Surface(self.size)
19
20        self.initialise_new_colours(self._fill_colour)
21        self.set_state_colour(WidgetState.BASE)
22
23        self.set_image()
24        self.set_geometry()
25
26    def set_image(self):
27        self.image = pygame.transform.scale(self._empty_surface, self.size)
28        self.image.fill(self._fill_colour)
29        pygame.draw.rect(self.image, self._border_colour, (0, 0, self.size[0],
30            self.size[1]), width=int(self.border_width))

```

### B.25.8 colour\_display.py

```

1 import pygame
2 from data.widgets.bases.widget import _Widget
3
4 class _ColourDisplay(_Widget):
5     def __init__(self, **kwargs):
6         super().__init__(**kwargs)
7
8         self._colour = None
9
10        self._empty_surface = pygame.Surface(self.size)
11
12    def set_colour(self, new_colour):
13        self._colour = new_colour
14
15    def set_image(self):
16        self.image = pygame.transform.scale(self._empty_surface, self.size)
17        self.image.fill(self._colour)
18
19    def process_event(self, event):
20        pass

```

### B.25.9 colour\_picker.py

```

1 import pygame
2 from data.widgets.bases.widget import _Widget
3 from data.widgets.colour_square import _ColourSquare
4 from data.widgets.colour_slider import _ColourSlider
5 from data.widgets.colour_display import _ColourDisplay
6 from data.components.custom_event import CustomEvent
7
8 class ColourPicker(_Widget):
9     def __init__(self, relative_width, event_type, **kwargs):
10         super().__init__(relative_size=(relative_width, relative_width),
11                         scale_mode='width', **kwargs)
12
13         self.image = pygame.Surface(self.size)
14         self.rect = self.image.get_rect()
15
16         self._square = _ColourSquare(
17             parent=self,
18             relative_position=(0.1, 0.1),
19             relative_width=0.5,
20             event_type=event_type
21         )
22         self._square.set_colour(kwargs.get('selected_colour'))
23
24         self._slider = _ColourSlider(
25             parent=self,
26             relative_position=(0.0, 0.7),
27             relative_width=1.0,
28             border_width=self.border_width,
29             border_colour=self._border_colour
30         )
31         self._slider.set_colour(kwargs.get('selected_colour'))
32
33         self._display = _ColourDisplay(
34             parent=self,
35             relative_position=(0.7, 0.1),
36             relative_size=(0.2, 0.5)
37         )
38         self._display.set_colour(kwargs.get('selected_colour'))
39
40         self._event_type = event_type
41         self._hover_event_type = event_type
42
43         self.set_image()
44         self.set_geometry()
45
46     def global_to_relative_pos(self, global_pos):
47         return (global_pos[0] - self.position[0], global_pos[1] - self.position[1])
48
49     def set_image(self):
50         self.image = pygame.Surface(self.size)
51         self.image.fill(self._fill_colour)
52
53         self._square.set_image()
54         self._square.set_geometry()
55         self.image.blit(self._square.image, self.global_to_relative_pos(self._square.position))
56
57         self._slider.set_image()
58         self._slider.set_geometry()
59         self.image.blit(self._slider.image, self.global_to_relative_pos(self._slider.position))

```

```

59         self._display.set_image()
60         self._display.set_geometry()
61         self.image.blit(self._display.image, self.global_to_relative_pos(self.
62             _display.position))
63
64         pygame.draw.rect(self.image, self._border_colour, (0, 0, self.size[0],
65             self.size[1]), width=int(self.border_width))
66
67     def set_surface_size(self, new_surface_size):
68         super().set_surface_size(new_surface_size)
69         self._square.set_surface_size(self.size)
70         self._slider.set_surface_size(self.size)
71         self._display.set_surface_size(self.size)
72
73     def get_picker_position(self):
74         return self.position
75
76     def process_event(self, event):
77         slider_colour = self._slider.process_event(event)
78         square_colour = self._square.process_event(event)
79
80         if square_colour:
81             self._display.set_colour(square_colour)
82             self.set_image()
83
84         if slider_colour:
85             self._square.set_colour(slider_colour)
86             self.set_image()
87
88         if event.type in [pygame.MOUSEBUTTONUP, pygame.MOUSEBUTTONDOWN, pygame.
89             MOUSEMOTION] and self.rect.collidepoint(event.pos):
90             return CustomEvent(self._event_type, colour=square_colour)

```

### B.25.10 colour\_slider.py

See Section 3.4.4.

### B.25.11 colour\_square.py

```

1 import pygame
2 from data.widgets.bases.widget import _Widget
3 from data.helpers.widget_helpers import create_square_gradient
4
5 class _ColourSquare(_Widget):
6     def __init__(self, relative_width, **kwargs):
7         super().__init__(relative_size=(relative_width, relative_width),
8             scale_mode='width', **kwargs)
8
9         self._colour = None
10
11    def set_colour(self, new_colour):
12        self._colour = pygame.Color(new_colour)
13
14    def get_colour(self):
15        return self._colour
16
17    def set_image(self):
18        self.image = create_square_gradient(side_length=self.size[0], colour=self.
19            _colour)

```

```
19
20     def process_event(self, event):
21         if event.type == pygame.MOUSEBUTTONDOWN:
22             relative_mouse_pos = (event.pos[0] - self.position[0], event.pos[1] -
23                                     self.position[1])
24
25             if (
26                 0 > relative_mouse_pos[0] or
27                 self.size[0] < relative_mouse_pos[0] or
28                 0 > relative_mouse_pos[1] or
29                 self.size[1] < relative_mouse_pos[1]
30             ): return None
31
32             self.set_colour(self.image.get_at(relative_mouse_pos))
33
34             return self._colour
35
36     return None
```

## B.25.12 dropdown.py

```
1 import pygame
2 from data.widgets.bases.widget import _Widget
3 from data.widgets.bases.pressable import _Pressable
4 from data.utils.constants import WidgetState
5 from data.helpers.data_helpers import get_user_settings
6 from data.helpers.font_helpers import text_width_to_font_size,
7     text_height_to_font_size
8 from data.utils.assets import GRAPHICS
9
10 user_settings = get_user_settings()
11
12 class Dropdown(_Pressable, _Widget):
13     def __init__(self, word_list, event=None, **kwargs):
14         _Pressable.__init__(
15             self,
16             event=event,
17             hover_func=self.hover_func,
18             down_func=lambda: self.set_state_colour(WidgetState.PRESS),
19             up_func=self.up_func,
20             sifx=None
21         )
22         _Widget.__init__(self, relative_size=None, **kwargs)
23
24         if kwargs.get('relative_width'):
25             self._relative_font_size = text_width_to_font_size(max(word_list, key=
26 len), self._font, kwargs.get('relative_width') * self.surface_size[0] - self.
27 margin) / self.surface_size[1]
28         elif kwargs.get('relative_height'):
29             self._relative_font_size = text_height_to_font_size(max(word_list, key=
30 len), self._font, kwargs.get('relative_height') * self.surface_size[1] - self.
31 margin) / self.surface_size[1]
32
33         self._word_list = [word_list[0].capitalize()]
34         self._word_list_copy = [word.capitalize() for word in word_list]
35
36         self._expanded = False
37         self._hovered_index = None
38
39         self._empty_surface = pygame.Surface((0, 0))
40         self._background_colour = self._fill_colour
```

```

37         self.initialise_new_colours(self._fill_colour)
38         self.set_state_colour(WidgetState.BASE)
39
40     self.set_image()
41     self.set_geometry()
42
43     @property
44     def size(self):
45         max_word = sorted(self._word_list_copy, key=len)[-1]
46         max_word_rect = self._font.get_rect(max_word, size=self.font_size)
47         all_words_rect = pygame.Rect(0, 0, max_word_rect.size[0], (max_word_rect.
48             size[1] * len(self._word_list)) + (self.margin * (len(self._word_list) - 1)))
49         all_words_rect = all_words_rect.inflate(2 * self.margin, 2 * self.margin)
50         return (all_words_rect.size[0] + max_word_rect.size[1], all_words_rect.
51             size[1])
52
53     def get_selected_word(self):
54         return self._word_list[0].lower()
55
56     def toggle_expanded(self):
57         if self._expanded:
58             self._word_list = [self._word_list_copy[0]]
59         else:
60             self._word_list = [*self._word_list_copy]
61
62         self._expanded = not(self._expanded)
63
64     def hover_func(self):
65         mouse_position = pygame.mouse.get_pos()
66         relative_position = (mouse_position[0] - self.position[0], mouse_position
67             [1] - self.position[1])
68         self._hovered_index = self.calculate_hovered_index(relative_position)
69         self.set_state_colour(WidgetState.HOVER)
70
71     def set_selected_word(self, word):
72         index = self._word_list_copy.index(word.capitalize())
73         selected_word = self._word_list_copy.pop(index)
74         self._word_list_copy.insert(0, selected_word)
75
76         if self._expanded:
77             self._word_list.pop(index)
78             self._word_list.insert(0, selected_word)
79         else:
80             self._word_list = [selected_word]
81
82         self.set_image()
83
84     def up_func(self):
85         if self.get_widget_state() == WidgetState.PRESS:
86             if self._expanded and self._hovered_index is not None:
87                 self.set_selected_word(self._word_list_copy[self._hovered_index])
88
89             self.toggle_expanded()
90
91             self._hovered_index = None
92
93             self.set_state_colour(WidgetState.BASE)
94             self.set_geometry()
95
96     def calculate_hovered_index(self, mouse_pos):
97         return int(mouse_pos[1] // (self.size[1] / len(self._word_list)))

```

```

96     def set_image(self):
97         text_surface = pygame.transform.scale(self._empty_surface, self.size)
98         self.image = text_surface
99
100        fill_rect = pygame.FRect(0, 0, self.size[0], self.size[1])
101        pygame.draw.rect(self.image, self._background_colour, fill_rect)
102        pygame.draw.rect(self.image, self._border_colour, fill_rect, width=int(
103            self.border_width))
104
105        word_box_height = (self.size[1] - (2 * self.margin) - ((len(self.
106            _word_list) - 1) * self.margin)) / len(self._word_list)
107
108        arrow_size = (GRAPHICS['dropdown_arrow_open'].width / GRAPHICS['
109            dropdown_arrow_open'].height * word_box_height, word_box_height)
110        open_arrow_surface = pygame.transform.scale(GRAPHICS['dropdown_arrow_open'],
111            arrow_size)
112        closed_arrow_surface = pygame.transform.scale(GRAPHICS['
113            dropdown_arrow_close'], arrow_size)
114        arrow_position = (self.size[0] - arrow_size[0] - self.margin, (
115            word_box_height) / 3)
116
116        if self._expanded:
117            self.image.blit(closed_arrow_surface, arrow_position)
118        else:
119            self.image.blit(open_arrow_surface, arrow_position)
120
121        for index, word in enumerate(self._word_list):
122            word_position = (self.margin, self.margin + (word_box_height + self.
123                margin) * index)
124            self._font.render_to(self.image, word_position, word, fgcolor=self.
125                _text_colour, size=self.font_size)
126
126        if self._hovered_index is not None:
127            overlay_surface = pygame.Surface((self.size[0], word_box_height + 2 *
128                self.margin), pygame.SRCALPHA)
129            overlay_surface.fill(*self._fill_colour.rgb, 128)
130            overlay_position = (0, (word_box_height + self.margin) * self.
131                _hovered_index)
132            self.image.blit(overlay_surface, overlay_position)

```

### B.25.13 icon.py

```

1 import pygame
2 from data.widgets.bases.widget import _Widget
3 from data.helpers.widget_helpers import create_text_box
4
5 class Icon(_Widget):
6     def __init__(self, icon, stretch=False, is_mask=False, smooth=False, fit_icon=
6         False, box_colours=None, **kwargs):
7         super().__init__(**kwargs)
8
9         if fit_icon:
10             aspect_ratio = icon.width / icon.height
11             self._relative_size = (self._relative_size[1] * aspect_ratio, self.
11                 _relative_size[1])
12
13             self._icon = icon
14             self._is_mask = is_mask
15             self._stretch = stretch
16             self._smooth = smooth
17             self._box_colours = box_colours
18

```

```

19         self._empty_surface = pygame.Surface((0, 0), pygame.SRCALPHA)
20
21     self.set_image()
22     self.set_geometry()
23
24     def set_icon(self, icon):
25         self._icon = icon
26         self.set_image()
27
28     def set_image(self):
29         if self._box_colours:
30             self.image = create_text_box(self.size, self.border_width, self.
31 _box_colours)
32         else:
33             self.image = pygame.transform.scale(self._empty_surface, self.size)
34
35         if self._fill_colour:
36             pygame.draw.rect(self.image, self._fill_colour, self.image.
37 get_rect(), border_radius=int(self.border_radius))
38
39         if self._stretch:
40             if self._smooth:
41                 scaled_icon = pygame.transform.smoothscale(self._icon, (self.size
42 [0] - (2 * self.margin), self.size[1] - (2 * self.margin)))
43             else:
44                 scaled_icon = pygame.transform.scale(self._icon, (self.size[0] -
45 (2 * self.margin), self.size[1] - (2 * self.margin)))
46
47             icon_position = (self.margin, self.margin)
48         else:
49             max_height = self.size[1] - (2 * self.margin)
50             max_width = self.size[0] - (2 * self.margin)
51             scale_factor = min(max_width / self._icon.width, max_height / self.
52 _icon.height)
53
54             if self._smooth:
55                 scaled_icon = pygame.transform.smoothscale_by(self._icon, (
56 scale_factor, scale_factor))
57             else:
58                 scaled_icon = pygame.transform.scale_by(self._icon, (scale_factor,
59 scale_factor))
60             icon_position = ((self.size[0] - scaled_icon.width) / 2, (self.size[1]
61 - scaled_icon.height) / 2)
62
63         if self._is_mask:
64             self.image.blit(scaled_icon, icon_position, None, pygame.
BLEND_RGBA_MULT)
65         else:
66             self.image.blit(scaled_icon, icon_position)
67
68         if self._box_colours is None and self.border_width:
69             pygame.draw.rect(self.image, self._border_colour, self.image.get_rect
() , width=int(self.border_width), border_radius=int(self.border_radius))
70
71     def process_event(self, event):
72         pass

```

**B.25.14 icon\_button.py**

```

1 from data.widgets.bases.pressable import _Pressable
2 from data.widgets.bases.box import _Box
3 from data.widgets.icon import Icon

```

```

4 from data.utils.constants import WidgetState, RED_BUTTON_COLOURS
5
6 class IconButton(_Box, _Pressable, Icon):
7     def __init__(self, event, box_colours=RED_BUTTON_COLOURS, **kwargs):
8         _Box.__init__(self, box_colours=box_colours)
9         _Pressable.__init__(
10             self,
11             event=event,
12             hover_func=lambda: self.set_state_colour(WidgetState.HOVER),
13             down_func=lambda: self.set_state_colour(WidgetState.PRESS),
14             up_func=lambda: self.set_state_colour(WidgetState.BASE),
15         )
16         Icon.__init__(self, box_colours=box_colours[WidgetState.BASE], **kwargs)
17
18     self.initialise_new_colours(self._fill_colour)
19     self.set_state_colour(WidgetState.BASE)

```

### B.25.15 move\_list.py

```

1 import pygame
2 from data.widgets.bases.widget import _Widget
3 from data.helpers.font_helpers import width_to_font_size
4
5 class MoveList(_Widget):
6     def __init__(self, relative_width, minimum_height=0, move_list=[], **kwargs):
7         super().__init__(relative_size=None, **kwargs)
8
9         self._relative_width = relative_width * self.surface_size[0] / self.
10        surface_size[1]
11        self._relative_minimum_height = minimum_height / self.surface_size[1]
12        self._move_list = move_list
13        self._relative_font_size = width_to_font_size(self._font, self.
14        surface_size[0] / 3.5) / self.surface_size[1]
15
16        self._empty_surface = pygame.Surface((0, 0), pygame.SRCALPHA)
17
18        self.set_image()
19        self.set_geometry()
20
21    @property
22    def size(self):
23        font_metrics = self._font.get_metrics('j', size=self.font_size)
24
25        width = self._relative_width * self.surface_size[1]
26        minimum_height = self._relative_minimum_height * self.surface_size[1]
27        row_gap = font_metrics[0][3] - font_metrics[0][2]
28        number_of_rows = 2 * ((len(self._move_list) + 1) // 2) + 1
29
30        return (width, max(minimum_height, row_gap * number_of_rows))
31
32    def register_get_rect(self, get_rect_func):
33        pass
34
35    def reset_move_list(self):
36        self._move_list = []
37        self.set_image()
38        self.set_geometry()
39
40    def append_to_move_list(self, new_move):
41        self._move_list.append(new_move)
42        self.set_image()
43        self.set_geometry()

```

```

42
43     def pop_from_move_list(self):
44         self._move_list.pop()
45         self.set_image()
46         self.set_geometry()
47
48     def set_image(self):
49         self.image = pygame.transform.scale(self._empty_surface, self.size)
50         self.image.fill(self._fill_colour)
51
52         font_metrics = self._font.get_metrics('j', size=self.font_size)
53         row_gap = font_metrics[0][3] - font_metrics[0][2]
54
55         for index, move in enumerate(self._move_list):
56             if index % 2 == 0:
57                 text_position = (self.size[0] / 7, row_gap * (1 + 2 * (index // 2)))
58             else:
59                 text_position = (self.size[0] * 4 / 7, row_gap * (1 + 2 * (index // 2)))
60
61             self._font.render_to(self.image, text_position, text=move, size=self.font_size, fgcolor=self._text_colour)
62
63             move_number = (index // 2) + 1
64             move_number_position = (self.size[0] / 14, row_gap * (1 + 2 * (index // 2)))
65             self._font.render_to(self.image, move_number_position, text=str(move_number), size=self.font_size, fgcolor=self._text_colour)
66
67     def process_event(self, event, scrolled_pos=None):
68         pass

```

### B.25.16 multiple\_icon\_button.py

```

1 import pygame
2 from data.utils.constants import WidgetState, LOCKED_BLUE_BUTTON_COLOURS,
3     LOCKED_RED_BUTTON_COLOURS, RED_BUTTON_COLOURS, BLUE_BUTTON_COLOURS
4 from data.components.custom_event import CustomEvent
5 from data.widgets.bases.circular import _Circular
6 from data.widgets.icon_button import IconButton
7 from data.widgets.bases.box import _Box
8
8 class MultipleIconButton(_Circular, IconButton):
9     def __init__(self, icons_dict, **kwargs):
10         _Circular.__init__(self, items_dict=icons_dict)
11         IconButton.__init__(self, icon=self.current_item, **kwargs)
12
13         self._fill_colour_copy = self._fill_colour
14
15         self._locked = None
16
17     def set_locked(self, is_locked):
18         self._locked = is_locked
19         if self._locked:
20             r, g, b, a = pygame.Color(self._fill_colour_copy).rgba
21             if self._box_colours_dict == BLUE_BUTTON_COLOURS:
22                 _Box.__init__(self, box_colours=LOCKED_BLUE_BUTTON_COLOURS)
23             elif self._box_colours_dict == RED_BUTTON_COLOURS:
24                 _Box.__init__(self, box_colours=LOCKED_RED_BUTTON_COLOURS)
25             else:

```

```

26         self.initialise_new_colours((max(r + 50, 0), max(g + 50, 0), max(b + 50,
27                                         0), a))
28     else:
29         if self._box_colours_dict == LOCKED_BLUE_BUTTON_COLOURS:
30             _Box.__init__(self, box_colours=BLUE_BUTTON_COLOURS)
31         elif self._box_colours_dict == LOCKED_RED_BUTTON_COLOURS:
32             _Box.__init__(self, box_colours=RED_BUTTON_COLOURS)
33         else:
34             self.initialise_new_colours(self._fill_colour_copy)
35
36     if self.rect.collidepoint(pygame.mouse.get_pos()):
37         self.set_state_colour(WidgetState.HOVER)
38     else:
39         self.set_state_colour(WidgetState.BASE)
40
41     def set_next_icon(self):
42         super().set_next_item()
43         self._icon = self.current_item
44         self.set_image()
45
46     def process_event(self, event):
47         widget_event = super().process_event(event)
48
49         if widget_event:
50             return CustomEvent(**vars(widget_event), data=self.current_key)

```

### B.25.17 piece\_display.py

```

1 import pygame
2 from data.utils.constants import WidgetState, BLUE_BUTTON_COLOURS,
3     RED_BUTTON_COLOURS
4 from data.states.game.components.piece_sprite import PieceSprite
5 from data.helpers.widget_helpers import create_text_box
6 from data.helpers.asset_helpers import scale_and_cache
7 from data.utils.enums import Score, Rotation, Colour
8 from data.widgets.bases.widget import _Widget
9
9 class PieceDisplay(_Widget):
10     def __init__(self, active_colour, **kwargs):
11         super().__init__(**kwargs)
12
13         self._active_colour = active_colour
14         self._piece_list = []
15         self._piece_surface = None
16         self._box_colours = BLUE_BUTTON_COLOURS[WidgetState.BASE] if active_colour
17         == Colour.BLUE else RED_BUTTON_COLOURS[WidgetState.BASE]
18
19         self.initialise_piece_surface()
20
21         self.set_image()
22         self.set_geometry()
23
24     def add_piece(self, piece):
25         self._piece_list.append(piece)
26         self._piece_list.sort(key=lambda piece: Score[piece.name])
27         self.initialise_piece_surface()
28
29     def remove_piece(self, piece):
30         self._piece_list.remove(piece)
31         self.initialise_piece_surface()
32
33     def reset_piece_list(self):

```

```

33         self._piece_list = []
34         self.initialise_piece_surface()
35
36     def initialise_piece_surface(self):
37         self._piece_surface = pygame.Surface((self.size[0] - 2 * self.margin, self.
38         .size[1] - 2 * self.margin), pygame.SRCALPHA)
39
40         if (len(self._piece_list) == 0):
41             self.set_image()
42             return
43
44         piece_width = min(self.size[1] - 2 * self.margin, (self.size[0] - 2 * self.
45         .margin) / len(self._piece_list))
46         piece_list = []
47
48         for index, piece in enumerate(self._piece_list):
49             piece_instance = PieceSprite(piece, self._active_colour.
50             get_flipped_colour(), Rotation.UP)
51             piece_instance.set_geometry((0, 0), piece_width)
52             piece_instance.set_image()
53             piece_list.append((piece_instance.image, (piece_width * index, (self.
54             .piece_surface.height - piece_width) / 2)))
55
56         self._piece_surface.fblits(piece_list)
57
58         self.set_image()
59
60     def set_image(self):
61         self.image = create_text_box(self.size, self.border_width, self.
62         .box_colours)
63
64         resized_piece_surface = scale_and_cache(self._piece_surface, (self.size[0]
65         - 2 * self.margin, self.size[1] - 2 * self.margin))
66         self.image.blit(resized_piece_surface, (self.margin, self.margin))
67
68     def process_event(self, event):
69         pass

```

### B.25.18 reactive\_button.py

See Section 3.4.4.

### B.25.19 reactive\_icon\_button.py

See Section 3.4.4.

### B.25.20 rectangle.py

```

1 import pygame
2 from data.widgets.bases.widget import _Widget
3
4 class Rectangle(_Widget):
5     def __init__(self, visible=False, **kwargs):
6         super().__init__(**kwargs)
7
8         self._empty_surface = pygame.Surface((0, 0), pygame.SRCALPHA)
9         self._visible = visible
10
11        self.set_image()
12        self.set_geometry()

```

```

13
14     def set_image(self):
15         self.image = pygame.transform.scale(self._empty_surface, self.size)
16         if self._visible:
17             pygame.draw.rect(self.image, self._fill_colour, self.image.get_rect(),
18                             border_radius=int(self.border_radius))
19
20             if self.border_width:
21                 pygame.draw.rect(self.image, self._border_colour, self.image.
22                                 get_rect(), width=int(self.border_width), border_radius=int(self.border_radius
23                               ))
24
25     def process_event(self, event):
26         pass

```

### B.25.21 scrollbar.py

```

1 import pygame
2 from data.widgets.bases.pressable import _Pressable
3 from data.widgets.bases.widget import _Widget
4 from data.utils.constants import WidgetState
5 from data.utils.enums import Miscellaneous
6
7 class _Scrollbar(_Pressable, _Widget):
8     def __init__(self, vertical, **kwargs):
9         _Pressable.__init__(
10             self,
11             event=Miscellaneous.PLACEHOLDER,
12             hover_func=lambda: self.set_state_colour(WidgetState.HOVER),
13             down_func=self.down_func,
14             up_func=self.up_func,
15             prolonged=True,
16             sfx=None
17         )
18         _Widget.__init__(self, **kwargs)
19
20         self._vertical = vertical
21         self._last_mouse_px = None
22
23         self._empty_surface = pygame.Surface(self.size, pygame.SRCALPHA)
24
25         self.initialise_new_colours(self._fill_colour)
26         self.set_state_colour(WidgetState.BASE)
27
28         self.set_image()
29         self.set_geometry()
30
31     def down_func(self):
32         if self._vertical:
33             self._last_mouse_px = pygame.mouse.get_pos()[1]
34         else:
35             self._last_mouse_px = pygame.mouse.get_pos()[0]
36
37         self.set_state_colour(WidgetState.PRESS)
38
39     def up_func(self):
40         self._last_mouse_px = None
41         self.set_state_colour(WidgetState.BASE)
42
43     def set_relative_position(self, relative_position):
44         self._relative_position = relative_position
45         self.set_geometry()

```

```

46
47     def set_relative_size(self, new_relative_size):
48         self._relative_size = new_relative_size
49
50     def set_image(self):
51         self.image = pygame.transform.scale(self._empty_surface, self.size)
52
53         if self._vertical:
54             rounded_radius = self.size[0] / 2
55         else:
56             rounded_radius = self.size[1] / 2
57
58         pygame.draw.rect(self.image, self._fill_colour, (0, 0, self.size[0], self.size[1]), border_radius=int(rounded_radius))
59
60     def process_event(self, event):
61         before_state = self.get_widget_state()
62         widget_event = super().process_event(event)
63         after_state = self.get_widget_state()
64
65         if event.type == pygame.MOUSEMOTION and self._last_mouse_px:
66             if self._vertical:
67                 offset_from_last_frame = event.pos[1] - self._last_mouse_px
68                 self._last_mouse_px = event.pos[1]
69
70                 return offset_from_last_frame
71             else:
72                 offset_from_last_frame = event.pos[0] - self._last_mouse_px
73                 self._last_mouse_px = event.pos[0]
74
75             return offset_from_last_frame
76
77
78         if widget_event or before_state != after_state:
79             return 0

```

### B.25.22 scroll\_area.py

```

1 import pygame
2 from data.widgets.bases.widget import _Widget
3 from data.widgets.scrollbar import _Scrollbar
4 from data.managers.theme import theme
5
6 SCROLLBAR_WIDTH_FACTOR = 0.05
7
8 class ScrollArea(_Widget):
9     def __init__(self, widget, vertical, scroll_factor=15, **kwargs):
10         super().__init__(**kwargs)
11         if vertical is False:
12             self._relative_size = kwargs.get('relative_size')
13
14         self._relative_scroll_factor = scroll_factor / self.surface_size[1]
15
16         self._scroll_percentage = 0
17         self._widget = widget
18         self._vertical = vertical
19
20         self._widget.register_get_rect(self.calculate_widget_rect)
21
22         if self._vertical:
23             anchor_x = 'right'
24             anchor_y = 'top'

```

```

25         scale_mode = 'height'
26     else:
27         anchor_x = 'left'
28         anchor_y = 'bottom'
29         scale_mode = 'width'
30
31     self._scrollbar = _Scrollbar(
32         parent=self,
33         relative_position=(0, 0),
34         relative_size=None,
35         anchor_x=anchor_x,
36         anchor_y=anchor_y,
37         fill_colour=theme['borderPrimary'],
38         scale_mode=scale_mode,
39         vertical=vertical,
40     )
41
42     self._empty_surface = pygame.Surface((0, 0), pygame.SRCALPHA)
43
44     self.set_image()
45     self.set_geometry()
46
47     @property
48     def scroll_factor(self):
49         return self._relative_scroll_factor * self.surface_size[1]
50
51     @property
52     def scrollbar_size(self):
53         if self._vertical:
54             return (self.size[0] * SCROLLBAR_WIDTH_FACTOR, min(1, self.size[1] /
55             self._widget.rect.height) * self.size[1])
56         else:
57             return (min(1, self.size[0] / (self._widget.rect.width + 0.001)) *
58             self.size[0], self.size[1] * SCROLLBAR_WIDTH_FACTOR)
59
60     @property
61     def size(self):
62         if self._vertical is False:
63             return (self._relative_size[0] * self.surface_size[0], self.
64             _relative_size[1] * self.surface_size[1]) # scale with horizontal width to
65             # always fill entire length of screen
66         else:
67             return super().size
68
69     def calculate_scroll_percentage(self, offset, scrollbar=False):
70         if self._vertical:
71             widget_height = self._widget.rect.height
72
73             if widget_height < self.size[1]:
74                 return 0
75
76             if scrollbar:
77                 self._scroll_percentage += offset / (self.size[1] - self.
78                 scrollbar_size[1] + 0.001)
79             else:
80                 max_scroll_height = widget_height - self.size[1]
81                 current_scroll_height = self._scroll_percentage *
82                 max_scroll_height
83                 self._scroll_percentage = (current_scroll_height + offset) / (
84                 max_scroll_height + 0.001)
85             else:
86                 widget_width = self._widget.rect.width

```

```
80
81         if widget_width < self.size[0]:
82             return 0
83
84         if scrollbar:
85             self._scroll_percentage += offset / (self.size[0] - self.
86             scrollbar_size[0] + 0.001)
87             else:
88                 max_scoll_width = widget_width - self.size[0]
89                 current_scroll_width = self._scroll_percentage * max_scoll_width
90                 self._scroll_percentage = (current_scroll_width + offset) /
91                 max_scoll_width
92
93         return min(1, max(0, self._scroll_percentage))
94
95     def calculate_widget_rect(self):
96         widget_position = self.calculate_widget_position()
97         return pygame.Rect(widget_position[0] - self.position[0], self.position
98 [1] + widget_position[1], self.size[0], self.size[1])
99
100    def calculate_widget_position(self):
101        if self._vertical:
102            return (0, -self._scroll_percentage * (self._widget.rect.height - self.
103             .size[1]))
104            else:
105                return (-self._scroll_percentage * (self._widget.rect.width - self.
106                 size[0]), 0)
107
108    def calculate_relative_scrollbar_position(self):
109        if self._vertical:
110            vertical_offset = (self.size[1] - self.scrollbar_size[1]) * self.
111             _scroll_percentage
112            scrollbar_position = (0, vertical_offset)
113            else:
114                horizontal_offset = (self.size[0] - self.scrollbar_size[0]) * self.
115             _scroll_percentage
116                scrollbar_position = (horizontal_offset, 0)
117
118        return (scrollbar_position[0] / self.size[0], scrollbar_position[1] / self
119             .size[1])
120
121    def set_widget(self, new_widget):
122        self._widget = new_widget
123        self.set_image()
124        self.set_geometry()
125
126    def set_image(self):
127        self.image = pygame.transform.scale(self._empty_surface, self.size)
128        self.image.fill(theme['fillPrimary'])
129
130        self._widget.set_image()
131        self.image.blit(self._widget.image, self.calculate_widget_position())
132
133        self._scrollbar.set_relative_position(self.
134        calculate_relative_scrollbar_position()) # WRONG USING RELATIVE
135        self._scrollbar.set_relative_size((self.scrollbar_size[0] / self.size[1],
136             self.scrollbar_size[1] / self.size[1]))
137        self._scrollbar.set_image()
138        relative_scrollbar_position = (self._scrollbar.rect.left - self.position
139             [0], self._scrollbar.rect.top - self.position[1])
140        self.image.blit(self._scrollbar.image, relative_scrollbar_position)
```

```

131     def set_geometry(self):
132         super().set_geometry()
133         self._widget.set_geometry()
134         self._scrollbar.set_geometry()
135
136     def set_surface_size(self, new_surface_size):
137         super().set_surface_size(new_surface_size)
138         self._widget.set_surface_size(new_surface_size)
139         self._scrollbar.set_surface_size(new_surface_size)
140
141     def process_event(self, event):
142         # WAITING FOR PYGAME-CE 2.5.3 TO RELEASE TO FIX SCROLL FLAGS
143         # self.image.scroll(0, SCROLL_FACTOR)
144         # self.image.scroll(0, -SCROLL_FACTOR)
145
146         offset = self._scrollbar.process_event(event)
147
148         if offset is not None:
149             self.set_image()
150
151             if abs(offset) > 0:
152                 self._scroll_percentage = self.calculate_scroll_percentage(offset,
153 scrollbar=True)
154
155                 if self.rect.collidepoint(pygame.mouse.get_pos()):
156                     if event.type == pygame.MOUSEBUTTONDOWN:
157                         if event.button == 4:
158                             self._scroll_percentage = self.calculate_scroll_percentage(-
self.scroll_factor)
159                             self.set_image()
160
161                         elif event.button == 5:
162                             if self._scroll_percentage == 100:
163                                 return
164
165                 self._scroll_percentage = self.calculate_scroll_percentage(
self.scroll_factor)
166                 self.set_image()
167
168             widget_event = self._widget.process_event(event, scrolled_pos=self.
calculate_widget_position())
169             if widget_event is not None:
170                 self.set_image()
171
172             return widget_event

```

### B.25.23 slider\_thumb.py

```

1 from data.widgets.bases.pressable import _Pressable
2 from data.utils.constants import WidgetState
3 from data.helpers.widget_helpers import create_slider_thumb
4 from data.managers.theme import theme
5
6 class _SliderThumb(_Pressable):
7     def __init__(self, radius, border_colour=theme['borderPrimary'], fill_colour=
theme['fillPrimary']):
8         super().__init__(
9             event=None,
10             down_func=self.down_func,
11             up_func=self.up_func,
12             hover_func=self.hover_func,
13             prolonged=True,

```

```

14         sfx=None
15     )
16     self._border_colour = border_colour
17     self._radius = radius
18     self._percent = None
19
20     self.state = WidgetState.BASE
21     self.initialise_new_colours(fill_colour)
22
23     def get_position(self):
24         return (self.rect.x, self.rect.y)
25
26     def set_position(self, position):
27         self.rect = self._thumb_surface.get_rect()
28         self.rect.topleft = position
29
30     def get_surface(self):
31         return self._thumb_surface
32
33     def set_surface(self, radius, border_width):
34         self._thumb_surface = create_slider_thumb(radius, self._colours[self.state],
35             self._border_colour, border_width)
36
37     def get_pressed(self):
38         return self._pressed
39
40     def down_func(self):
41         self.state = WidgetState.PRESS
42
43     def up_func(self):
44         self.state = WidgetState.BASE
45
46     def hover_func(self):
47         self.state = WidgetState.HOVER

```

### B.25.24 switch.py

```

1 import pygame
2 from data.widgets.bases.widget import _Widget
3 from data.widgets.bases.pressable import _Pressable
4 from data.utils.constants import WidgetState
5 from data.helpers.widget_helpers import create_switch
6 from data.components.custom_event import CustomEvent
7 from data.managers.theme import theme
8
9 class Switch(_Pressable, _Widget):
10     def __init__(self, relative_height, event, fill_colour=theme['fillTertiary'],
11                  on_colour=theme['fillSecondary'], off_colour=theme['fillPrimary'], **kwargs):
12         _Pressable.__init__(
13             self,
14             event=event,
15             hover_func=self.hover_func,
16             down_func=lambda: self.set_state_colour(WidgetState.PRESS),
17             up_func=self.up_func,
18         )
19         _Widget.__init__(self, relative_size=(relative_height * 2, relative_height),
20                          scale_mode='height', fill_colour=fill_colour, **kwargs)
21
22         self._on_colour = on_colour
23         self._off_colour = off_colour
24         self._background_colour = None

```

```

24         self._is_toggled = None
25         self.set_toggle_state(False)
26
27     self.initialise_new_colours(self._fill_colour)
28     self.set_state_colour(WidgetState.BASE)
29
30     self.set_image()
31     self.set_geometry()
32
33     def hover_func(self):
34         self.set_state_colour(WidgetState.HOVER)
35
36     def set_toggle_state(self, is_toggled):
37         self._is_toggled = is_toggled
38         if is_toggled:
39             self._background_colour = self._on_colour
40         else:
41             self._background_colour = self._off_colour
42
43     self.set_image()
44
45     def up_func(self):
46         if self.get_widget_state() == WidgetState.PRESS:
47             toggle_state = not(self._is_toggled)
48             self.set_toggle_state(toggle_state)
49
50         self.set_state_colour(WidgetState.BASE)
51
52     def draw_thumb(self):
53         margin = self.size[1] * 0.1
54         thumb_radius = (self.size[1] / 2) - margin
55
56         if self._is_toggled:
57             thumb_center = (self.size[0] - margin - thumb_radius, self.size[1] /
58                             2)
58         else:
59             thumb_center = (margin + thumb_radius, self.size[1] / 2)
60
61         pygame.draw.circle(self.image, self._fill_colour, thumb_center,
62                           thumb_radius)
62
63     def set_image(self):
64         self.image = create_switch(self.size, self._background_colour)
65         self.draw_thumb()
66
67     def process_event(self, event):
68         data = super().process_event(event)
69
70         if data:
71             return CustomEvent(**vars(data), toggled=self._is_toggled)

```

### B.25.25 text.py

```

1 import pygame
2 from data.widgets.bases.widget import _Widget
3 from data.helpers.font_helpers import text_width_to_font_size,
4     text_height_to_font_size, height_to_font_size
4 from data.helpers.widget_helpers import create_text_box
5
6 class Text(_Widget): # Pure text
7     def __init__(self, text, center=True, fit_vertical=True, box_colours=None,
8                  strength=0.05, font_size=None, **kwargs):

```

```

8         super().__init__(**kwargs)
9         self._text = text
10        self._fit_vertical = fit_vertical
11        self._strength = strength
12        self._box_colours = box_colours
13
14        if fit_vertical:
15            self._relative_font_size = text_height_to_font_size(self._text, self.
16            _font, (self.size[1] - 2 * (self.margin + self.border_width)) / self.
17            surface_size[1])
18        else:
19            self._relative_font_size = text_width_to_font_size(self._text, self.
20            _font, (self.size[0] - 2 * (self.margin + self.border_width)) / self.
21            surface_size[1])
22
23        if font_size:
24            self._relative_font_size = font_size / self.surface_size[1]
25
26        self._center = center
27        self.rect = self._font.get_rect(self._text, size=self.font_size)
28        self.rect.topleft = self.position
29
30        self._empty_surface = pygame.Surface((0, 0), pygame.SRCALPHA)
31
32        self.set_image()
33        self.set_geometry()
34
35    def resize_text(self):
36        if self._fit_vertical:
37            self._relative_font_size = text_height_to_font_size(self._text, self.
38            _font, (self.size[1] - 2 * (self.margin + self.border_width)) / self.
39            surface_size[1])
40        else:
41            ideal_font_size = height_to_font_size(self._font, target_height=(self.
42            size[1] - (self.margin + self.border_width)) / self.surface_size[1]
43            new_font_size = text_width_to_font_size(self._text, self._font, (self.
44            size[0] - (self.margin + self.border_width)) / self.surface_size[1])
45
46            if new_font_size < ideal_font_size:
47                self._relative_font_size = new_font_size
48            else:
49                self._relative_font_size = ideal_font_size
50
51    def set_text(self, new_text):
52        self._text = new_text
53
54        self.resize_text()
55        self.set_image()
56
57    def set_image(self):
58        if self._box_colours:
59            self.image = create_text_box(self.size, self.border_width, self.
60            _box_colours)
61        else:
62            text_surface = pygame.transform.scale(self._empty_surface, self.size)
63            self.image = text_surface
64
65            if self._fill_colour:
66                fill_rect = pygame.FRect(0, 0, self.size[0], self.size[1])
67                pygame.draw.rect(self.image, self._fill_colour, fill_rect,
68                border_radius=int(self.border_radius))
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```

```

60         self._font.strength = self._strength
61         font_rect_size = self._font.get_rect(self._text, size=self.font_size).size
62         if self._center:
63             font_position = ((self.size[0] - font_rect_size[0]) / 2, (self.size[1]
64             - font_rect_size[1]) / 2)
65         else:
66             font_position = (self.margin / 2, (self.size[1] - font_rect_size[1]) /
67             2)
67         self._font.render_to(self.image, font_position, self._text, fgcolor=self.
68         _text_colour, size=self.font_size)
69
70         if self._box_colours is None and self.border_width:
71             fill_rect = pygame.FRect(0, 0, self.size[0], self.size[1])
72             pygame.draw.rect(self.image, self._border_colour, fill_rect, width=int
73             (self.border_width), border_radius=int(self.border_radius))
74
75     def process_event(self, event):
76         pass

```

**B.25.26 text\_button.py**

```

1  from data.widgets.bases.pressable import _Pressable
2  from data.widgets.bases.box import _Box
3  from data.widgets.text import Text
4  from data.utils.constants import WidgetState, BLUE_BUTTON_COLOURS
5
6  class TextButton(_Box, _Pressable, Text):
7      def __init__(self, event, **kwargs):
8          _Box.__init__(self, box_colours=BLUE_BUTTON_COLOURS)
9          _Pressable.__init__(
10              self,
11              event=event,
12              hover_func=lambda: self.set_state_colour(WidgetState.HOVER),
13              down_func=lambda: self.set_state_colour(WidgetState.PRESS),
14              up_func=lambda: self.set_state_colour(WidgetState.BASE),
15          )
16          Text.__init__(self, box_colours=BLUE_BUTTON_COLOURS[WidgetState.BASE], **
17          kwargs)
18
19          self.initialise_new_colours(self._fill_colour)
20          self.set_state_colour(WidgetState.BASE)

```

**B.25.27 text\_input.py**

See Section 3.4.4.

**B.25.28 timer.py**

```

1  import pygame
2  from data.utils.constants import WidgetState, BLUE_BUTTON_COLOURS,
3      RED_BUTTON_COLOURS
4  from data.components.custom_event import CustomEvent
5  from data.managers.animation import animation
6  from data.utils.enums import Colour
7  from data.widgets.text import Text
8
9  class Timer(Text):
10      def __init__(self, active_colour, event=None, start_mins=60, **kwargs):
11          box_colours = BLUE_BUTTON_COLOURS[WidgetState.BASE] if active_colour ==
12          Colour.BLUE else RED_BUTTON_COLOURS[WidgetState.BASE]

```

```

11         self._current_ms = float(start_mins) * 60 * 1000
12         self._active_colour = active_colour
13         self._active = False
14         self._timer_running = False
15         self._event = event
16
17     super().__init__(text=self.format_to_text(), fit_vertical=False,
18                      box_colours=box_colours, **kwargs)
19
20     def set_active(self, is_active):
21         if self._active == is_active:
22             return
23
24         if is_active and self._timer_running is False:
25             self._timer_running = True
26             animation.set_timer(1000, self.decrement_second)
27
28         self._active = is_active
29
30     def set_time(self, milliseconds):
31         self._current_ms = milliseconds
32         self._text = self.format_to_text()
33         self.set_image()
34         self.set_geometry()
35
36     def get_time(self):
37         return self._current_ms / (1000 * 60)
38
39     def decrement_second(self):
40         if self._active:
41             self.set_time(self._current_ms - 1000)
42
43             if self._current_ms <= 0:
44                 self._active = False
45                 self._timer_running = False
46                 self.set_time(0)
47                 pygame.event.post(pygame.event.Event(pygame.MOUSEMOTION, pos=
48                               pygame.mouse.get_pos())) # RANDOM EVENT TO TRIGGER process_event
49             else:
50                 animation.set_timer(1000, self.decrement_second)
51         else:
52             self._timer_running = False
53
54     def format_to_text(self):
55         raw_seconds = self._current_ms / 1000
56         minutes, seconds = divmod(raw_seconds, 60)
57         return f'{str(int(minutes)).zfill(2)}:{str(int(seconds)).zfill(2)}'
58
59     def process_event(self, event):
60         if self._current_ms <= 0:
61             return CustomEvent(**vars(self._event), active_colour=self.
62                               _active_colour)

```

### B.25.29 volume\_slider.py

```

1 import pygame
2 from data.helpers.asset_helpers import scale_and_cache
3 from data.helpers.widget_helpers import create_slider
4 from data.utils.event_types import SettingsEventType
5 from data.components.custom_event import CustomEvent
6 from data.widgets.slider_thumb import _SliderThumb

```

```

7  from data.widgets.bases.widget import _Widget
8  from data.utils.constants import WidgetState
9  from data.managers.theme import theme
10
11 class VolumeSlider(_Widget):
12     def __init__(self, relative_length, default_volume, volume_type, thumb_colour=
13         theme['fillSecondary'], **kwargs):
14         super().__init__(relative_size=(relative_length, relative_length * 0.2),
15                         **kwargs)
16
17         self._volume_type = volume_type
18         self._selected_percent = default_volume
19         self._last_mouse_x = None
20
21         self._thumb = _SliderThumb(radius=self.size[1] / 2, border_colour=self.
22             _border_colour, fill_colour=thumb_colour)
23         self._gradient_surface = create_slider(self.calculate_slider_size(), self.
24             _fill_colour, self.border_width, self._border_colour)
25
26         self._empty_surface = pygame.Surface(self.size, pygame.SRCALPHA)
27
28     @property
29     def position(self):
30         '''Minus so easier to position slider by starting from the left edge of
31         the slider instead of the thumb'''
32         return (self._relative_position[0] * self.surface_size[0] - (self.size[1]
33             / 2), self._relative_position[1] * self.surface_size[1])
34
35     def calculate_slider_position(self):
36         return (self.size[1] / 2, self.size[1] / 4)
37
38     def calculate_slider_size(self):
39         return (self.size[0] - 2 * (self.size[1] / 2), self.size[1] / 2)
40
41     def calculate_selected_percent(self, mouse_pos):
42         if self._last_mouse_x is None:
43             return
44
45         x_change = (mouse_pos[0] - self._last_mouse_x) / (self.
46             calculate_slider_size()[0] - 2 * self.border_width)
47         return max(0, min(self._selected_percent + x_change, 1))
48
49     def calculate_thumb_position(self):
50         gradient_size = self.calculate_slider_size()
51         x = gradient_size[0] * self._selected_percent
52         y = 0
53
54         return (x, y)
55
56     def relative_to_global_position(self, position):
57         relative_x, relative_y = position
58         return (relative_x + self.position[0], relative_y + self.position[1])
59
60     def set_image(self):
61         gradient_scaled = scale_and_cache(self._gradient_surface, self.
62             calculate_slider_size())
63         gradient_position = self.calculate_slider_position()
64
65         self.image = pygame.transform.scale(self._empty_surface, (self.size))
66         self.image.blit(gradient_scaled, gradient_position)
67
68         thumb_position = self.calculate_thumb_position()

```

```

61         self._thumb.set_surface(radius=self.size[1] / 2, border_width=self.
62             border_width)
63         self._thumb.set_position(self.relative_to_global_position((thumb_position
64             [0], thumb_position[1])))
65
66     def set_volume(self, volume):
67         self._selected_percent = volume
68         self.set_image()
69
70     def process_event(self, event):
71         if event.type not in [pygame.MOUSEMOTION, pygame.MOUSEBUTTONDOWN, pygame.
72             MOUSEBUTTONUP]:
73             return
74
75         before_state = self._thumb.state
76         self._thumb.process_event(event)
77         after_state = self._thumb.state
78
79         if before_state != after_state:
80             self.set_image()
81
82         if event.type in [pygame.MOUSEBUTTONDOWN, pygame.MOUSEBUTTONUP]:
83             self._last_mouse_x = None
84             return CustomEvent(SettingsEventType.VOLUME_SLIDER_CLICK, volume=
85             round(self._selected_percent, 3), volume_type=self._volume_type)
86
87         if self._thumb.state == WidgetState.PRESS:
88             selected_percent = self.calculate_selected_percent(event.pos)
89             self._last_mouse_x = event.pos[0]
90
91             if selected_percent:
92                 self._selected_percent = selected_percent
93                 self.set_image()
94             return CustomEvent(SettingsEventType.VOLUME_SLIDER_SLIDE)

```

**B.25.30 \_\_init\_\_.py**

```

1  from data.widgets.bases.widget import _Widget
2  from data.widgets.bases.pressable import _Pressable
3  from data.widgets.bases.circular import _Circular
4  from data.widgets.bases.box import _Box
5  from data.widgets.colour_display import _ColourDisplay
6  from data.widgets.colour_square import _ColourSquare
7  from data.widgets.colour_slider import _ColourSlider
8  from data.widgets.slider_thumb import _SliderThumb
9  from data.widgets.scrollbar import _Scrollbar
10
11 from data.widgets.board_thumbnail_button import BoardThumbnailButton
12 from data.widgets.multiple_icon_button import MultipleIconButton
13 from data.widgets.reactive_icon_button import ReactiveIconButton
14 from data.widgets.board_thumbnail import BoardThumbnail
15 from data.widgets.reactive_button import ReactiveButton
16 from data.widgets.volume_slider import VolumeSlider
17 from data.widgets.colour_picker import ColourPicker
18 from data.widgets.colour_button import ColourButton
19 from data.widgets.browser_strip import BrowserStrip
20 from data.widgets.piece_display import PieceDisplay
21 from data.widgets.browser_item import BrowserItem
22 from data.widgets.text_button import TextButton

```

```

23 from data.widgets.icon_button import IconButton
24 from data.widgets.scroll_area import ScrollArea
25 from data.widgets.chessboard import Chessboard
26 from data.widgets.text_input import TextInput
27 from data.widgets.rectangle import Rectangle
28 from data.widgets.move_list import MoveList
29 from data.widgets.dropdown import Dropdown
30 from data.widgets.carousel import Carousel
31 from data.widgets.switch import Switch
32 from data.widgets.timer import Timer
33 from data.widgets.text import Text
34 from data.widgets.icon import Icon
35
36 __all__ = ['Text', 'TextButton', 'ColourPicker', 'ColourButton', 'Switch', ''
37             'Dropdown', 'IconButton', 'Icon', 'VolumeSlider', 'TextInput', ''
38             'MultipleIconButton', 'Carousel', 'Timer', 'Rectangle', 'Chessboard', ''
39             'ScrollArea', 'MoveList', 'BoardThumbnail', 'BrowserStrip', 'BrowserItem', ''
40             'PieceDisplay', 'BoardThumbnailButton', 'ReactiveButton', 'ReactiveIconButton']

```

## B.26 data\widgets\bases

### B.26.1 box.py

```

1 from data.utils.constants import WidgetState
2
3 class _Box:
4     def __init__(self, box_colours):
5         self._box_colours_dict = box_colours
6         self._box_colours = self._box_colours_dict[WidgetState.BASE]
7
8     def set_state_colour(self, state):
9         self._box_colours = self._box_colours_dict[state]
10        super().set_state_colour(state)

```

### B.26.2 circular.py

See Section 3.4.3.

### B.26.3 pressable.py

```

1 import pygame
2 from data.utils.constants import WidgetState
3 from data.managers.audio import audio
4 from data.utils.assets import SFX
5
6 class _Pressable:
7     def __init__(self, event, down_func=None, up_func=None, hover_func=None,
8                  prolonged=False, sfx=SFX['button_click'], **kwargs):
9         self._down_func = down_func
10        self._up_func = up_func
11        self._hover_func = hover_func
12        self._pressed = False
13        self._prolonged = prolonged
14        self._sfx = sfx
15
16        self._event = event
17
18        self._widget_state = WidgetState.BASE

```

```

19         self._colours = {}
20
21     def set_state_colour(self, state):
22         self._fill_colour = self._colours[state]
23
24         self.set_image()
25
26     def initialise_new_colours(self, colour):
27         r, g, b, a = pygame.Color(colour).rgba
28
29         self._colours = {
30             WidgetState.BASE: pygame.Color(r, g, b, a),
31             WidgetState.HOVER: pygame.Color(min(r + 25, 255), min(g + 25, 255),
32             min(b + 25, 255), a),
33             WidgetState.PRESS: pygame.Color(min(r + 50, 255), min(g + 50, 255),
34             min(b + 50, 255), a)
35         }
36
37     def get_widget_state(self):
38         return self._widget_state
39
40     def process_event(self, event):
41         match event.type:
42             case pygame.MOUSEBUTTONDOWN:
43                 if self.rect.collidepoint(event.pos):
44                     self._down_func()
45                     self._widget_state = WidgetState.PRESS
46
47             case pygame.MOUSEBUTTONUP:
48                 if self.rect.collidepoint(event.pos):
49                     if self._widget_state == WidgetState.PRESS:
50                         if self._sfx:
51                             audio.play_sfx(self._sfx)
52
53                         self._up_func()
54                         self._widget_state = WidgetState.HOVER
55                         return self._event
56
57             elif self._widget_state == WidgetState.BASE:
58                 self._hover_func()
59
60             elif self._prolonged and self._widget_state == WidgetState.PRESS:
61                 if self._sfx:
62                     audio.play_sfx(self._sfx)
63                     self._up_func()
64                     self._widget_state = WidgetState.BASE
65                     return self._event
66
67             case pygame.MOUSEMOTION:
68                 if self.rect.collidepoint(event.pos):
69                     if self._widget_state == WidgetState.PRESS:
70                         return
71                     elif self._widget_state == WidgetState.BASE:
72                         self._hover_func()
73                         self._widget_state = WidgetState.HOVER
74                     elif self._widget_state == WidgetState.HOVER:
75                         self._hover_func()
76
77             else:
78                 if self._prolonged is False:
79                     if self._widget_state in [WidgetState.PRESS, WidgetState.
80                     HOVER]:
81                         self._widget_state = WidgetState.BASE

```

```
78         self._up_func()
79     elif self._widget_state == WidgetState.BASE:
80         return
81     elif self._prolonged is True:
82         if self._widget_state in [WidgetState.PRESS, WidgetState.
83             BASE]:
84             return
85     else:
86         self._widget_state = WidgetState.BASE
87         self._up_func()
```

#### B.26.4 widget.py

See Section 3.4.3.