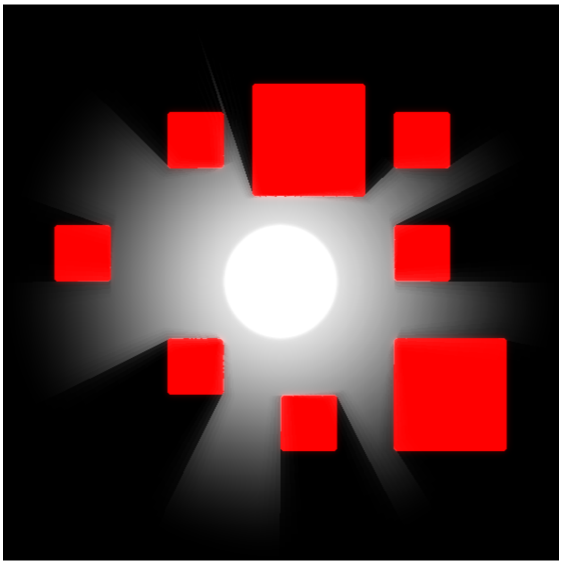
NEA report

# Laser Chess

**Toby Mok**



Candidate Number: 6100
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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/`.

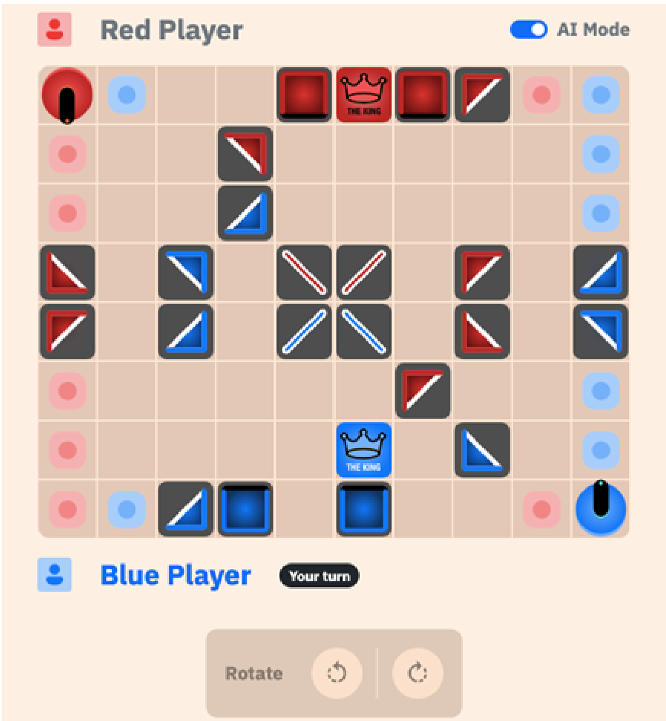


Figure 1.1: Online implementation on laser-chess.com

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 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 unreliably 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 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 & 3 & 5*
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 2 & 4*
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 significant 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. Unliked 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 |
| • Versatile and intuitive, uses simple syntax and dynamic typing<br>• Supports both object-oriented and procedural programming<br>• Rich ecosystem of third-party modules and libraries<br>• Interpreted language, good for portability and easy debugging | • Slow at runtime<br>• High memory consumption |

| 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

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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 mines.

### 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.

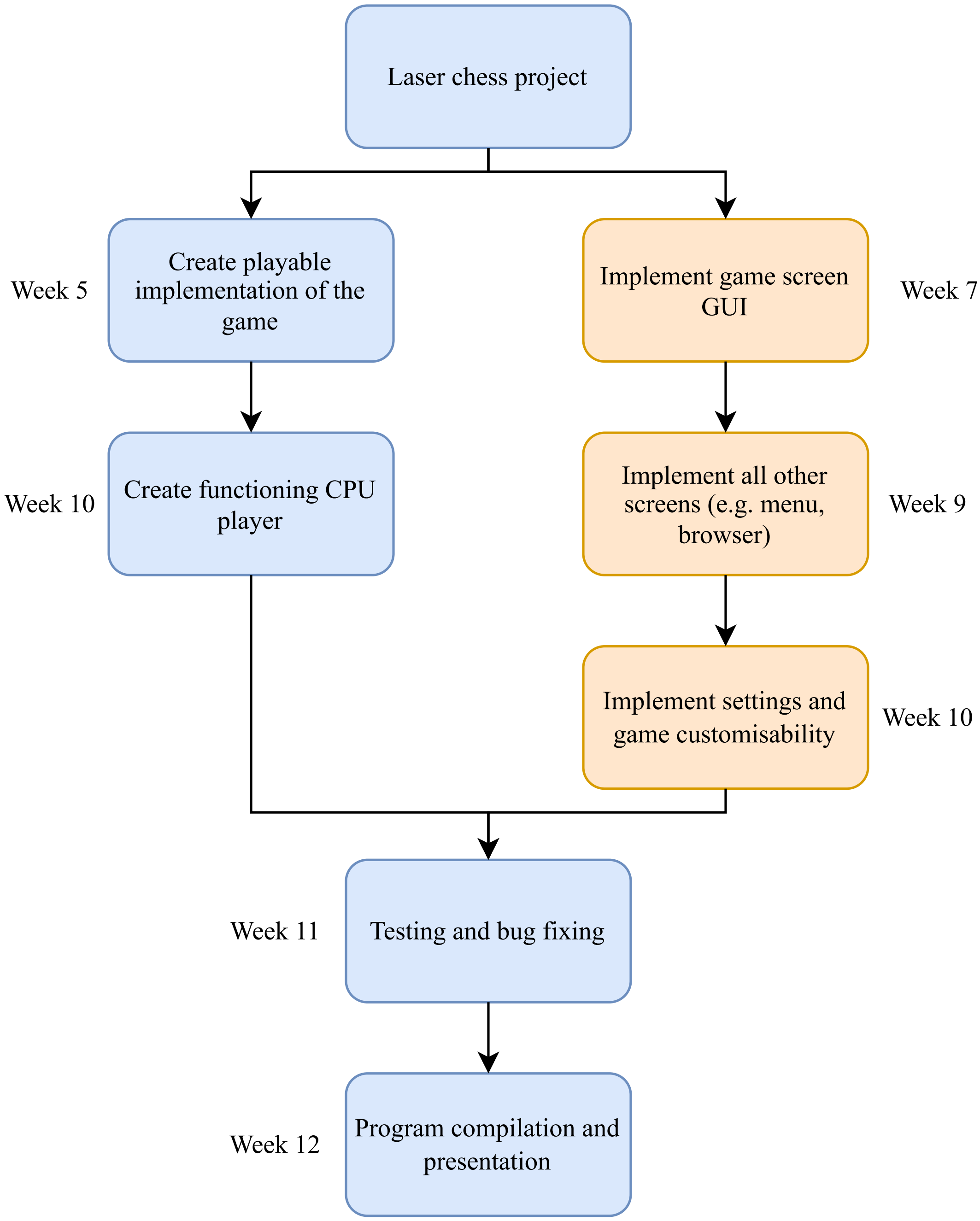
## 1.5 Limitations

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.


Laser chess project
Week 5
Create playable implementation of the game
Implement game screen GUI
Week 7
Week 10
Create functioning CPU player
Implement all other screens (e.g. menu, browser)
Week 9
Implement settings and game customisability
Week 10
Week 11
Testing and bug fixing
Week 12
Program compilation and presentation

# 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:

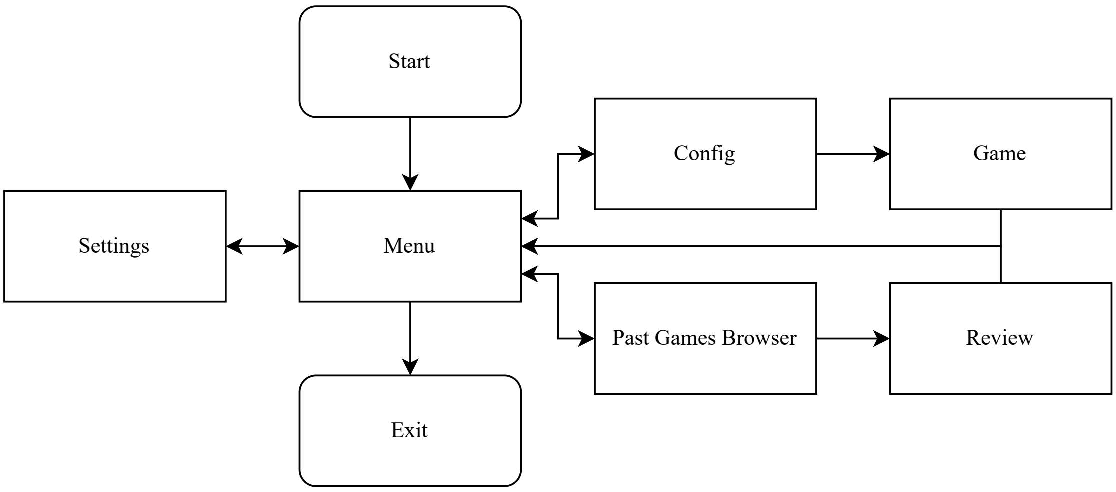



Figure 2.1: Flowchart for Program Overview

### 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

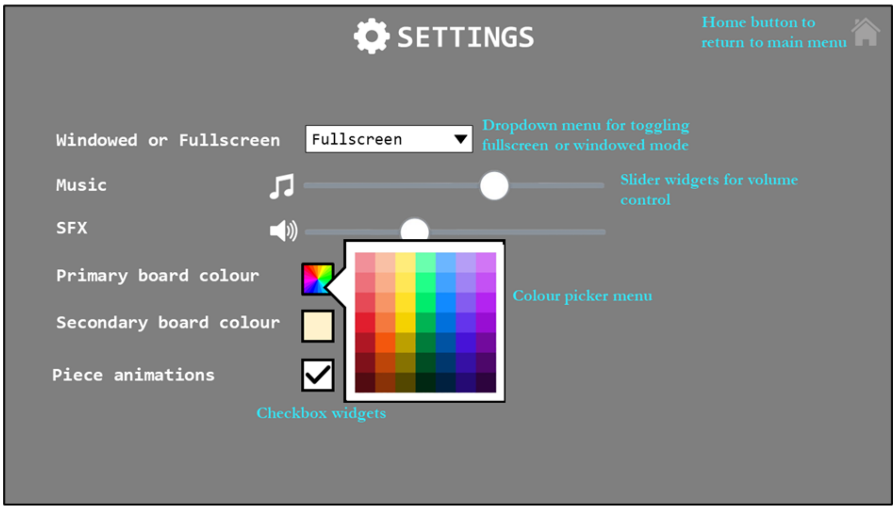



Figure 2.3: Settings screen prototype

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.

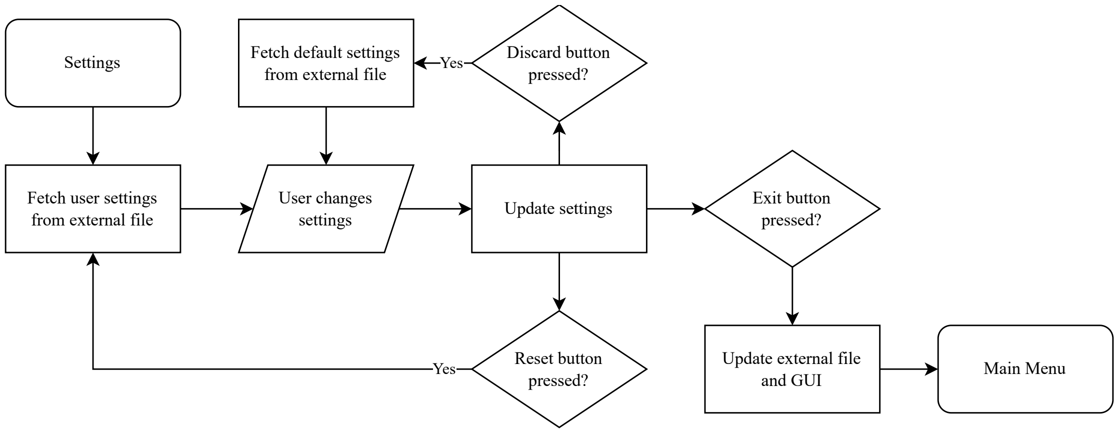



Figure 2.4: Flowchart for Settings

### 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.

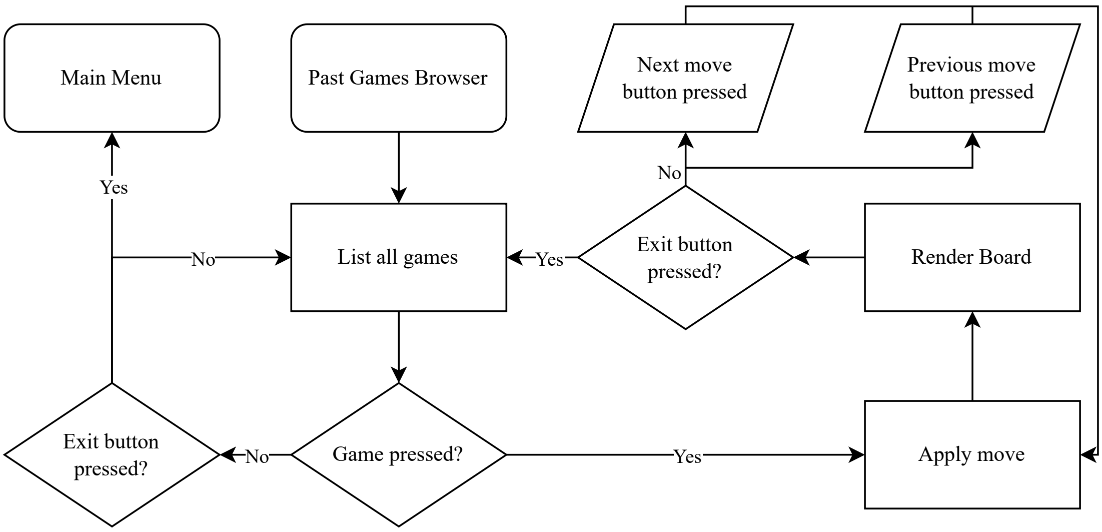



Figure 2.6: Flowchart for Browser

### 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.

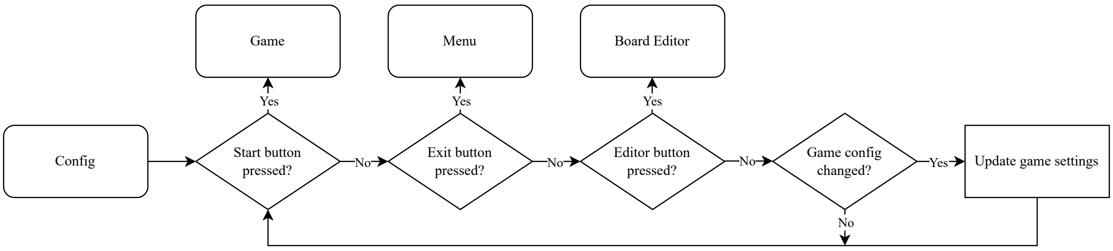



Figure 2.8: Flowchart for Config

### 2.1.5 Game

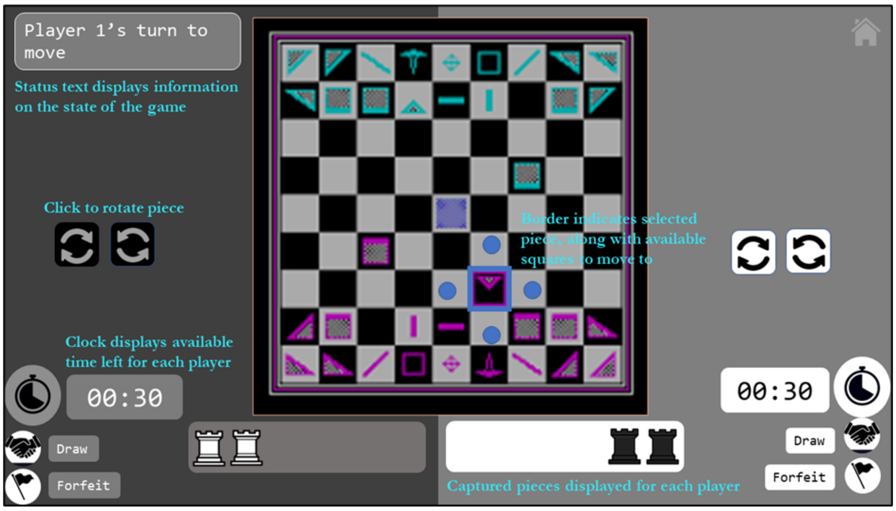



Figure 2.9: Game screen prototype

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, surrounding 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.

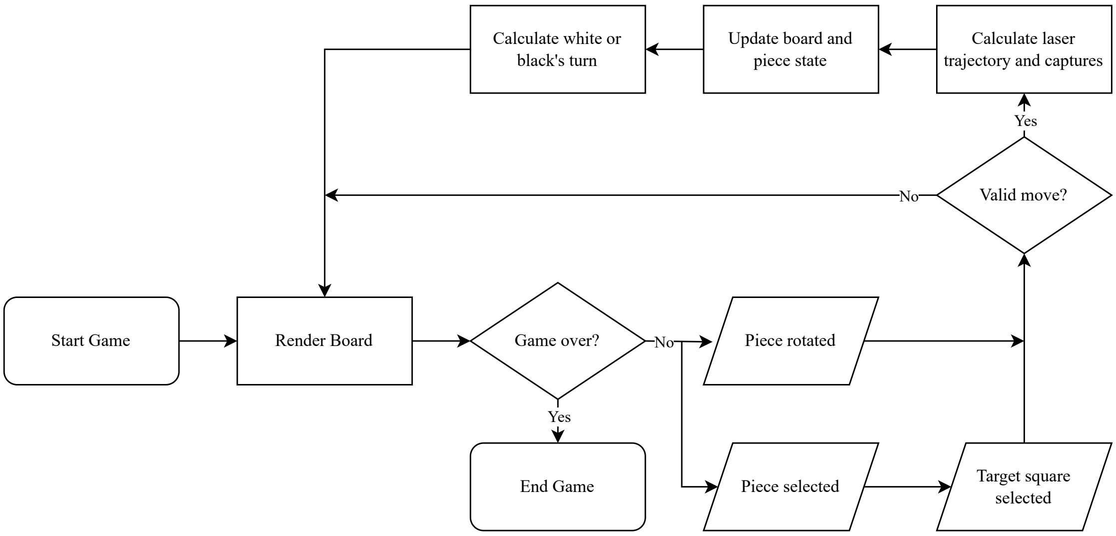



Figure 2.10: Flowchart for Game

### 2.1.6 Board Editor

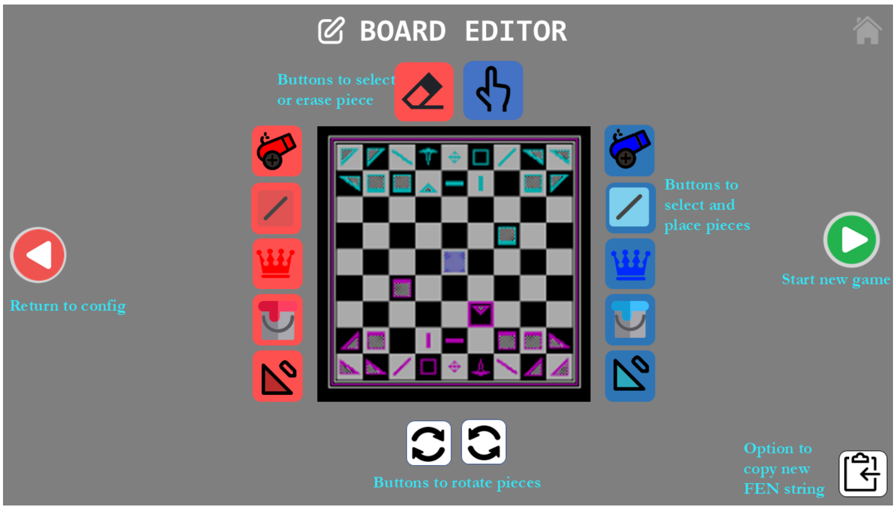



Figure 2.11: Editor screen prototype

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).

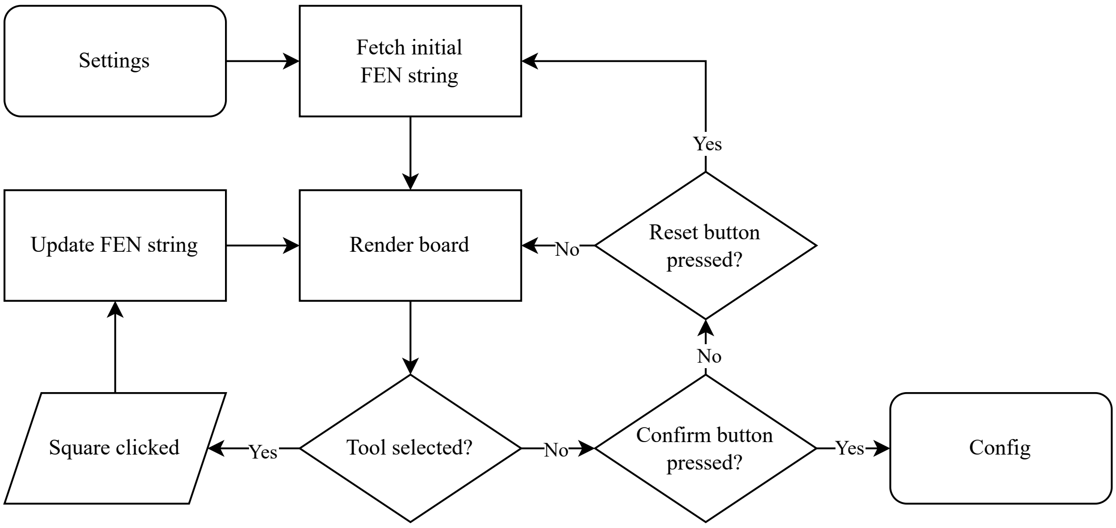



Figure 2.12: Flowchart for board editor

## 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 maximising the player's advantage in each recursive call.

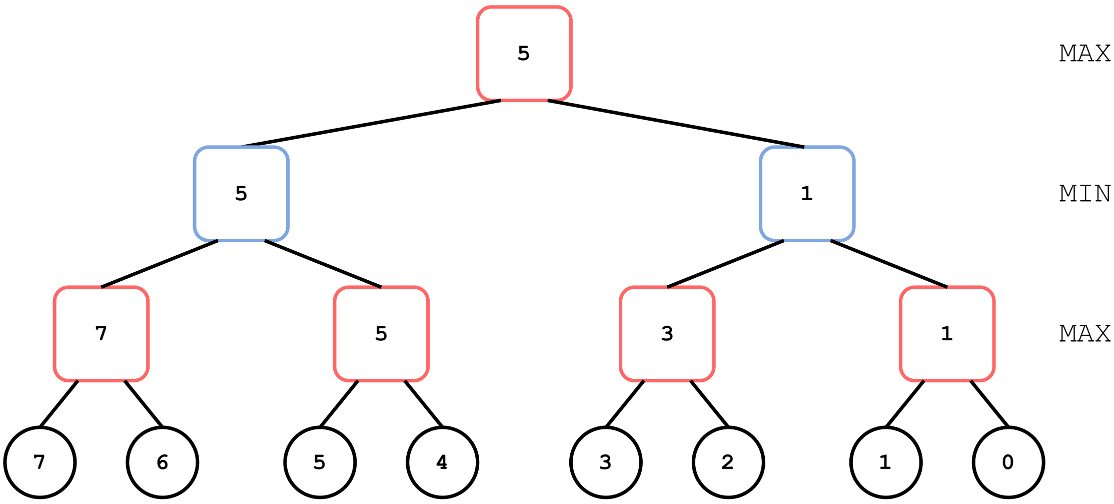



Figure 2.13: Example minimax tree

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 ← −∞
        for child of node do
            value ← MAX(value, MINIMAX(child, depth − 1, false))
        end for
        return value
    else
        value ← +∞
        for child of node do
            value ← MIN(value, 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:

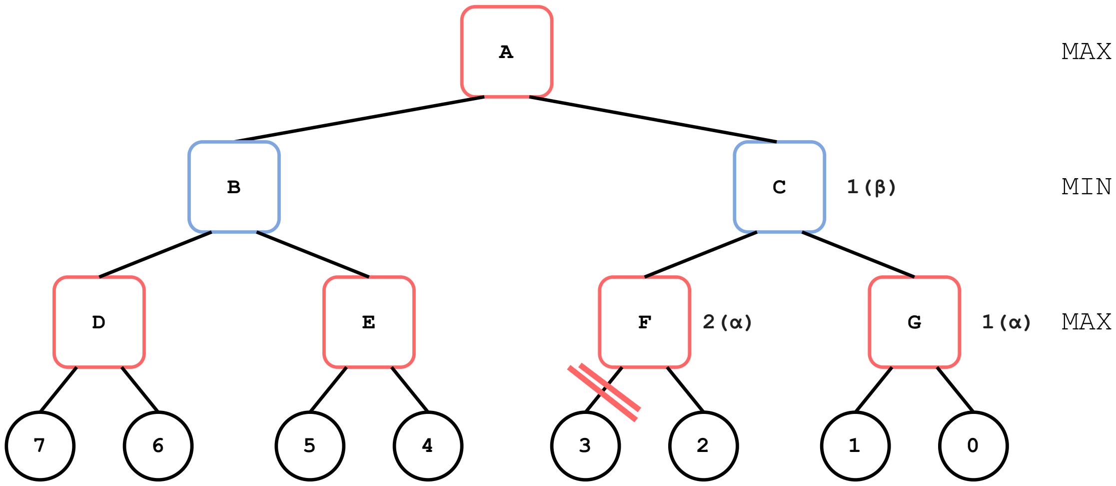



Figure 2.14: Example minimax tree with alpha-beta pruning

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 is 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**
      $value \leftarrow \text{MAX}(value, \text{MINIMAX}(child, depth - 1, \alpha, \beta, false))$
      **if** $value > \beta$ **then break**
      **end if**
      $\alpha \leftarrow \text{MAX}(\alpha, value)$
    **end for**
    **return** *value*
  **else**
    $value \leftarrow +\infty$
    **for** child of node **do**
      $value \leftarrow \text{MIN}(value, \text{MINIMAX}(child, depth - 1, \alpha, \beta, true))$
      **if** $value < \alpha$ **then break**
      **end if**
      $\beta \leftarrow \text{MIN}(\beta, value)$
    **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, α, β, maximisingPlayer)
    hash_key ← HASH(node)
    entry ← GETENTRY(hash_key)

    if entry.hash_key = hash_key AND entry.hash_key ≥ depth then
        if entry.hash_key = EXACT then
            return entry.value
        else if entry.hash_key = LOWER then
            α ← MAX(α, entry.value)
        else if entry.hash_key = UPPER then
            β ← MIN(β, entry.value)
        end if
        if α ≥ β then
            return entry.value
        end if
    end if

     ...normal minimax...

    entry.value ← value
    entry.depth ← depth
    if value ≤ α then
        entry.flag ← UPPER
    else if value ≥ β then
        entry.flag ← LOWER
    else
        entry.flag ← 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 ← 0
    for each square on board do
        if square is not empty then
            hash ⊕ RANDOMINTS[square][piece on square]
        end if
    end for
    return hash
end function

function UPDATEHASH(hash, move)
    hash ⊕ RANDOMINTS[source square][piece]
    hash ⊕ RANDOMINTS[destination square][piece]
    if red to move then
        hash ⊕ hash for red to move ▷ 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 characteris/ 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).

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

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:

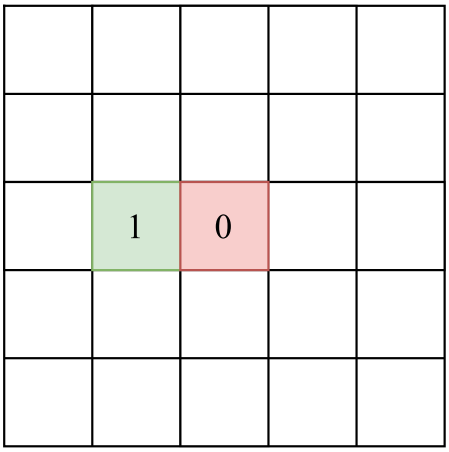



Figure 2.16: shifted_bitboard = piece_bitboard >> 1

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.

$$\text{available\_squares\_right} = (\text{piece\_bitboard} >> 1)\ \&\ \sim \text{all\_pieces\_bitboard}$$

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:

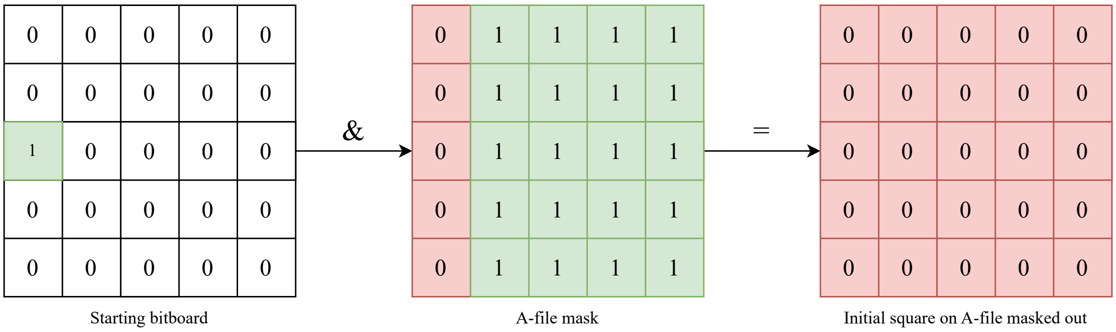



Figure 2.17: A-file mask example

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)
  $masked\_a\_square \leftarrow selected\_square \ \& \ A\_FILE\_MASK$
  $masked\_j\_square \leftarrow selected\_square \ \& \ J\_FILE\_MASK$

  $top\_left \leftarrow masked\_a\_square << 9$
  $top\_left \leftarrow masked\_a\_square << 9$
  $top\_middle \leftarrow selected\_square << 10$
  $top\_right \leftarrow masked\_ << 11$
  $middle\_right \leftarrow masked\_ << 1$
  $bottom\_right \leftarrow masked\_ >> 9$
  $bottom\_middle \leftarrow selected\_square >> 10$
  $bottom\_left \leftarrow masked\_a\_square >> 11$
  $middle\_left \leftarrow masked\_a\_square >> 1$

  $possible\_moves = top\_left \mid top\_middle \mid top\_right \mid middle\_right \mid bottom\_right \mid bottom\_middle \mid bottom\_left \mid middle\_left$
  $valid\_moves = possible\_moves \ \& \sim ALL\_PIECES\_BITBOARD$

  **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:

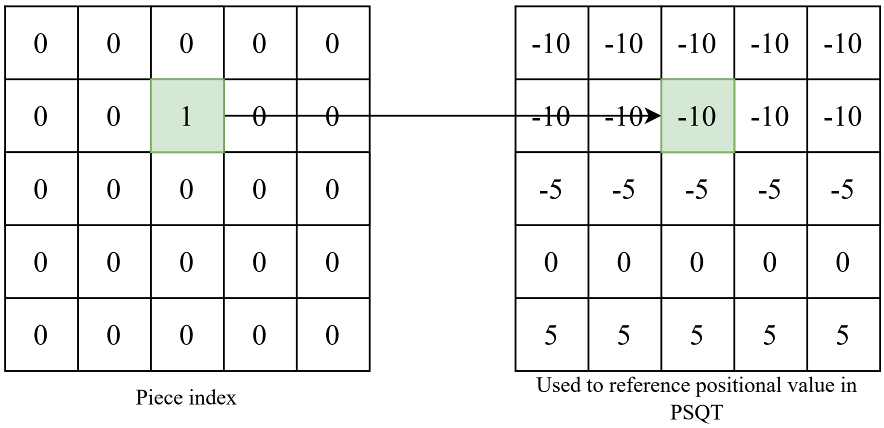



Figure 2.18: PSQT showing the bonus position value gained for the square occupied by a pharaoh

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 topleft 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:

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

$$\text{blue\_psqt\_value} = \text{PHARAOH\_PSQT[FLIP[square]]}$$

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 ← 0
    for all pieces do
        for square in bitboards[piece] do
            if square = 1 then
                if colour is blue then
                    positional_score ← positional_score + PSQT[piece][square]
                else
                    positional_score ← 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 on 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

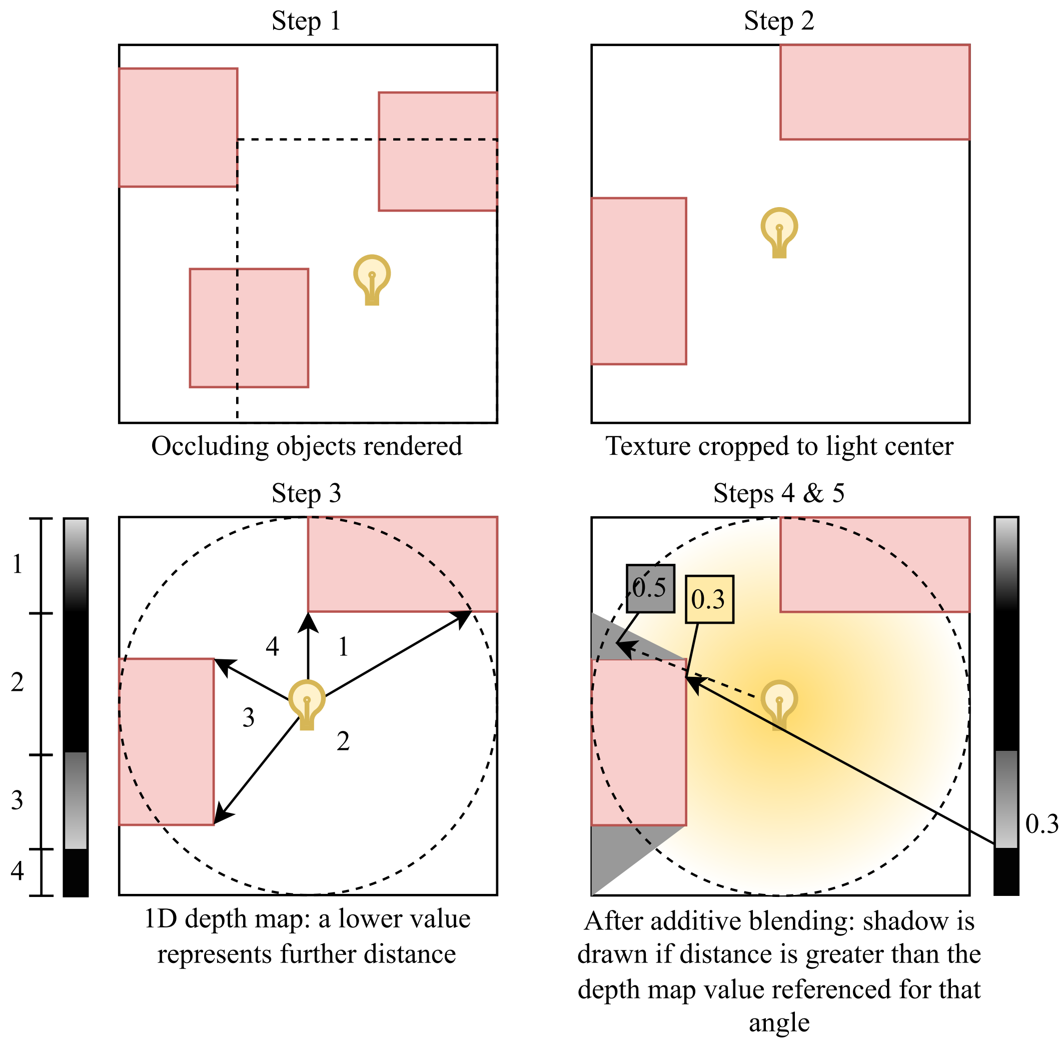



Figure 2.20: Workflow for 2D shadow mapping

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 ($\frac{\pi}{2} < \theta < \frac{\pi}{2}$), 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

To 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

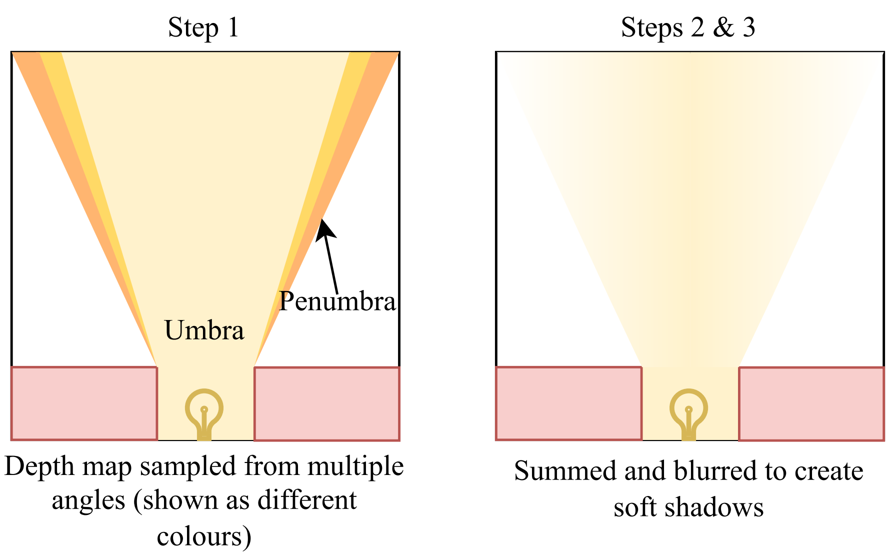



Figure 2.21: Workflow for 2D soft shadows

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:

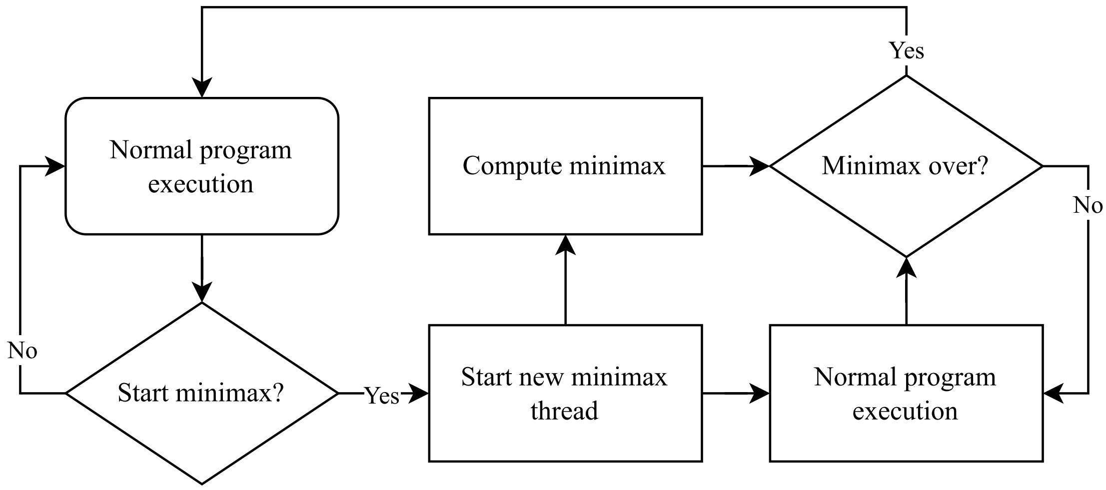



Figure 2.22: Multi-threading for minimax

## 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[1], and so the table therefore adheres to the third normal form.

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

```
CREATE TABLE games(
    id INTEGER PRIMARY KEY,
    winner INTEGER,
    cpu_depth INTEGER,
    time real NOT NULL,
    moves TEXT NOT NULL,
    cpu_enabled INTEGER NOT NULL,
    created_dt TIMESTAMP NOT NULL,
    number_of_moves INTEGER NOT NULL,
    initial_fen_string TEXT NOT NULL,
)
```

Removing an entity can also be done similarly:

```
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.

```
INSERT INTO games (
    cpu_enabled,
    cpu_depth,
    winner,
    time,
    number_of_moves,
    moves,
    initial_fen_string,
    created_dt
)
```

[1]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.

```
    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.

```
    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.

```
    SELECT * FROM
        (SELECT ROW_NUMBER() OVER (
            PARTITION BY attribute1
            ORDER BY attribute2 ASC
        ) AS row_num, * FROM games)
    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

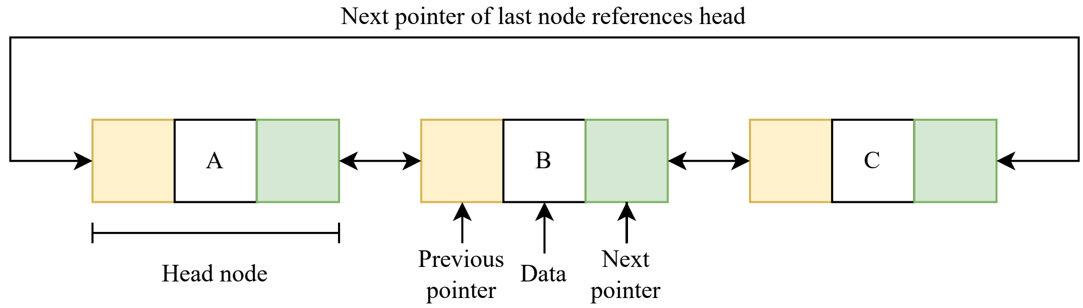



Figure 2.23: Structure of a circular doubly-linked list

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 ← node
        node.next ← node.previous ← head
    else
        node.next ← head
        node.previous ← head.previous
        head.previous.next ← node
        head.previous ← node

        head ← node
    end if
end function


Require: LEN(list) > 0
function DATA_IN_LIST(data)
    current_node ← head.next
    while current_node ≠ head do
        if current_node.data = data then
            return True
        end if
        current_node ← current_node.next
    end while
    return False
end function


Require: Data in list
function REMOVE(data)
    current_node ← head
    while current_node.data ≠ data do
        current_node ← current_node.next
    end while

    current_node.previous.next ← current_node.next
    current_node.next.previous ← 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.

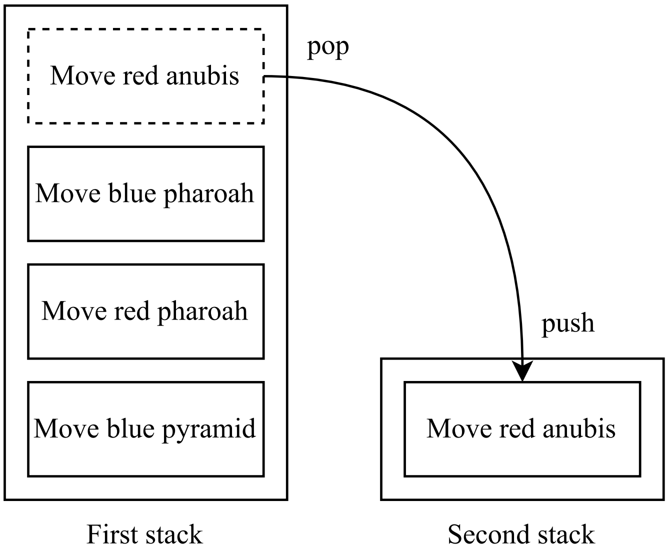



Figure 2.24: *Move red anubis* is undone and pushed onto the second stack

## 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 show 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** |
|---|---|
| startup | Initialise variables and functions when state set as displayed screen |
| cleanup | Cleanup any variables and functions when state removed from screen |
| draw | Draw to display |
| update | Update any variables for every game tick |
| handle_resize | Scale GUI when window resized |
| get_event | 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 |
|---|---|
| set_image | Render widget to internal image attribute for Pygame sprite class |
| set_geometry | Set position and size of image |
| set_screen_size | Set screen size for resizing purposes |
| get_event | Receives Pygame events and processes them |
| screen_size* | Returns screen size in pixels |
| position* | Returns topleft of widget rect |
| size* | Returns size of widget in pixels |
| margin* | Returns distance between border and actual widget image |
| border_width* | Returns border width |
| border_radius* | Returns border radius for rounded corners |
| font_size* | 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 |
|---|---|
| get_event | Receives Pygame events and sets current state accordingly |
| set_state | Sets current Pressable state, called by `get_event` |
| set_colours | 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 `alert_listener` is called |
| alert_listener | Sends event to all subscribed instances |
| toggle_win | Sends event for win view |
| toggle_pause | Sends event for pause view |

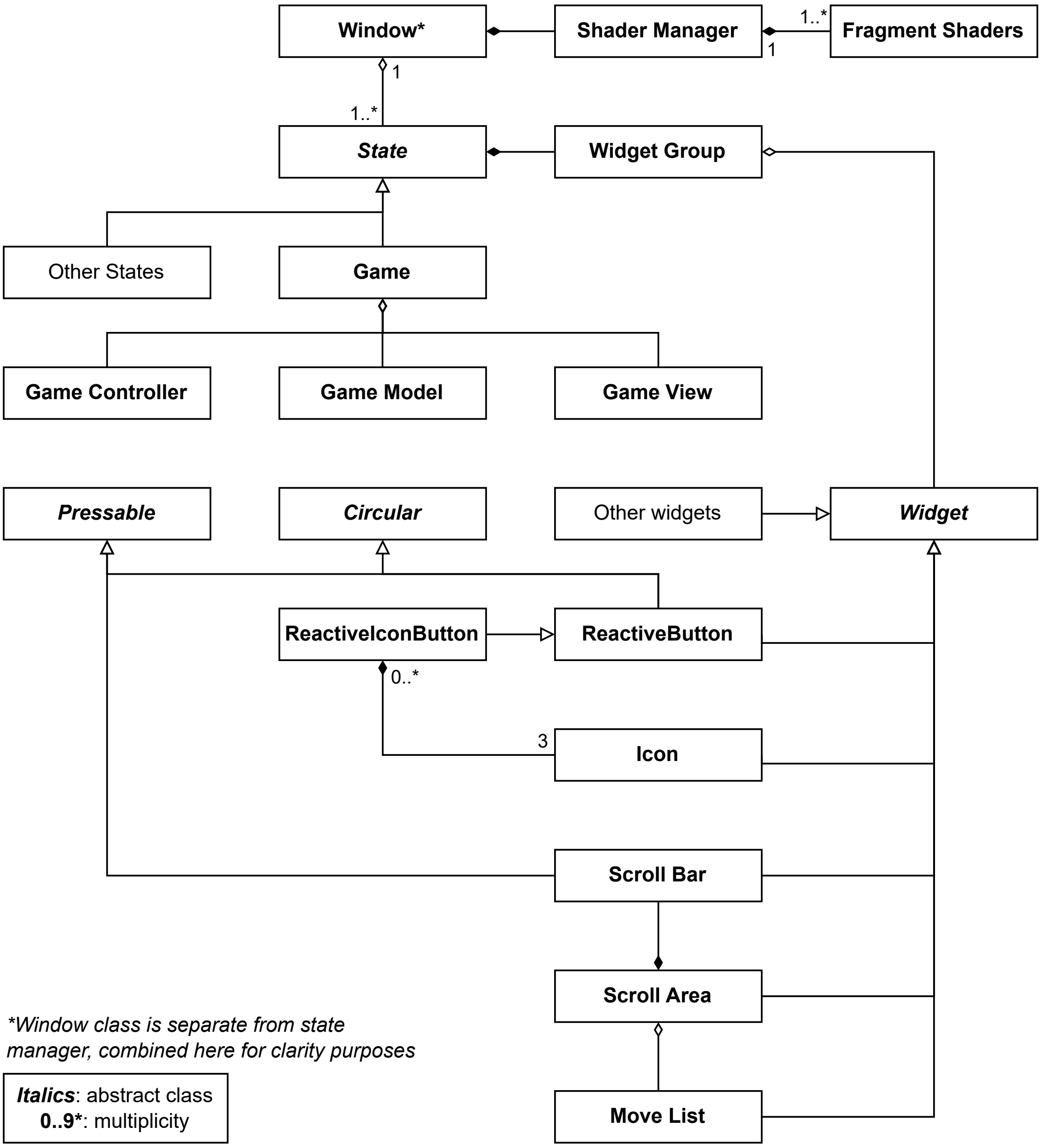
| **Method Name** | **Description** |
|---|---|
| ... | ... |

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

## 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.

```
resources/ ........................ Asset files used in program
data/
├── database/
│   ├── migrations/ ............... Database migrations that track changes to table
│   └── database.db                 schema
├── helpers/
│   ├── bitboard_helpers.py
│   └── ...
│   shaders/
│   ├── classes/ .................. Python classes for each fragment shader
│   ├── fragments/ ................ Fragment shader code
│   └── vertex/ ................... Vertex shader code
├── widgets/
│   ├── bases/ .................... Abstract classes for widgets
│   └── ...
├── states/
│   ├── game/
│   │   ├── components/ ........... Collection of classes involved in running of game screen
│   │   ├── cpu/ .................. Contains CPU engine classes and ancilliary helper classes
│   │   ├── mvc/
│   │   ├── game.py
│   │   └── widget_dict.py ........ Initalises a dictionary containing widgets for the game screen GUI
│   └── ...
├── utils/
│   ├── assets.py ................. File containing dictionaries of external loaded assets
│   ├── constants.py .............. File containing constants used by multiple files
│   ├── enums.py .................. File containing Python enum classes
│   └── event_types.py ............ File containing screen-specific EventType enum classes
├── app_data/ ..................... JSON files used to store settings and configurations
├── components/ ................... Collection of useful classes used in multiple areas
├── managers/ ..................... Collection of classes that manage game systems
├── main.py
├── setup.py
├── control.py
├── constants.py
├── loading_screen.py
└── windows_setup.py
```

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

```
from sys import platform
# Initialises Pygame
import data.setup

# Windows OS requires some configuration for Pygame to scale GUI continuously
    while window is being resized
if platform == 'win32':
    import data.windows_setup as win_setup

from data.loading_screen import LoadingScreen

states = [None, None]

def load_states():
    """
    Initialises instances of all screens, executed on another thread with results
    being stored to the main thread by modifying a mutable such as the states list
    """
    from data.control import Control
    from data.states.game.game import Game
    from data.states.menu.menu import Menu
    from data.states.settings.settings import Settings
    from data.states.config.config import Config
    from data.states.browser.browser import Browser
    from data.states.review.review import Review
    from data.states.editor.editor import Editor

```

```
    # Initialise dictionary containing each screen in the game, referenced in Control class by the current state's 'next' and 'previous' attributes, corresponding to a key in this dictionary
    state_dict = {
        'menu': Menu(),
        'game': Game(),
        'settings': Settings(),
        'config': Config(),
        'browser': Browser(),
        'review': Review(),
        'editor': Editor()
    }

    app = Control()

    states[0] = app
    states[1] = state_dict

loading_screen = LoadingScreen(load_states)

def main():
    """
    Executed by run.py, starts main game loop
    """
    app, state_dict = states

    if platform == 'win32':
        win_setup.set_win_resize_func(app.update_window)

    app.setup_states(state_dict, 'menu')
    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`

```
import pygame
import threading
import sys
from pathlib import Path
from data.helpers.load_helpers import load_gfx, load_sfx
from data.managers.window import window
from data.managers.audio import audio

FPS = 30
start_ticks = pygame.time.get_ticks()
logo_gfx_path = (Path(__file__).parent / '../resources/graphics/gui/icons/logo/logo.png').resolve()
sfx_path_1 = (Path(__file__).parent / '../resources/sfx/loading_screen/loading_screen_1.wav').resolve()
sfx_path_2 = (Path(__file__).parent / '../resources/sfx/loading_screen/loading_screen_2.wav').resolve()

def easeOutBack(progress):
    """
    Represents a cubic function for easing the logo position.
    Starts quickly and has small overshoot, then ends slowly.
```

```

    Args:
        progress (float): x-value for cubic function ranging from 0-1.

    Returns:
        float: 2.70x^3 + 1.70x^2 + 0x + 1, where x is time elapsed.
    """
    c2 = 1.70158
    c3 = 2.70158

    return c3 * ((progress - 1) ** 3) + c2 * ((progress - 1) ** 2) + 1

class LoadingScreen:
    def __init__(self, target_func):
        """
        Creates new thread, and sets the load_state() function as its target.
        Then starts draw loop for the loading screen.

        Args:
            target_func (Callable): function to be run on thread.
        """
        self._clock = pygame.time.Clock()
        self._thread = threading.Thread(target=target_func)
        self._thread.start()

        self._logo_surface = load_gfx(logo_gfx_path)
        self._logo_surface = pygame.transform.scale(self._logo_surface, (96, 96))
        audio.play_sfx(load_sfx(sfx_path_1))
        audio.play_sfx(load_sfx(sfx_path_2))

        self.run()

    @property
    def logo_position(self):
        duration = 1000
        displacement = 50
        elapsed_ticks = pygame.time.get_ticks() - start_ticks
        progress = min(1, elapsed_ticks / duration)
        center_pos = ((window.screen.size[0] - self._logo_surface.size[0]) / 2, (window.screen.size[1] - self._logo_surface.size[1]) / 2)

        return (center_pos[0], center_pos[1] + displacement - displacement * easeOutBack(progress))

    @property
    def logo_opacity(self):
        return min(255, (pygame.time.get_ticks() - start_ticks) / 5)

    @property
    def duration_not_over(self):
        return (pygame.time.get_ticks() - start_ticks) < 1500

    def event_loop(self):
        """
        Handles events for the loading screen, no user input is taken except to quit the game.
        """
        for event in pygame.event.get():
            if event.type == pygame.QUIT:
                pygame.quit()
                sys.exit()

```

```
    def draw(self):
        """
        Draws logo to screen.
        """
        window.screen.fill((0, 0, 0))

        self._logo_surface.set_alpha(self.logo_opacity)
        window.screen.blit(self._logo_surface, self.logo_position)

        window.update()

    def run(self):
        """
        Runs while the thread is still setting up our screens, or the minimum
    loading screen duration is not reached yet.
        """
        while self._thread.is_alive() or self.duration_not_over:
            self.event_loop()
            self.draw()
            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)

```
import pygame
from PIL import Image
from functools import cache
from random import randint
import math

@cache
def scale_and_cache(image, target_size):
    """
    Caches image when resized repeatedly.

    Args:
        image (pygame.Surface): Image surface to be resized.
        target_size (tuple[float, float]): New image size.

    Returns:
        pygame.Surface: Resized image surface.
    """
    return pygame.transform.scale(image, target_size)

@cache
def smoothscale_and_cache(image, target_size):
    """
    Same as scale_and_cache, but with the Pygame smoothscale function.

    Args:
        image (pygame.Surface): Image surface to be resized.
        target_size (tuple[float, float]): New image size.

    Returns:
        pygame.Surface: Resized image surface.
    """
    return pygame.transform.smoothscale(image, target_size)

def gif_to_frames(path):
```

```
    """
    Uses the PIL library to break down GIFs into individual frames.

    Args:
        path (str): Directory path to GIF file.

    Yields:
        PIL.Image: Single frame.
    """
    try:
        image = Image.open(path)

        first_frame = image.copy().convert('RGBA')
        yield first_frame
        image.seek(1)

        while True:
            current_frame = image.copy()
            yield current_frame
            image.seek(image.tell() + 1)
    except EOFError:
        pass

def get_perimeter_sample(image_size, number):
    """
    Used for particle drawing class, generates roughly equally distributed points around a rectangular image surface's perimeter.

    Args:
        image_size (tuple[float, float]): Image surface size.
        number (int): Number of points to be generated.

    Returns:
        list[tuple[int, int], ...]: List of random points on perimeter of image surface.
    """
    perimeter = 2 * (image_size[0] + image_size[1])
    # Flatten perimeter to a single number representing the distance from the top-middle of the surface going clockwise, and create a list of equally spaced points
    perimeter_offsets = [(image_size[0] / 2) + (i * perimeter / number) for i in range(0, number)]
    pos_list = []

    for perimeter_offset in perimeter_offsets:
        # For every point, add a random offset
        max_displacement = int(perimeter / (number * 4))
        perimeter_offset += randint(-max_displacement, max_displacement)

        if perimeter_offset > perimeter:
            perimeter_offset -= perimeter

        # Convert 1D distance back into 2D points on image surface perimeter
        if perimeter_offset < image_size[0]:
            pos_list.append((perimeter_offset, 0))
        elif perimeter_offset < image_size[0] + image_size[1]:
            pos_list.append((image_size[0], perimeter_offset - image_size[0]))
        elif perimeter_offset < image_size[0] + image_size[1] + image_size[0]:
            pos_list.append((perimeter_offset - image_size[0] - image_size[1], image_size[1]))
        else:
            pos_list.append((0, perimeter - perimeter_offset))
```

```
    return pos_list

def get_angle_between_vectors(u, v, deg=True):
    """
    Uses the dot product formula to find the angle between two vectors.

    Args:
        u (list[int, int]): Vector 1.
        v (list[int, int]): Vector 2.
        deg (bool, optional): Return results in degrees. Defaults to True.

    Returns:
        float: Angle between vectors.
    """
    dot_product = sum(i * j for (i, j) in zip(u, v))
    u_magnitude = math.sqrt(u[0] ** 2 + u[1] ** 2)
    v_magnitude = math.sqrt(v[0] ** 2 + v[1] ** 2)

    cos_angle = dot_product / (u_magnitude * v_magnitude)
    radians = math.acos(min(max(cos_angle, -1), 1))

    if deg:
        return math.degrees(radians)
    else:
        return radians

def get_rotational_angle(u, v, deg=True):
    """
    Get bearing angle relative to positive x-axis centered on second vector.

    Args:
        u (list[int, int]): Vector 1.
        v (list[int, int]): Vector 2, set as center of axes.
        deg (bool, optional): Return results in degrees. Defaults to True.

    Returns:
        float: Bearing angle between vectors.
    """
    radians = math.atan2(u[1] - v[1], u[0] -v[0])

    if deg:
        return math.degrees(radians)
    else:
        return radians

def get_vector(src_vertex, dest_vertex):
    """
    Get vector describing translation between two points.

    Args:
        src_vertex (list[int, int]): Source vertex.
        dest_vertex (list[int, int]): Destination vertex.

    Returns:
        tuple[int, int]: Vector between the two points.
    """
    return (dest_vertex[0] - src_vertex[0], dest_vertex[1] - src_vertex[1])

def get_next_corner(vertex, image_size):
    """
    Used in particle drawing system, finds coordinates of the next corner going
    clockwise, given a point on the perimeter.
```

```

    Args:
        vertex (list[int, int]): Point on perimeter.
        image_size (list[int, int]): Image size.

    Returns:
        list[int, int]: Coordinates of corner on perimeter.
    """
    corners = [(0, 0), (image_size[0], 0), (image_size[0], image_size[1]), (0, image_size[1])]

    if vertex in corners:
        return corners[(corners.index(vertex) + 1) % len(corners)]

    if vertex[1] == 0:
        return (image_size[0], 0)
    elif vertex[0] == image_size[0]:
        return image_size
    elif vertex[1] == image_size[1]:
        return (0, image_size[1])
    elif vertex[0] == 0:
        return (0, 0)

def pil_image_to_surface(pil_image):
    """
    Args:
        pil_image (PIL.Image): Image to be converted.

    Returns:
        pygame.Surface: Converted image surface.
    """
    return pygame.image.frombytes(pil_image.tobytes(), pil_image.size, pil_image.mode).convert()

def calculate_frame_index(elapsed_milliseconds, start_index, end_index, fps):
    """
    Determine frame of animated GIF to be displayed.

    Args:
        elapsed_milliseconds (int): Milliseconds since GIF started playing.
        start_index (int): Start frame of GIF.
        end_index (int): End frame of GIF.
        fps (int): Number of frames to be played per second.

    Returns:
        int: Displayed frame index of GIF.
    """
    ms_per_frame = int(1000 / fps)
    return start_index + ((elapsed_milliseconds // ms_per_frame) % (end_index - start_index))

def draw_background(screen, background, current_time=0):
    """
    Draws background to screen

    Args:
        screen (pygame.Surface): Screen to be drawn to
        background (list[pygame.Surface, ...] | pygame.Surface): Background to be drawn, if GIF, list of surfaces indexed to select frame to be drawn
        current_time (int, optional): Used to calculate frame index for GIF. Defaults to 0.
    """
```

```
    if isinstance(background, list):
        # Animated background passed in as list of surfaces, calculate_frame_index() used to get index of frame to be drawn
        frame_index = calculate_frame_index(current_time, 0, len(background), fps=8)
        scaled_background = scale_and_cache(background[frame_index], screen.size)
        screen.blit(scaled_background, (0, 0))
    else:
        scaled_background = scale_and_cache(background, screen.size)
        screen.blit(scaled_background, (0, 0))

def get_highlighted_icon(icon):
    """
    Used for pressable icons, draws overlay on icon to show as pressed.

    Args:
        icon (pygame.Surface): Icon surface.

    Returns:
        pygame.Surface: Icon with overlay drawn on top.
    """
    icon_copy = icon.copy()
    overlay = pygame.Surface((icon.get_width(), icon.get_height()), pygame.SRCALPHA)
    overlay.fill((0, 0, 0, 128))
    icon_copy.blit(overlay, (0, 0))
    return icon_copy
```

data_helpers.py (Functions used for file handling and JSON parsing)

```
import json
from pathlib import Path

module_path = Path(__file__).parent
default_file_path = (module_path / '../app_data/default_settings.json').resolve()
user_file_path = (module_path / '../app_data/user_settings.json').resolve()
themes_file_path = (module_path / '../app_data/themes.json').resolve()

def load_json(path):
    """
    Args:
        path (str): Path to JSON file.

    Raises:
        Exception: Invalid file.

    Returns:
        dict: Parsed JSON file.
    """
    try:
        with open(path, 'r') as f:
            file = json.load(f)

        return file
    except:
        raise Exception('Invalid JSON file (data_helpers.py)')

def get_user_settings():
    return load_json(user_file_path)

def get_default_settings():
```

```
    return load_json(default_file_path)

def get_themes():
    return load_json(themes_file_path)

def update_user_settings(data):
    """
    Rewrites JSON file for user settings with new data.

    Args:
        data (dict): Dictionary storing updated user settings.

    Raises:
        Exception: Invalid file.
    """
    try:
        with open(user_file_path, 'w') as f:
            json.dump(data, f, indent=4)
    except:
        raise Exception('Invalid JSON file (data_helpers.py)')
```

widget_helpers.py (Files used for creating widgets)

```
import pygame
from math import sqrt

def create_slider(size, fill_colour, border_width, border_colour):
    """
    Creates surface for sliders.

    Args:
        size (list[int, int]): Image size.
        fill_colour (pygame.Color): Fill (inner) colour.
        border_width (float): Border width.
        border_colour (pygame.Color): Border colour.

    Returns:
        pygame.Surface: Slider image surface.
    """
    gradient_surface = pygame.Surface(size, pygame.SRCALPHA)
    border_rect = pygame.FRect((0, 0, gradient_surface.width, gradient_surface.
    height))

    # Draws rectangle with a border radius half of image height, to draw an
    rectangle with semicurclar cap (obround)
    pygame.draw.rect(gradient_surface, fill_colour, border_rect, border_radius=int
    (size[1] / 2))
    pygame.draw.rect(gradient_surface, border_colour, border_rect , width=int(
    border_width), border_radius=int(size[1] / 2))

    return gradient_surface

def create_slider_gradient(size, border_width, border_colour):
    """
    Draws surface for colour slider, with a full colour gradient as fill colour.

    Args:
        size (list[int, int]): Image size.
        border_width (float): Border width.
        border_colour (pygame.Color): Border colour.

```

```
    Returns:
        pygame.Surface: Slider image surface.
    """
    gradient_surface = pygame.Surface(size, pygame.SRCALPHA)

    first_round_end = gradient_surface.height / 2
    second_round_end = gradient_surface.width - first_round_end
    gradient_y_mid = gradient_surface.height / 2

    # Iterate through length of slider
    for i in range(gradient_surface.width):
        draw_height = gradient_surface.height

        if i < first_round_end or i > second_round_end:
            # Draw semicircular caps if x-distance less than or greater than radius of cap (half of image height)
            distance_from_cutoff = min(abs(first_round_end - i), abs(i - second_round_end))
            draw_height = calculate_gradient_slice_height(distance_from_cutoff, gradient_surface.height / 2)

        # Get colour from distance from left side of slider
        color = pygame.Color(0)
        color.hsva = (int(360 * i / gradient_surface.width), 100, 100, 100)

        draw_rect = pygame.FRect((0, 0, 1, draw_height - 2 * border_width))
        draw_rect.center = (i, gradient_y_mid)

        pygame.draw.rect(gradient_surface, color, draw_rect)

    border_rect = pygame.FRect((0, 0, gradient_surface.width, gradient_surface.height))
    pygame.draw.rect(gradient_surface, border_colour, border_rect , width=int(border_width), border_radius=int(size[1] / 2))

    return gradient_surface

def calculate_gradient_slice_height(distance, radius):
    """
    Calculate height of vertical slice of semicircular slider cap.

    Args:
        distance (float): x-distance from center of circle.
        radius (float): Radius of semicircle.

    Returns:
        float: Height of vertical slice.
    """
    return sqrt(radius ** 2 - distance ** 2) * 2 + 2

def create_slider_thumb(radius, colour, border_colour, border_width):
    """
    Creates surface with bordered circle.

    Args:
        radius (float): Radius of circle.
        colour (pygame.Color): Fill colour.
        border_colour (pygame.Color): Border colour.
        border_width (float): Border width.

    Returns:
        pygame.Surface: Circle surface.
```

```
    """
    thumb_surface = pygame.Surface((radius * 2, radius * 2), pygame.SRCALPHA)
    pygame.draw.circle(thumb_surface, border_colour, (radius, radius), radius,
    width=int(border_width))
    pygame.draw.circle(thumb_surface, colour, (radius, radius), (radius -
    border_width))

    return thumb_surface

def create_square_gradient(side_length, colour):
    """
    Creates a square gradient for the colour picker widget, gradient transitioning
     between saturation and value.
    Uses smoothscale to blend between colour values for individual pixels.

    Args:
        side_length (float): Length of a square side.
        colour (pygame.Color): Colour with desired hue value.

    Returns:
        pygame.Surface: Square gradient surface.
    """
    square_surface = pygame.Surface((side_length, side_length))

    mix_1 = pygame.Surface((1, 2))
    mix_1.fill((255, 255, 255))
    mix_1.set_at((0, 1), (0, 0, 0))
    mix_1 = pygame.transform.smoothscale(mix_1, (side_length, side_length))

    hue = colour.hsva[0]
    saturated_rgb = pygame.Color(0)
    saturated_rgb.hsva = (hue, 100, 100)

    mix_2 = pygame.Surface((2, 1))
    mix_2.fill((255, 255, 255))
    mix_2.set_at((1, 0), saturated_rgb)
    mix_2 = pygame.transform.smoothscale(mix_2,(side_length, side_length))

    mix_1.blit(mix_2, (0, 0), special_flags=pygame.BLEND_MULT)

    square_surface.blit(mix_1, (0, 0))

    return square_surface

def create_switch(size, colour):
    """
    Creates surface for switch toggle widget.

    Args:
        size (list[int, int]): Image size.
        colour (pygame.Color): Fill colour.

    Returns:
        pygame.Surface: Switch surface.
    """
    switch_surface = pygame.Surface((size[0], size[1]), pygame.SRCALPHA)
    pygame.draw.rect(switch_surface, colour, (0, 0, size[0], size[1]),
    border_radius=int(size[1] / 2))

    return switch_surface

def create_text_box(size, border_width, colours):
```

```
    """
    Creates bordered textbox with shadow, flat, and highlighted vertical regions.

    Args:
        size (list[int, int]): Image size.
        border_width (float): Border width.
        colours (list[pygame.Color, ...]): List of 4 colours, representing border colour, shadow colour, flat colour and highlighted colour.

    Returns:
        pygame.Surface: Textbox surface.
    """
    surface = pygame.Surface(size, pygame.SRCALPHA)

    pygame.draw.rect(surface, colours[0], (0, 0, *size))
    pygame.draw.rect(surface, colours[2], (border_width, border_width, size[0] - 2 * border_width, size[1] - 2 * border_width))
    pygame.draw.rect(surface, colours[3], (border_width, border_width, size[0] - 2 * border_width, border_width))
    pygame.draw.rect(surface, colours[1], (border_width, size[1] - 2 * border_width, size[0] - 2 * border_width, border_width))

    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

```
from data.helpers.data_helpers import get_themes, get_user_settings

themes = get_themes()
user_settings = get_user_settings()

def flatten_dictionary_generator(dictionary, parent_key=None):
    """
    Recursive depth-first search to yield all items in a dictionary.

    Args:
        dictionary (dict): Dictionary to be iterated through.
        parent_key (str, optional): Prefix added to every key. Defaults to None.

    Yields:
        dict | tuple[str, str]: Another dictionary or key, value pair.
    """
    for key, value in dictionary.items():
        if parent_key:
            new_key = parent_key + key.capitalize()
        else:
            new_key = key

        if isinstance(value, dict):
            yield from flatten_dictionary(value, new_key).items()
        else:
            yield new_key, value

def flatten_dictionary(dictionary, parent_key=''):
```

```
    return dict(flatten_dictionary_generator(dictionary, parent_key))

class ThemeManager:
    def __init__(self):
        self.__dict__.update(flatten_dictionary(themes['colours']))
        self.__dict__.update(flatten_dictionary(themes['dimensions']))

    def __getitem__(self, arg):
        """
        Override default class's __getitem__ dunder method, to make retrieving an instance attribute nicer with [] notation.

        Args:
            arg (str): Attribute name.

        Raises:
            KeyError: Instance does not have requested attribute.

        Returns:
            str | int: Instance attribute.
        """
        item = self.__dict__.get(arg)

        if item is None:
            raise KeyError('(ThemeManager.__getitem__) Requested theme item not found:', arg)

        return item

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

```
import pygame
from data.helpers.board_helpers import coords_to_screen_pos
from data.utils.enums import LaserType, Colour, ShaderType
from data.managers.animation import animation
from data.utils.assets import GRAPHICS, SFX
from data.utils.constants import EMPTY_BB
from data.managers.window import window
from data.managers.audio import audio

type_to_image = {
    LaserType.END: ['laser_end_1', 'laser_end_2'],
    LaserType.STRAIGHT: ['laser_straight_1', 'laser_straight_2'],
    LaserType.CORNER: ['laser_corner_1', 'laser_corner_2']
}

GLOW_SCALE_FACTOR = 1.5

class LaserDraw:
    def __init__(self, board_position, board_size):
        self._board_position = board_position
        self._square_size = board_size[0] / 10
        self._laser_lists = []
```

```python

    @property
    def firing(self):
        return len(self._laser_lists) > 0

    def add_laser(self, laser_result, laser_colour):
        """
        Adds a laser to the board.

        Args:
            laser_result (Laser): Laser class instance containing laser trajectory
 info.
            laser_colour (Colour.RED | Colour.BLUE): Active colour of laser.
        """
        laser_path = laser_result.laser_path.copy()
        laser_types = [LaserType.END]
        # List of angles in degree to rotate the laser image surface when drawn
        laser_rotation = [laser_path[0][1]]
        laser_lights = []

        # Iterates through every square laser passes through
        for i in range(1, len(laser_path)):
            previous_direction = laser_path[i-1][1]
            current_coords, current_direction = laser_path[i]

            if current_direction == previous_direction:
                laser_types.append(LaserType.STRAIGHT)
                laser_rotation.append(current_direction)
            elif current_direction == previous_direction.get_clockwise():
                laser_types.append(LaserType.CORNER)
                laser_rotation.append(current_direction)
            elif current_direction == previous_direction.get_anticlockwise():
                laser_types.append(LaserType.CORNER)
                laser_rotation.append(current_direction.get_anticlockwise())

            # Adds a shader ray effect on the first and last square of the laser
trajectory
            if i in [1, len(laser_path) - 1]:
                abs_position = coords_to_screen_pos(current_coords, self.
_board_position, self._square_size)
                laser_lights.append([
                    (abs_position[0] / window.size[0], abs_position[1] / window.
size[1]),
                    0.35,
                    (0, 0, 255) if laser_colour == Colour.BLUE else (255, 0, 0),
                ])

        # Sets end laser draw type if laser hits a piece or piece is anubis
        if laser_result.end_cap:
            laser_types[-1] = LaserType.END
            laser_path[-1] = (laser_path[-1][0], laser_path[-2][1].get_opposite())
            laser_rotation[-1] = laser_path[-2][1].get_opposite()

        # Played audio cue if piece is destroyed
        if laser_result.hit_square_bitboard != EMPTY_BB:
            audio.play_sfx(SFX['piece_destroy'])

        laser_path = [(coords, rotation, type) for (coords, dir), rotation, type
in zip(laser_path, laser_rotation, laser_types)]
        self._laser_lists.append((laser_path, laser_colour))

        window.clear_effect(ShaderType.RAYS)
```

```
        window.set_effect(ShaderType.RAYS, lights=laser_lights)
        animation.set_timer(1000, self.remove_laser)

        audio.play_sfx(SFX['laser_1'])
        audio.play_sfx(SFX['laser_2'])

    def remove_laser(self):
        """
        Removes a laser from the board.
        """
        self._laser_lists.pop(0)

        if len(self._laser_lists) == 0:
            window.clear_effect(ShaderType.RAYS)

    def draw_laser(self, screen, laser_list, glow=True):
        """
        Draws every laser on the screen.

        Args:
            screen (pygame.Surface): The screen to draw on.
            laser_list (list): The list of laser segments to draw.
            glow (bool, optional): Whether to draw a glow effect. Defaults to True.
        """
        laser_path, laser_colour = laser_list
        laser_list = []
        glow_list = []

        for coords, rotation, type in laser_path:
            square_x, square_y = coords_to_screen_pos(coords, self._board_position, self._square_size)
            image = GRAPHICS[type_to_image[type][laser_colour]]
            rotated_image = pygame.transform.rotate(image, rotation.to_angle())
            scaled_image = pygame.transform.scale(rotated_image, (self._square_size + 1, self._square_size + 1)) # +1 to prevent rounding creating black lines
            laser_list.append((scaled_image, (square_x, square_y)))

            # Scales up the laser image surface as a glow surface
            scaled_glow = pygame.transform.scale(rotated_image, (self._square_size * GLOW_SCALE_FACTOR, self._square_size * GLOW_SCALE_FACTOR))
            offset = self._square_size * ((GLOW_SCALE_FACTOR - 1) / 2)
            glow_list.append((scaled_glow, (square_x - offset, square_y - offset)))

        # Scaled glow surfaces drawn on top with the RGB_ADD blend mode
        if glow:
            screen.fblits(glow_list, pygame.BLEND_RGB_ADD)

        screen.blits(laser_list)

    def draw(self, screen):
        """
        Draws all lasers on the screen.

        Args:
            screen (pygame.Surface): The screen to draw on.
        """
        for laser_list in self._laser_lists:
            self.draw_laser(screen, laser_list)
```

```python
    def handle_resize(self, board_position, board_size):
        """
        Handles resizing of the board.

        Args:
            board_position (tuple[int, int]): The new position of the board.
            board_size (tuple[int, int]): The new size of the board.
        """
        self._board_position = board_position
        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

```python
import pygame
from random import randint
from data.helpers.asset_helpers import get_perimeter_sample, get_vector,
    get_angle_between_vectors, get_next_corner
from data.states.game.components.piece_sprite import PieceSprite
from data.helpers.data_helpers import get_user_settings

particles_disabled = not(get_user_settings()['particles'])

class ParticlesDraw:
    def __init__(self, gravity=0.2, rotation=180, shrink=0.5, opacity=150):
        self._particles = []
        self._glow_particles = []

        self._gravity = gravity
        self._rotation = rotation
        self._shrink = shrink
        self._opacity = opacity

    def fragment_image(self, image, number):
        image_size = image.get_rect().size
        """
        1. Takes an image surface and samples random points on the perimeter.
        2. Iterates through points, and depending on the nature of two consecutive
         points, finds a corner between them.
        3. Draws a polygon with the points as the vertices to mask out the area
        not in the fragment.

        Args:
            image (pygame.Surface): Image to fragment.
            number (int): The number of fragments to create.

        Returns:
            list[pygame.Surface]: List of image surfaces with fragment of original
         surface drawn on top.
        """
        center = image.get_rect().center
        points_list = get_perimeter_sample(image_size, number)
        fragment_list = []

        points_list.append(points_list[0])

```

```
        # Iterate through points_list, using the current point and the next one
        for i in range(len(points_list) - 1):
            vertex_1 = points_list[i]
            vertex_2 = points_list[i + 1]
            vector_1 = get_vector(center, vertex_1)
            vector_2 = get_vector(center, vertex_2)
            angle = get_angle_between_vectors(vector_1, vector_2)

            cropped_image = pygame.Surface(image_size, pygame.SRCALPHA)
            cropped_image.fill((0, 0, 0, 0))
            cropped_image.blit(image, (0, 0))

            corners_to_draw = None

            if vertex_1[0] == vertex_2[0] or vertex_1[1] == vertex_2[1]: # Points on the same side
                corners_to_draw = 4

            elif abs(vertex_1[0] - vertex_2[0]) == image_size[0] or abs(vertex_1[1] - vertex_2[1]) == image_size[1]: # Points on opposite sides
                corners_to_draw = 2

            elif angle < 180: # Points on adjacent sides
                corners_to_draw = 3

            else:
                corners_to_draw = 1

            corners_list = []
            for j in range(corners_to_draw):
                if len(corners_list) == 0:
                    corners_list.append(get_next_corner(vertex_2, image_size))
                else:
                    corners_list.append(get_next_corner(corners_list[-1], image_size))

            pygame.draw.polygon(cropped_image, (0, 0, 0, 0), (center, vertex_2, *corners_list, vertex_1))

            fragment_list.append(cropped_image)

        return fragment_list

    def add_captured_piece(self, piece, colour, rotation, position, size):
        """
        Adds a captured piece to fragment into particles.

        Args:
            piece (Piece): The piece type.
            colour (Colour): The active colour of the piece.
            rotation (int): The rotation of the piece.
            position (tuple[int, int]): The position where particles originate from.
            size (tuple[int, int]): The size of the piece.
        """
        if particles_disabled:
            return

        piece_sprite = PieceSprite(piece, colour, rotation)
        piece_sprite.set_geometry((0, 0), size)
        piece_sprite.set_image()

```

```
        particles = self.fragment_image(piece_sprite.image, 5)

        for particle in particles:
            self.add_particle(particle, position)

    def add_sparks(self, radius, colour, position):
        """
        Adds laser spark particles.

        Args:
            radius (int): The radius of the sparks.
            colour (Colour): The active colour of the sparks.
            position (tuple[int, int]): The position where particles originate from.
        """
        if particles_disabled:
            return

        for i in range(randint(10, 15)):
            velocity = [randint(-15, 15) / 10, randint(-20, 0) / 10]
            random_colour = [min(max(val + randint(-20, 20), 0), 255) for val in colour]
            self._particles.append([None, [radius, random_colour], [*position], velocity, 0])

    def add_particle(self, image, position):
        """
        Adds a particle.

        Args:
            image (pygame.Surface): The image of the particle.
            position (tuple): The position of the particle.
        """
        if particles_disabled:
            return

        velocity = [randint(-15, 15) / 10, randint(-20, 0) / 10]

        # Each particle is stored with its attributes: [surface, copy of surface, position, velocity, lifespan]
        self._particles.append([image, image.copy(), [*position], velocity, 0])

    def update(self):
        """
        Updates each particle and its attributes.
        """
        for i in range(len(self._particles) - 1, -1, -1):
            particle = self._particles[i]

            #update position
            particle[2][0] += particle[3][0]
            particle[2][1] += particle[3][1]

            #update lifespan
            self._particles[i][4] += 0.01

            if self._particles[i][4] >= 1:
                self._particles.pop(i)
                continue

            if isinstance(particle[1], pygame.Surface): # Particle is a piece
                # Update velocity
```

```
                particle[3][1] += self._gravity

                # Update size
                image_size = particle[1].get_rect().size
                end_size = ((1 - self._shrink) * image_size[0], (1 - self._shrink) * image_size[1])
                target_size = (image_size[0] - particle[4] * (image_size[0] - end_size[0]), image_size[1] - particle[4] * (image_size[1] - end_size[1]))

                # Update rotation
                rotation = (self._rotation if particle[3][0] <= 0 else -self._rotation) * particle[4]

                updated_image = pygame.transform.scale(pygame.transform.rotate(particle[1], rotation), target_size)

            elif isinstance(particle[1], list): # Particle is a spark
                # Update size
                end_radius = (1 - self._shrink) * particle[1][0]
                target_radius = particle[1][0] - particle[4] * (particle[1][0] - end_radius)

                updated_image = pygame.Surface((target_radius * 2, target_radius * 2), pygame.SRCALPHA)
                pygame.draw.circle(updated_image, particle[1][1], (target_radius, target_radius), target_radius)

            # Update opacity
            alpha = 255 - particle[4] * (255 - self._opacity)

            updated_image.fill((255, 255, 255, alpha), None, pygame.BLEND_RGBA_MULT)

            particle[0] = updated_image

    def draw(self, screen):
        """
        Draws the particles, indexing the surface and position attributes for each particle.

        Args:
            screen (pygame.Surface): The screen to draw on.
        """
        screen.blits([
            (particle[0], particle[2]) for particle in self._particles
        ])
```

### 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

```python
import pygame
from data.utils.constants import SCREEN_SIZE
from data.managers.theme import theme
from data.utils.assets import DEFAULT_FONT

DEFAULT_SURFACE_SIZE = SCREEN_SIZE
REQUIRED_KWARGS = ['relative_position', 'relative_size']

class _Widget(pygame.sprite.Sprite):
    def __init__(self, **kwargs):
        """
        Every widget has the following attributes:

        surface (pygame.Surface): The surface the widget is drawn on.
        raw_surface_size (tuple[int, int]): The initial size of the window screen, remains constant.
        parent (_Widget, optional): The parent widget position and size is relative to.

        Relative to current surface:
        relative_position (tuple[float, float]): The position of the widget relative to its surface.
        relative_size (tuple[float, float]): The scale of the widget relative to its surface.

        Remains constant, relative to initial screen size:
        relative_font_size (float, optional): The relative font size of the widget.
        relative_margin (float): The relative margin of the widget.
        relative_border_width (float): The relative border width of the widget.
        relative_border_radius (float): The relative border radius of the widget.

        anchor_x (str): The horizontal anchor direction ('left', 'right', 'center').
        anchor_y (str): The vertical anchor direction ('top', 'bottom', 'center').
        fixed_position (tuple[int, int], optional): The fixed position of the widget in pixels.
        border_colour (pygame.Color): The border color of the widget.
        text_colour (pygame.Color): The text color of the widget.
        fill_colour (pygame.Color): The fill color of the widget.
        font (pygame.freetype.Font): The font used for the widget.
        """
        super().__init__()

        for required_kwarg in REQUIRED_KWARGS:
            if required_kwarg not in kwargs:
                raise KeyError(f'(_Widget.__init__) Required keyword "{required_kwarg}" not in base kwargs')

        self._surface = None # Set in WidgetGroup, as needs to be reassigned every frame
        self._raw_surface_size = DEFAULT_SURFACE_SIZE

        self._parent = kwargs.get('parent')

        self._relative_font_size = None # Set in subclass

```

```
        self._relative_position = kwargs.get('relative_position')
        self._relative_margin = theme['margin'] / self._raw_surface_size[1]
        self._relative_border_width = theme['borderWidth'] / self._raw_surface_size[1]
        self._relative_border_radius = theme['borderRadius'] / self._raw_surface_size[1]

        self._border_colour = pygame.Color(theme['borderPrimary'])
        self._text_colour = pygame.Color(theme['textPrimary'])
        self._fill_colour = pygame.Color(theme['fillPrimary'])
        self._font = DEFAULT_FONT

        self._anchor_x = kwargs.get('anchor_x') or 'left'
        self._anchor_y = kwargs.get('anchor_y') or 'top'
        self._fixed_position = kwargs.get('fixed_position')
        scale_mode = kwargs.get('scale_mode') or 'both'

        if kwargs.get('relative_size'):
            match scale_mode:
                case 'height':
                    self._relative_size = kwargs.get('relative_size')
                case 'width':
                    self._relative_size = ((kwargs.get('relative_size')[0] * self.surface_size[0]) / self.surface_size[1], (kwargs.get('relative_size')[1] * self.surface_size[0]) / self.surface_size[1])
                case 'both':
                    self._relative_size = ((kwargs.get('relative_size')[0] * self.surface_size[0]) / self.surface_size[1], kwargs.get('relative_size')[1])
                case _:
                    raise ValueError('(_Widget.__init__) Unknown scale mode:', scale_mode)
        else:
            self._relative_size = (1, 1)

        if 'margin' in kwargs:
            self._relative_margin = kwargs.get('margin') / self._raw_surface_size[1]

            if (self._relative_margin * 2) > min(self._relative_size[0], self._relative_size[1]):
                raise ValueError('(_Widget.__init__) Margin larger than specified size!')

        if 'border_width' in kwargs:
            self._relative_border_width = kwargs.get('border_width') / self._raw_surface_size[1]

        if 'border_radius' in kwargs:
            self._relative_border_radius = kwargs.get('border_radius') / self._raw_surface_size[1]

        if 'border_colour' in kwargs:
            self._border_colour = pygame.Color(kwargs.get('border_colour'))

        if 'fill_colour' in kwargs:
            self._fill_colour = pygame.Color(kwargs.get('fill_colour'))

        if 'text_colour' in kwargs:
            self._text_colour = pygame.Color(kwargs.get('text_colour'))

        if 'font' in kwargs:
            self._font = kwargs.get('font')
```

```python

    @property
    def surface_size(self):
        """
        Gets the size of the surface widget is drawn on.
        Can be either the window size, or another widget size if assigned to a
    parent.

        Returns:
            tuple[int, int]: The size of the surface.
        """
        if self._parent:
            return self._parent.size
        else:
            return self._raw_surface_size

    @property
    def position(self):
        """
        Gets the position of the widget.
        Accounts for fixed position attribute, where widget is positioned in
    pixels regardless of screen size.
        Acounts for anchor direction, where position attribute is calculated
    relative to one side of the screen.

        Returns:
            tuple[int, int]: The position of the widget.
        """
        x, y = None, None
        if self._fixed_position:
            x, y = self._fixed_position
        if x is None:
            x = self._relative_position[0] * self.surface_size[0]
        if y is None:
            y = self._relative_position[1] * self.surface_size[1]

        if self._anchor_x == 'left':
            x = x
        elif self._anchor_x == 'right':
            x = self.surface_size[0] - x - self.size[0]
        elif self._anchor_x == 'center':
            x = (self.surface_size[0] / 2 - self.size[0] / 2) + x

        if self._anchor_y == 'top':
            y = y
        elif self._anchor_y == 'bottom':
            y = self.surface_size[1] - y - self.size[1]
        elif self._anchor_y == 'center':
            y = (self.surface_size[1] / 2 - self.size[1] / 2) + y

        # Position widget relative to parent, if exists.
        if self._parent:
            return (x + self._parent.position[0], y + self._parent.position[1])

        return (x, y)

    @property
    def size(self):
        return (self._relative_size[0] * self.surface_size[1], self._relative_size
    [1] * self.surface_size[1])

    @property
```

```
    def margin(self):
        return self._relative_margin * self._raw_surface_size[1]

    @property
    def border_width(self):
        return self._relative_border_width * self._raw_surface_size[1]

    @property
    def border_radius(self):
        return self._relative_border_radius * self._raw_surface_size[1]

    @property
    def font_size(self):
        return self._relative_font_size * self.surface_size[1]

    def set_image(self):
        """
        Abstract method to draw widget.
        """
        raise NotImplementedError

    def set_geometry(self):
        """
        Sets the position and size of the widget.
        """
        self.rect = self.image.get_rect()

        if self._anchor_x == 'left':
            if self._anchor_y == 'top':
                self.rect.topleft = self.position
            elif self._anchor_y == 'bottom':
                self.rect.topleft = self.position
            elif self._anchor_y == 'center':
                self.rect.topleft = self.position
        elif self._anchor_x == 'right':
            if self._anchor_y == 'top':
                self.rect.topleft = self.position
            elif self._anchor_y == 'bottom':
                self.rect.topleft = self.position
            elif self._anchor_y == 'center':
                self.rect.topleft = self.position
        elif self._anchor_x == 'center':
            if self._anchor_y == 'top':
                self.rect.topleft = self.position
            elif self._anchor_y == 'bottom':
                self.rect.topleft = self.position
            elif self._anchor_y == 'center':
                self.rect.topleft = self.position

    def set_surface_size(self, new_surface_size):
        """
        Sets the new size of the surface widget is drawn on.

        Args:
            new_surface_size (tuple[int, int]): The new size of the surface.
        """
        self._raw_surface_size = new_surface_size

    def process_event(self, event):
        """
        Abstract method to handle events.

```

```
        Args:
            event (pygame.Event): The event to process.
        """
        raise NotImplementedError
```

### Circular

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

```
from data.components.circular_linked_list import CircularLinkedList

class _Circular:
    def __init__(self, items_dict, **kwargs):
        # The key, value pairs are stored within a dictionary, while the keys to access them are stored within circular linked list.
        self._items_dict = items_dict
        self._keys_list = CircularLinkedList(list(items_dict.keys()))

    @property
    def current_key(self):
        """
        Gets the current head node of the linked list, and returns a key stored as the node data.
        Returns:
            Data of linked list head.
        """
        return self._keys_list.get_head().data

    @property
    def current_item(self):
        """
        Gets the value in self._items_dict with the key being self.current_key.

        Returns:
            Value stored with key being current head of linked list.
        """
        return self._items_dict[self.current_key]

    def set_next_item(self):
        """
        Sets the next item in as the current item.
        """
        self._keys_list.shift_head()

    def set_previous_item(self):
        """
        Sets the previous item as the current item.
        """
        self._keys_list.unshift_head()

    def set_to_key(self, key):
        """
        Sets the current item to the specified key.

        Args:
            key: The key to set as the current item.

        Raises:
            ValueError: If no nodes within the circular linked list contains the key as its data.
```

```
        """
        if self._keys_list.data_in_list(key) is False:
            raise ValueError('(_Circular.set_to_key) Key not found:', key)

        for _ in range(len(self._items_dict)):
            if self.current_key == key:
                self.set_image()
                self.set_geometry()
                return

            self.set_next_item()
```

### Circular Linked List

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

circular_linked_list.py

```
class Node:
    def __init__(self, data):
        self.data = data
        self.next = None
        self.previous = None

class CircularLinkedList:
    def __init__(self, list_to_convert=None):
        """
        Initialises a CircularLinkedList object.

        Args:
            list_to_convert (list, optional): Creates a linked list from existing
    items. Defaults to None.
        """
        self._head = None

        if list_to_convert:
            for item in list_to_convert:
                self.insert_at_end(item)

    def __str__(self):
        """
        Returns a string representation of the circular linked list.

        Returns:
            str: Linked list formatted as string.
        """
        if self._head is None:
            return '| empty |'

        characters = '| -> '
        current_node = self._head
        while True:
            characters += str(current_node.data) + ' -> '
            current_node = current_node.next

            if current_node == self._head:
                characters += '|'
                return characters

    def insert_at_beginning(self, data):
        """
```

```
        Inserts a node at the beginning of the circular linked list.

        Args:
            data: The data to insert.
        """
        new_node = Node(data)

        if self._head is None:
            self._head = new_node
            new_node.next = self._head
            new_node.previous = self._head
        else:
            new_node.next = self._head
            new_node.previous = self._head.previous
            self._head.previous.next = new_node
            self._head.previous = new_node

            self._head = new_node

    def insert_at_end(self, data):
        """
        Inserts a node at the end of the circular linked list.

        Args:
            data: The data to insert.
        """
        new_node = Node(data)

        if self._head is None:
            self._head = new_node
            new_node.next = self._head
            new_node.previous = self._head
        else:
            new_node.next = self._head
            new_node.previous = self._head.previous
            self._head.previous.next = new_node
            self._head.previous = new_node

    def insert_at_index(self, data, index):
        """
        Inserts a node at a specific index in the circular linked list.
        The head node is taken as index 0.

        Args:
            data: The data to insert.
            index (int): The index to insert the data at.

        Raises:
            ValueError: Index is out of range.
        """
        if index < 0:
            raise ValueError('Invalid index! (CircularLinkedList.insert_at_index)'
    )

        if index == 0 or self._head is None:
            self.insert_at_beginning(data)
        else:
            new_node = Node(data)
            current_node = self._head
            count = 0

            while count < index - 1 and current_node.next != self._head:
```

```
                current_node = current_node.next
                count += 1

            if count == (index - 1):
                new_node.next = current_node.next
                new_node.previous = current_node
                current_node.next = new_node
            else:
                raise ValueError('Index out of range! (CircularLinkedList.
    insert_at_index)')

    def delete(self, data):
        """
        Deletes a node with the specified data from the circular linked list.

        Args:
            data: The data to delete.

        Raises:
            ValueError: No nodes in the list contain the specified data.
        """
        if self._head is None:
            return

        current_node = self._head

        while current_node.data != data:
            current_node = current_node.next

            if current_node == self._head:
                raise ValueError('Data not found in circular linked list! (
    CircularLinkedList.delete)')

        if self._head.next == self._head:
            self._head = None
        else:
            current_node.previous.next = current_node.next
            current_node.next.previous = current_node.previous

    def data_in_list(self, data):
        """
        Checks if the specified data is in the circular linked list.

        Args:
            data: The data to check.

        Returns:
            bool: True if the data is in the list, False otherwise.
        """
        if self._head is None:
            return False

        current_node = self._head
        while True:
            if current_node.data == data:
                return True

            current_node = current_node.next
            if current_node == self._head:
                return False

    def shift_head(self):
```

```
        """
        Shifts the head of the circular linked list to the next node.
        """
        self._head = self._head.next

    def unshift_head(self):
        """
        Shifts the head of the circular linked list to the previous node.
        """
        self._head = self._head.previous

    def get_head(self):
        """
        Gets the head node of the circular linked list.

        Returns:
            Node: The head node.
        """
        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`

```python
from data.utils.event_types import GameEventType, SettingsEventType,
    ConfigEventType, BrowserEventType, EditorEventType

# Required keyword arguments when creating a CustomEvent object with a specific
    EventType
required_args = {
    GameEventType.BOARD_CLICK: ['coords'],
    GameEventType.ROTATE_PIECE: ['rotation_direction'],
    GameEventType.SET_LASER: ['laser_result'],
    GameEventType.UPDATE_PIECES: ['move_notation'],
    GameEventType.TIMER_END: ['active_colour'],
    GameEventType.PIECE_DROP: ['coords', 'piece', 'colour', 'rotation', '
    remove_overlay'],
    SettingsEventType.COLOUR_SLIDER_SLIDE: ['colour'],
    SettingsEventType.PRIMARY_COLOUR_PICKER_CLICK: ['colour'],
    SettingsEventType.SECONDARY_COLOUR_PICKER_CLICK: ['colour'],
    SettingsEventType.DROPDOWN_CLICK: ['selected_word'],
    SettingsEventType.VOLUME_SLIDER_CLICK: ['volume', 'volume_type'],
    SettingsEventType.SHADER_PICKER_CLICK: ['data'],
    SettingsEventType.PARTICLES_CLICK: ['toggled'],
    SettingsEventType.OPENGL_CLICK: ['toggled'],
    ConfigEventType.TIME_TYPE: ['time'],
    ConfigEventType.FEN_STRING_TYPE: ['time'],
    ConfigEventType.CPU_DEPTH_CLICK: ['data'],
    ConfigEventType.PVC_CLICK: ['data'],
    ConfigEventType.PRESET_CLICK: ['fen_string'],
    BrowserEventType.BROWSER_STRIP_CLICK: ['selected_index'],
    BrowserEventType.PAGE_CLICK: ['data'],
    EditorEventType.PICK_PIECE_CLICK: ['piece', 'active_colour'],
    EditorEventType.ROTATE_PIECE_CLICK: ['rotation_direction'],
}

class CustomEvent():
    def __init__(self, type, **kwargs):
        self.__dict__.update(kwargs)
        self.type = type

    @classmethod
    def create_event(event_cls, event_type, **kwargs):
        """
        @classmethod Factory method used to instance CustomEvent object, to check
    for required keyword arguments

        Args:
            event_cls (CustomEvent): Reference to own class.
            event_type: The state EventType.

        Raises:
            ValueError: If required keyword argument for passed event type not
    present.
            ValueError: If keyword argument passed is not required for passed
    event type.

        Returns:
            CustomEvent: Initialised CustomEvent instance.
        """
        if event_type in required_args:

            for required_arg in required_args[event_type]:
                if required_arg not in kwargs:
                    raise ValueError(f"Argument '{required_arg}' required for {
    event_type.name} event (GameEvent.create_event)")
```

```

            for kwarg in kwargs:
                if kwarg not in required_args[event_type]:
                    raise ValueError(f"Argument '{kwarg}' not included in
    required_args dictionary for event '{event_type}'! (GameEvent.create_event)")

            return event_cls(event_type, **kwargs)

        else:
            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

```
from data.widgets.reactive_button import ReactiveButton
from data.utils.constants import WidgetState
from data.widgets.icon import Icon

class ReactiveIconButton(ReactiveButton):
    def __init__(self, base_icon, hover_icon, press_icon, **kwargs):
        # Composition is used here, to initialise the Icon widgets for each widget
     state
        widgets_dict = {
            WidgetState.BASE: Icon(
                parent=kwargs.get('parent'),
                relative_size=kwargs.get('relative_size'),
                relative_position=(0, 0),
                icon=base_icon,
                fill_colour=(0, 0, 0, 0),
                border_width=0,
                margin=0,
                fit_icon=True,
            ),
            WidgetState.HOVER: Icon(
                parent=kwargs.get('parent'),
                relative_size=kwargs.get('relative_size'),
                relative_position=(0, 0),
                icon=hover_icon,
                fill_colour=(0, 0, 0, 0),
                border_width=0,
                margin=0,
                fit_icon=True,
            ),
            WidgetState.PRESS: Icon(
                parent=kwargs.get('parent'),
                relative_size=kwargs.get('relative_size'),
                relative_position=(0, 0),
                icon=press_icon,
                fill_colour=(0, 0, 0, 0),
                border_width=0,
                margin=0,
                fit_icon=True,
            )
        }

        super().__init__(
            widgets_dict=widgets_dict,
            **kwargs
```

```
        )
```

### 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`

```python
from data.components.custom_event import CustomEvent
from data.widgets.bases.pressable import _Pressable
from data.widgets.bases.circular import _Circular
from data.widgets.bases.widget import _Widget
from data.utils.constants import WidgetState

class ReactiveButton(_Pressable, _Circular, _Widget):
    def __init__(self, widgets_dict, event, center=False, **kwargs):
        # Multiple inheritance used here, to combine the functionality of multiple super classes
        _Pressable.__init__(
            self,
            event=event,
            hover_func=lambda: self.set_to_key(WidgetState.HOVER),
            down_func=lambda: self.set_to_key(WidgetState.PRESS),
            up_func=lambda: self.set_to_key(WidgetState.BASE),
            **kwargs
        )
        # Aggregation used to cycle between external widgets
        _Circular.__init__(self, items_dict=widgets_dict)
        _Widget.__init__(self, **kwargs)

        self._center = center

        self.initialise_new_colours(self._fill_colour)

    @property
    def position(self):
        """
        Overrides position getter method, to always position icon in the center if self._center is True.

        Returns:
            list[int, int]: Position of widget.
        """
        position = super().position

        if self._center:
            self._size_diff = (self.size[0] - self.rect.width, self.size[1] - self.rect.height)
            return (position[0] + self._size_diff[0] / 2, position[1] + self._size_diff[1] / 2)
        else:
            return position

    def set_image(self):
        """
        Sets current icon to image.
        """
        self.current_item.set_image()
        self.image = self.current_item.image

    def set_geometry(self):
```

```
        """
        Sets size and position of widget.
        """
        super().set_geometry()
        self.current_item.set_geometry()
        self.current_item.rect.topleft = self.rect.topleft

    def set_surface_size(self, new_surface_size):
        """
        Overrides base method to resize every widget state icon, not just the
    current one.

        Args:
            new_surface_size (list[int, int]): New surface size.
        """
        super().set_surface_size(new_surface_size)
        for item in self._items_dict.values():
            item.set_surface_size(new_surface_size)

    def process_event(self, event):
        """
        Processes Pygame events.

        Args:
            event (pygame.Event): Event to process.

        Returns:
            CustomEvent: CustomEvent of current item, with current key included
        """
        widget_event = super().process_event(event)
        self.current_item.process_event(event)

        if widget_event:
            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

```
import pygame
from data.helpers.widget_helpers import create_slider_gradient
from data.helpers.asset_helpers import smoothscale_and_cache
from data.widgets.slider_thumb import _SliderThumb
from data.widgets.bases.widget import _Widget
from data.utils.constants import WidgetState

class _ColourSlider(_Widget):
    def __init__(self, relative_width, **kwargs):
        super().__init__(relative_size=(relative_width, relative_width * 0.2), **
    kwargs)

        # Initialise slider thumb.
        self._thumb = _SliderThumb(radius=self.size[1] / 2, border_colour=self.
    _border_colour)

        self._selected_percent = 0
        self._last_mouse_x = None

```

```python
        self._gradient_surface = create_slider_gradient(self.gradient_size, self.border_width, self._border_colour)
        self._empty_surface = pygame.Surface(self.size, pygame.SRCALPHA)

    @property
    def gradient_size(self):
        return (self.size[0] - 2 * (self.size[1] / 2), self.size[1] / 2)

    @property
    def gradient_position(self):
        return (self.size[1] / 2, self.size[1] / 4)

    @property
    def thumb_position(self):
        return (self.gradient_size[0] * self._selected_percent, 0)

    @property
    def selected_colour(self):
        colour = pygame.Color(0)
        colour.hsva = (int(self._selected_percent * 360), 100, 100, 100)
        return colour

    def calculate_gradient_percent(self, mouse_pos):
        """
        Calculate what percentage slider thumb is at based on change in mouse position.

        Args:
            mouse_pos (list[int, int]): Position of mouse on window screen.

        Returns:
            float: Slider scroll percentage.
        """
        if self._last_mouse_x is None:
            return

        x_change = (mouse_pos[0] - self._last_mouse_x) / (self.gradient_size[0] - 2 * self.border_width)
        return max(0, min(self._selected_percent + x_change, 1))

    def relative_to_global_position(self, position):
        """
        Transforms position from being relative to widget rect, to window screen.

        Args:
            position (list[int, int]): Position relative to widget rect.

        Returns:
            list[int, int]: Position relative to window screen.
        """
        relative_x, relative_y = position
        return (relative_x + self.position[0], relative_y + self.position[1])

    def set_colour(self, new_colour):
        """
        Sets selected_percent based on the new colour's hue.

        Args:
            new_colour (pygame.Color): New slider colour.
        """
        colour = pygame.Color(new_colour)
        hue = colour.hsva[0]
```

```
        self._selected_percent = hue / 360
        self.set_image()

    def set_image(self):
        """
        Draws colour slider to widget image.
        """
        # Scales initalised gradient surface instead of redrawing it everytime set_image is called
        gradient_scaled = smoothscale_and_cache(self._gradient_surface, self.gradient_size)

        self.image = pygame.transform.scale(self._empty_surface, (self.size))
        self.image.blit(gradient_scaled, self.gradient_position)

        # Resets thumb colour, image and position, then draws it to the widget image
        self._thumb.initialise_new_colours(self.selected_colour)
        self._thumb.set_surface(radius=self.size[1] / 2, border_width=self.border_width)
        self._thumb.set_position(self.relative_to_global_position((self.thumb_position[0], self.thumb_position[1])))

        thumb_surface = self._thumb.get_surface()
        self.image.blit(thumb_surface, self.thumb_position)

    def process_event(self, event):
        """
        Processes Pygame events.

        Args:
            event (pygame.Event): Event to process.

        Returns:
            pygame.Color: Current colour slider is displaying.
        """
        if event.type not in [pygame.MOUSEMOTION, pygame.MOUSEBUTTONDOWN, pygame.MOUSEBUTTONUP]:
            return

        # Gets widget state before and after event is processed by slider thumb
        before_state = self._thumb.state
        self._thumb.process_event(event)
        after_state = self._thumb.state

        # If widget state changes (e.g. hovered -> pressed), redraw widget
        if before_state != after_state:
            self.set_image()

        if event.type == pygame.MOUSEMOTION:
            if self._thumb.state == WidgetState.PRESS:
                # Recalculates slider colour based on mouse position change
                selected_percent = self.calculate_gradient_percent(event.pos)
                self._last_mouse_x = event.pos[0]

                if selected_percent is not None:
                    self._selected_percent = selected_percent

                    return self.selected_colour

        if event.type == pygame.MOUSEBUTTONUP:
            # When user stops scrolling, return new slider colour
```

```
            self._last_mouse_x = None
            return self.selected_colour

        if event.type == pygame.MOUSEBUTTONDOWN or before_state != after_state:
            # Redraws widget when slider thumb is hovered or pressed
            return self.selected_colour
```

### TextInput

The `TextInput` widget is used for inputting fen strings and time controls.
`text_input.py`

```
import pyperclip
import pygame
from data.utils.constants import WidgetState, INPUT_COLOURS
from data.components.custom_event import CustomEvent
from data.widgets.bases.pressable import _Pressable
from data.managers.logs import initialise_logger
from data.managers.animation import animation
from data.widgets.bases.box import _Box
from data.utils.enums import CursorMode
from data.managers.cursor import cursor
from data.managers.theme import theme
from data.widgets.text import Text

logger = initialise_logger(__name__)

class TextInput(_Box, _Pressable, Text):
    def __init__(self, event, blinking_interval=530, validator=(lambda x: True),
    default='', placeholder='PLACEHOLDER TEXT', placeholder_colour=(200, 200, 200)
    , cursor_colour=theme['textSecondary'], **kwargs):
        self._cursor_index = None
        # Multiple inheritance used here, adding the functionality of pressing,
    and custom box colours, to the text widget
        _Box.__init__(self, box_colours=INPUT_COLOURS)
        _Pressable.__init__(
            self,
            event=None,
            hover_func=lambda: self.set_state_colour(WidgetState.HOVER),
            down_func=lambda: self.set_state_colour(WidgetState.PRESS),
            up_func=lambda: self.set_state_colour(WidgetState.BASE),
            sfx=None
        )
        Text.__init__(self, text="", center=False, box_colours=INPUT_COLOURS[
    WidgetState.BASE], **kwargs)

        self.initialise_new_colours(self._fill_colour)
        self.set_state_colour(WidgetState.BASE)

        pygame.key.set_repeat(500, 50)

        self._blinking_fps = 1000 / blinking_interval
        self._cursor_colour = cursor_colour
        self._cursor_colour_copy = cursor_colour
        self._placeholder_colour = placeholder_colour
        self._text_colour_copy = self._text_colour

        self._placeholder_text = placeholder
        self._is_placeholder = None
        if default:
            self._text = default
```

```python
            self.is_placeholder = False
        else:
            self._text = self._placeholder_text
            self.is_placeholder = True

        self._event = event
        self._validator = validator
        self._blinking_cooldown = 0

        self._empty_cursor = pygame.Surface((0, 0), pygame.SRCALPHA)

        self.resize_text()
        self.set_image()
        self.set_geometry()

    @property
    # Encapsulated getter method
    def is_placeholder(self):
        return self._is_placeholder

    @is_placeholder.setter
    # Encapsulated setter method, used to replace text colour if placeholder text is shown
    def is_placeholder(self, is_true):
        self._is_placeholder = is_true

        if is_true:
            self._text_colour = self._placeholder_colour
        else:
            self._text_colour = self._text_colour_copy

    @property
    def cursor_size(self):
        cursor_height = (self.size[1] - self.border_width * 2) * 0.75
        return (cursor_height * 0.1, cursor_height)

    @property
    def cursor_position(self):
        current_width = (self.margin / 2)
        for index, metrics in enumerate(self._font.get_metrics(self._text, size=self.font_size)):
            if index == self._cursor_index:
                return (current_width - self.cursor_size[0], (self.size[1] - self.cursor_size[1]) / 2)

            glyph_width = metrics[4]
            current_width += glyph_width
        return (current_width - self.cursor_size[0], (self.size[1] - self.cursor_size[1]) / 2)

    @property
    def text(self):
        if self.is_placeholder:
            return ''

        return self._text

    def relative_x_to_cursor_index(self, relative_x):
        """
        Calculates cursor index using mouse position relative to the widget position.

```

```
        Args:
            relative_x (int): Horizontal distance of the mouse from the left side of the widget.

        Returns:
            int: Cursor index.
        """
        current_width = 0

        for index, metrics in enumerate(self._font.get_metrics(self._text, size=self.font_size)):
            glyph_width = metrics[4]

            if current_width >= relative_x:
                return index

            current_width += glyph_width

        return len(self._text)

    def set_cursor_index(self, mouse_pos):
        """
        Sets cursor index based on mouse position.

        Args:
            mouse_pos (list[int, int]): Mouse position relative to window screen.
        """
        if mouse_pos is None:
            self._cursor_index = mouse_pos
            return

        relative_x = mouse_pos[0] - (self.margin / 2) - self.rect.left
        relative_x = max(0, relative_x)
        self._cursor_index = self.relative_x_to_cursor_index(relative_x)

    def focus_input(self, mouse_pos):
        """
        Draws cursor and sets cursor index when user clicks on widget.

        Args:
            mouse_pos (list[int, int]): Mouse position relative to window screen.
        """
        if self.is_placeholder:
            self._text = ''
            self.is_placeholder = False

        self.set_cursor_index(mouse_pos)
        self.set_image()
        cursor.set_mode(CursorMode.IBEAM)

    def unfocus_input(self):
        """
        Removes cursor when user unselects widget.
        """
        if self._text == '':
            self._text = self._placeholder_text
            self.is_placeholder = True
            self.resize_text()

        self.set_cursor_index(None)
        self.set_image()
        cursor.set_mode(CursorMode.ARROW)
```

```

    def set_text(self, new_text):
        """
        Called by a state object to change the widget text externally.

        Args:
            new_text (str): New text to display.

        Returns:
            CustomEvent: Object containing the new text to alert state of a text update.
        """
        super().set_text(new_text)
        return CustomEvent(**vars(self._event), text=self.text)

    def process_event(self, event):
        """
        Processes Pygame events.

        Args:
            event (pygame.Event): Event to process.

        Returns:
            CustomEvent: Object containing the new text to alert state of a text update.
        """
        previous_state = self.get_widget_state()
        super().process_event(event)
        current_state = self.get_widget_state()

        match event.type:
            case pygame.MOUSEMOTION:
                if self._cursor_index is None:
                    return

                # If mouse is hovering over widget, turn mouse cursor into an I-beam
                if self.rect.collidepoint(event.pos):
                    if cursor.get_mode() != CursorMode.IBEAM:
                        cursor.set_mode(CursorMode.IBEAM)
                else:
                    if cursor.get_mode() == CursorMode.IBEAM:
                        cursor.set_mode(CursorMode.ARROW)

                return

            case pygame.MOUSEBUTTONUP:
                # When user selects widget
                if previous_state == WidgetState.PRESS:
                    self.focus_input(event.pos)
                # When user unselects widget
                if current_state == WidgetState.BASE and self._cursor_index is not None:
                    self.unfocus_input()
                    return CustomEvent(**vars(self._event), text=self.text)

            case pygame.KEYDOWN:
                if self._cursor_index is None:
                    return

                # Handling Ctrl-C and Ctrl-V shortcuts
                if event.mod & (pygame.KMOD_CTRL):
```

```python
                if event.key == pygame.K_c:
                    pyperclip.copy(self.text)
                    logger.info(f'COPIED {self.text}')

                elif event.key == pygame.K_v:
                    pasted_text = pyperclip.paste()
                    pasted_text = ''.join(char for char in pasted_text if 32 <= ord(char) <= 127)
                    self._text = self._text[:self._cursor_index] + pasted_text + self._text[self._cursor_index:]
                    self._cursor_index += len(pasted_text)

                elif event.key == pygame.K_BACKSPACE or event.key == pygame.K_DELETE:
                    self._text = ''
                    self._cursor_index = 0

                self.resize_text()
                self.set_image()
                self.set_geometry()

                return

            match event.key:
                case pygame.K_BACKSPACE:
                    if self._cursor_index > 0:
                        self._text = self._text[:self._cursor_index - 1] + self._text[self._cursor_index:]
                    self._cursor_index = max(0, self._cursor_index - 1)

                case pygame.K_RIGHT:
                    self._cursor_index = min(len(self._text), self._cursor_index + 1)

                case pygame.K_LEFT:
                    self._cursor_index = max(0, self._cursor_index - 1)

                case pygame.K_ESCAPE:
                    self.unfocus_input()
                    return CustomEvent(**vars(self._event), text=self.text)

                case pygame.K_RETURN:
                    self.unfocus_input()
                    return CustomEvent(**vars(self._event), text=self.text)

                case _:
                    if not event.unicode:
                        return

                    potential_text = self._text[:self._cursor_index] + event.unicode + self._text[self._cursor_index:]

                    # Validator lambda function used to check if inputted text is valid before displaying
                    # e.g. Time control input has a validator function checking if text represents a float
                    if self._validator(potential_text) is False:
                        return

                    self._text = potential_text
                    self._cursor_index += 1

```

```python
                self._blinking_cooldown += 1
                animation.set_timer(500, lambda: self.subtract_blinking_cooldown
    (1))

                self.resize_text()
                self.set_image()
                self.set_geometry()

    def subtract_blinking_cooldown(self, cooldown):
        """
        Subtracts blinking cooldown after certain timeframe. When
    blinking_cooldown is 1, cursor is able to be drawn.

        Args:
            cooldown (float): Duration before cursor can no longer be drawn.
        """
        self._blinking_cooldown = self._blinking_cooldown - cooldown

    def set_image(self):
        """
        Draws text input widget to image.
        """
        super().set_image()

        if self._cursor_index is not None:
            scaled_cursor = pygame.transform.scale(self._empty_cursor, self.
    cursor_size)
            scaled_cursor.fill(self._cursor_colour)
            self.image.blit(scaled_cursor, self.cursor_position)

    def update(self):
        """
        Overrides based update method, to handle cursor blinking.
        """
        super().update()
        # Calculate if cursor should be shown or not
        cursor_frame = animation.calculate_frame_index(0, 2, self._blinking_fps)
        if cursor_frame == 1 and self._blinking_cooldown == 0:
            self._cursor_colour = (0, 0, 0, 0)
        else:
            self._cursor_colour = self._cursor_colour_copy
        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`

```python
from random import getrandbits
from data.states.game.components.fen_parser import encode_fen_string
from data.states.game.widget_dict import GAME_WIDGETS
from data.states.game.cpu.cpu_thread import CPUThread
from data.components.custom_event import CustomEvent
from data.helpers.bitboard_helpers import is_occupied
from data.helpers import input_helpers as ip_helpers
```

```python
from data.states.game.components.board import Board
from data.states.game.components.move import Move
from data.utils.event_types import GameEventType
from data.managers.logs import initialise_logger
from data.managers.animation import animation
from data.states.game.cpu.engines import *
from data.utils.constants import EMPTY_BB
from data.utils.enums import Colour

logger = initialise_logger(__name__)

# TEMP
CPU_LIMIT_MS = 1500000

class GameModel:
    def __init__(self, game_config):
        self._listeners = {
            'game': [],
            'win': [],
            'pause': [],
        }
        self.states = {
            'CPU_ENABLED': game_config['CPU_ENABLED'],
            'CPU_DEPTH': game_config['CPU_DEPTH'],
            'AWAITING_CPU': False,
            'WINNER': None,
            'PAUSED': False,
            'ACTIVE_COLOUR': game_config['COLOUR'],
            'TIME_ENABLED': game_config['TIME_ENABLED'],
            'TIME': game_config['TIME'],
            'START_FEN_STRING': game_config['FEN_STRING'],
            'MOVES': [],
            'ZOBRIST_KEYS': []
        }

        self._board = Board(fen_string=game_config['FEN_STRING'])

        self._cpu = IDMinimaxCPU(self.states['CPU_DEPTH'], self.cpu_callback,
    verbose=False)
        self._cpu_thread = CPUThread(self._cpu)
        self._cpu_thread.start()
        self._cpu_move = None

        logger.info(f'Initialising CPU depth of {self.states['CPU_DEPTH']}')

    def register_listener(self, listener, parent_class):
        """
        Registers listener method of another MVC class.

        Args:
            listener (callable): Listener callback function.
            parent_class (str): Class name.
        """
        self._listeners[parent_class].append(listener)

    def alert_listeners(self, event):
        """
        Alerts all registered classes of an event by calling their listener
    function.

        Args:
            event (GameEventType): Event to pass as argument.
```

```

        Raises:
            Exception: If an unrecgonised event tries to be passed onto listeners.
        """
        for parent_class, listeners in self._listeners.items():
            match event.type:
                case GameEventType.UPDATE_PIECES:
                    if parent_class in 'game':
                        for listener in listeners: listener(event)

                case GameEventType.SET_LASER:
                    if parent_class == 'game':
                        for listener in listeners: listener(event)

                case GameEventType.PAUSE_CLICK:
                    if parent_class in ['pause', 'game']:
                        for listener in listeners:
                            listener(event)

                case _:
                    raise Exception('Unhandled event type (GameModel.
alert_listeners)')

    def set_winner(self, colour=None):
        """
        Sets winner.

        Args:
            colour (Colour, optional): Describes winnner colour, or draw. Defaults
 to None.
        """
        self.states['WINNER'] = colour

    def toggle_paused(self):
        """
        Toggles pause screen, and alerts pause view.
        """
        self.states['PAUSED'] = not self.states['PAUSED']
        game_event = CustomEvent.create_event(GameEventType.PAUSE_CLICK)
        self.alert_listeners(game_event)

    def get_terminal_move(self):
        """
        Debugging method for inputting a move from the terminal.

        Returns:
            Move: Parsed move.
        """
        while True:
            try:
                move_type = ip_helpers.parse_move_type(input('Input move type (m/r
): '))
                src_square = ip_helpers.parse_notation(input("From: "))
                dest_square = ip_helpers.parse_notation(input("To: "))
                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))

    def make_move(self, move):
```

```
        """
        Takes a Move object and applies it to the board.

        Args:
            move (Move): Move to apply.
        """
        colour = self._board.bitboards.get_colour_on(move.src)
        piece = self._board.bitboards.get_piece_on(move.src, colour)
        # Apply move and get results of laser trajectory
        laser_result = self._board.apply_move(move, add_hash=True)

        self.alert_listeners(CustomEvent.create_event(GameEventType.SET_LASER,
    laser_result=laser_result))

        # Sets new active colour and checks for a win
        self.states['ACTIVE_COLOUR'] = self._board.get_active_colour()
        self.set_winner(self._board.check_win())

        move_notation = move.to_notation(colour, piece, laser_result.
    hit_square_bitboard)

        self.alert_listeners(CustomEvent.create_event(GameEventType.UPDATE_PIECES,
     move_notation=move_notation))

        # Adds move to move history list for review screen
        self.states['MOVES'].append({
            'time': {
                Colour.BLUE: GAME_WIDGETS['blue_timer'].get_time(),
                Colour.RED: GAME_WIDGETS['red_timer'].get_time()
            },
            'move': move_notation,
            'laserResult': laser_result
        })

    def make_cpu_move(self):
        """
        Starts CPU calculations on the separate thread.
        """
        self.states['AWAITING_CPU'] = True

        # Employ time management system to kill search if using an iterative
    deepening CPU
        # if isinstance(self._cpu, IDMinimaxCPU):
        #     move_id = getrandbits(32)
        #     self._cpu_thread.start_cpu(self.get_board(), id=move_id)
        #     animation.set_timer(CPU_LIMIT_MS, lambda: self._cpu_thread.stop_cpu(
    id=move_id))
        # else:
        self._cpu_thread.start_cpu(self.get_board())

    def cpu_callback(self, move):
        """
        Callback function passed to CPU thread. Called when CPU stops processing.

        Args:
            move (Move): Move that CPU found.
        """
        if self.states['WINNER'] is None:
            # CPU move passed back to main thread by reassigning variable
            self._cpu_move = move
            self.states['AWAITING_CPU'] = False
```

```
    def check_cpu(self):
        """
        Constantly checks if CPU calculations are finished, so that make_move can be run on the main thread.
        """
        if self._cpu_move is not None:
            self.make_move(self._cpu_move)
            self._cpu_move = None

    def kill_thread(self):
        """
        Interrupt and kill CPU thread.
        """
        self._cpu_thread.kill_thread()
        self.states['AWAITING_CPU'] = False

    def is_selectable(self, bitboard):
        """
        Checks if square is occupied by a piece of the current active colour.

        Args:
            bitboard (int): Bitboard representing single square.

        Returns:
            bool: True if square is occupied by a piece of the current active colour. False if not.
        """
        return is_occupied(self._board.bitboards.combined_colour_bitboards[self.states['ACTIVE_COLOUR']], bitboard)

    def get_available_moves(self, bitboard):
        """
        Gets all surrounding empty squares. Used for drawing overlay.

        Args:
            bitboard (int): Bitboard representing single center square.

        Returns:
            int: Bitboard representing all empty surrounding squares.
        """
        if (bitboard & self._board.get_all_active_pieces()) != EMPTY_BB:
            return self._board.get_valid_squares(bitboard)

        return EMPTY_BB

    def get_piece_list(self):
        """
        Returns:
            list[Piece, ...]: Array of all pieces on the board.
        """
        return self._board.get_piece_list()

    def get_piece_info(self, bitboard):
        """
        Args:
            bitboard (int): Square containing piece.

        Returns:
            tuple[Colour, Rotation, Piece]: Piece information.
        """
        colour = self._board.bitboards.get_colour_on(bitboard)
        rotation = self._board.bitboards.get_rotation_on(bitboard)
```

```python
        piece = self._board.bitboards.get_piece_on(bitboard, colour)
        return (piece, colour, rotation)

    def get_fen_string(self):
        return encode_fen_string(self._board.bitboards)

    def get_board(self):
        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 appropiate handling function within the view class is called by mapping the event type to the corresponding handler function.

game_view.py

```python
import pygame
from data.utils.enums import Colour, StatusText, Miscellaneous, ShaderType
from data.states.game.components.overlay_draw import OverlayDraw
from data.states.game.components.capture_draw import CaptureDraw
from data.states.game.components.piece_group import PieceGroup
from data.states.game.components.laser_draw import LaserDraw
from data.states.game.components.father import DragAndDrop
from data.helpers.bitboard_helpers import bitboard_to_coords
from data.helpers.board_helpers import screen_pos_to_coords
from data.states.game.widget_dict import GAME_WIDGETS
from data.components.custom_event import CustomEvent
from data.components.widget_group import WidgetGroup
from data.utils.event_types import GameEventType
from data.managers.window import window
from data.managers.audio import audio
from data.utils.assets import SFX

class GameView:
    def __init__(self, model):
        self._model = model
        self._hide_pieces = False
        self._selected_coords = None
        self._event_to_func_map = {
            GameEventType.UPDATE_PIECES: self.handle_update_pieces,
            GameEventType.SET_LASER: self.handle_set_laser,
            GameEventType.PAUSE_CLICK: self.handle_pause,
        }

        # Register model event handling with process_model_event()
        self._model.register_listener(self.process_model_event, 'game')

        # Initialise WidgetGroup with map of widgets
        self._widget_group = WidgetGroup(GAME_WIDGETS)
        self._widget_group.handle_resize(window.size)
        self.initialise_widgets()

        self._laser_draw = LaserDraw(self.board_position, self.board_size)
        self._overlay_draw = OverlayDraw(self.board_position, self.board_size)
        self._drag_and_drop = DragAndDrop(self.board_position, self.board_size)
        self._capture_draw = CaptureDraw(self.board_position, self.board_size)
        self._piece_group = PieceGroup()
        self.handle_update_pieces()
```

```python

        self.set_status_text(StatusText.PLAYER_MOVE)

    @property
    def board_position(self):
        return GAME_WIDGETS['chessboard'].position

    @property
    def board_size(self):
        return GAME_WIDGETS['chessboard'].size

    @property
    def square_size(self):
        return self.board_size[0] / 10

    def initialise_widgets(self):
        """
        Run methods on widgets stored in GAME_WIDGETS dictionary to reset them.
        """
        GAME_WIDGETS['move_list'].reset_move_list()
        GAME_WIDGETS['move_list'].kill()
        GAME_WIDGETS['help'].kill()
        GAME_WIDGETS['tutorial'].kill()

        GAME_WIDGETS['scroll_area'].set_image()

        GAME_WIDGETS['chessboard'].refresh_board()

        GAME_WIDGETS['blue_piece_display'].reset_piece_list()
        GAME_WIDGETS['red_piece_display'].reset_piece_list()

    def set_status_text(self, status):
        """
        Sets text on status text widget.

        Args:
            status (StatusText): The game stage for which text should be displayed for.
        """
        match status:
            case StatusText.PLAYER_MOVE:
                GAME_WIDGETS['status_text'].set_text(f"{self._model.states['ACTIVE_COLOUR'].name}'s turn to move")
            case StatusText.CPU_MOVE:
                GAME_WIDGETS['status_text'].set_text("CPU thinking...") # CPU calculating a crazy move...
            case StatusText.WIN:
                if self._model.states['WINNER'] == Miscellaneous.DRAW:
                    GAME_WIDGETS['status_text'].set_text("Game is a draw! Boring...")
                else:
                    GAME_WIDGETS['status_text'].set_text(f"{self._model.states['WINNER'].name} won!")
            case StatusText.DRAW:
                GAME_WIDGETS['status_text'].set_text("Game is a draw! Boring...")

    def handle_resize(self):
        """
        Handles resizing of the window.
        """
        self._overlay_draw.handle_resize(self.board_position, self.board_size)
        self._capture_draw.handle_resize(self.board_position, self.board_size)
```

```python
        self._piece_group.handle_resize(self.board_position, self.board_size)
        self._laser_draw.handle_resize(self.board_position, self.board_size)
        self._laser_draw.handle_resize(self.board_position, self.board_size)
        self._widget_group.handle_resize(window.size)

        if self._laser_draw.firing:
            self.update_laser_mask()

    def handle_update_pieces(self, event=None):
        """
        Callback function to update pieces after move.

        Args:
            event (GameEventType, optional): If updating pieces after player move, event contains move information. Defaults to None.
            toggle_timers (bool, optional): Toggle timers on and off for new active colour. Defaults to True.
        """
        piece_list = self._model.get_piece_list()
        self._piece_group.initialise_pieces(piece_list, self.board_position, self.board_size)

        if event:
            GAME_WIDGETS['move_list'].append_to_move_list(event.move_notation)
            GAME_WIDGETS['scroll_area'].set_image()
            audio.play_sfx(SFX['piece_move'])

        # If active colour is starting colour, as player always moves first
        if ['b', 'r'][self._model.states['ACTIVE_COLOUR']] == self._model.states['START_FEN_STRING'][-1]:
            self.set_status_text(StatusText.PLAYER_MOVE)
        else:
            if self._model.states['CPU_ENABLED']:
                self.set_status_text(StatusText.CPU_MOVE)
            else:
                self.set_status_text(StatusText.PLAYER_MOVE)

        if self._model.states['TIME_ENABLED']:
            self.toggle_timer(self._model.states['ACTIVE_COLOUR'], True)
            self.toggle_timer(self._model.states['ACTIVE_COLOUR'].get_flipped_colour(), False)

        if self._model.states['WINNER'] is not None:
            self.handle_game_end()

        # Update occlusion mask for rays shader with new piece positions
        self.update_laser_mask()

    def handle_game_end(self, play_sfx=True):
        self.toggle_timer(self._model.states['ACTIVE_COLOUR'], False)
        self.toggle_timer(self._model.states['ACTIVE_COLOUR'].get_flipped_colour(), False)

        if self._model.states['WINNER'] == Miscellaneous.DRAW:
            self.set_status_text(StatusText.DRAW)
        else:
            self.set_status_text(StatusText.WIN)

        if play_sfx:
            audio.play_sfx(SFX['sphinx_destroy_1'])
            audio.play_sfx(SFX['sphinx_destroy_2'])
            audio.play_sfx(SFX['sphinx_destroy_3'])
```

```

    def handle_set_laser(self, event):
        """
        Callback function to draw laser after move.

        Args:
            event (GameEventType): Contains laser trajectory information.
        """
        laser_result = event.laser_result

        # If laser has hit a piece
        if laser_result.hit_square_bitboard:
            coords_to_remove = bitboard_to_coords(laser_result.hit_square_bitboard)
            self._piece_group.remove_piece(coords_to_remove)

            if laser_result.piece_colour == Colour.BLUE:
                GAME_WIDGETS['red_piece_display'].add_piece(laser_result.piece_hit)
            elif laser_result.piece_colour == Colour.RED:
                GAME_WIDGETS['blue_piece_display'].add_piece(laser_result.piece_hit)

            # Draw piece capture GFX
            self._capture_draw.add_capture(
                laser_result.piece_hit,
                laser_result.piece_colour,
                laser_result.piece_rotation,
                coords_to_remove,
                laser_result.laser_path[0][0],
                self._model.states['ACTIVE_COLOUR']
            )

        self._laser_draw.add_laser(laser_result, self._model.states['ACTIVE_COLOUR'])

    def handle_pause(self, event=None):
        """
        Callback function for pausing timer.

        Args:
            event (None): Event argument not used.
        """
        is_active = not(self._model.states['PAUSED'])
        self.toggle_timer(self._model.states['ACTIVE_COLOUR'], is_active)

    def initialise_timers(self):
        """
        Initialises both timers with the correct amount of time and starts the timer for the active colour.
        """
        if self._model.states['TIME_ENABLED']:
            GAME_WIDGETS['blue_timer'].set_time(self._model.states['TIME'] * 60 * 1000)
            GAME_WIDGETS['red_timer'].set_time(self._model.states['TIME'] * 60 * 1000)
        else:
            GAME_WIDGETS['blue_timer'].kill()
            GAME_WIDGETS['red_timer'].kill()

        self.toggle_timer(self._model.states['ACTIVE_COLOUR'], True)

```

```
    def toggle_timer(self, colour, is_active):
        """
        Stops or resumes timer.

        Args:
            colour (Colour): Timer to toggle.
            is_active (bool): Whether to pause or resume timer.
        """
        if colour == Colour.BLUE:
            GAME_WIDGETS['blue_timer'].set_active(is_active)
        elif colour == Colour.RED:
            GAME_WIDGETS['red_timer'].set_active(is_active)

    def update_laser_mask(self):
        """
        Uses pygame.mask to create a mask for the pieces.
        Used for occluding the ray shader.
        """
        temp_surface = pygame.Surface(window.size, pygame.SRCALPHA)
        self._piece_group.draw(temp_surface)
        mask = pygame.mask.from_surface(temp_surface, threshold=127)
        mask_surface = mask.to_surface(unsetcolor=(0, 0, 0, 255), setcolor=(255, 0, 0, 255))

        window.set_apply_arguments(ShaderType.RAYS, occlusion=mask_surface)

    def draw(self):
        """
        Draws GUI and pieces onto the screen.
        """
        self._widget_group.update()
        self._capture_draw.update()

        self._widget_group.draw()
        self._overlay_draw.draw(window.screen)

        if self._hide_pieces is False:
            self._piece_group.draw(window.screen)

        self._laser_draw.draw(window.screen)
        self._drag_and_drop.draw(window.screen)
        self._capture_draw.draw(window.screen)

    def process_model_event(self, event):
        """
        Registered listener function for handling GameModel events.
        Each event is mapped to a callback function, and the appropiate one is run.

        Args:
            event (GameEventType): Game event to process.

        Raises:
            KeyError: If an unrecgonised event type is passed as the argument.
        """
        try:
            self._event_to_func_map.get(event.type)(event)
        except:
            raise KeyError('Event type not recognized in Game View (GameView.process_model_event):', event.type)

    def set_overlay_coords(self, available_coords_list, selected_coord):
```

```
        """
        Set board coordinates for potential moves overlay.

        Args:
            available_coords_list (list[tuple[int, int]], ...): Array of
    coordinates
            selected_coord (list[int, int]): Coordinates of selected piece.
        """
        self._selected_coords = selected_coord
        self._overlay_draw.set_selected_coords(selected_coord)
        self._overlay_draw.set_available_coords(available_coords_list)

    def get_selected_coords(self):
        return self._selected_coords

    def set_dragged_piece(self, piece, colour, rotation):
        """
        Passes information of the dragged piece to the dragging drawing class.

        Args:
            piece (Piece): Piece type of dragged piece.
            colour (Colour): Colour of dragged piece.
            rotation (Rotation): Rotation of dragged piece.
        """
        self._drag_and_drop.set_dragged_piece(piece, colour, rotation)

    def remove_dragged_piece(self):
        """
        Stops drawing dragged piece when user lets go of piece.
        """
        self._drag_and_drop.remove_dragged_piece()

    def convert_mouse_pos(self, event):
        """
        Passes information of what mouse cursor is interacting with to a
    GameController object.

        Args:
            event (pygame.Event): Mouse event to process.

        Returns:
            CustomEvent | None: Contains information what mouse is doing.
        """
        clicked_coords = screen_pos_to_coords(event.pos, self.board_position, self
    .board_size)

        if event.type == pygame.MOUSEBUTTONDOWN:
            if clicked_coords:
                return CustomEvent.create_event(GameEventType.BOARD_CLICK, coords=
    clicked_coords)

            else:
                return None

        elif event.type == pygame.MOUSEBUTTONUP:
            if self._drag_and_drop.dragged_sprite:
                piece, colour, rotation = self._drag_and_drop.get_dragged_info()
                piece_dragged = self._drag_and_drop.remove_dragged_piece()
                return CustomEvent.create_event(GameEventType.PIECE_DROP, coords=
    clicked_coords, piece=piece, colour=colour, rotation=rotation, remove_overlay=
    piece_dragged)

```

```
    def add_help_screen(self):
        """
        Draw help overlay when player clicks on the help button.
        """
        self._widget_group.add(GAME_WIDGETS['help'])
        self._widget_group.handle_resize(window.size)

    def add_tutorial_screen(self):
        """
        Draw tutorial overlay when player clicks on the tutorial button.
        """
        self._widget_group.add(GAME_WIDGETS['tutorial'])
        self._widget_group.handle_resize(window.size)
        self._hide_pieces = True

    def remove_help_screen(self):
        GAME_WIDGETS['help'].kill()

    def remove_tutorial_screen(self):
        GAME_WIDGETS['tutorial'].kill()
        self._hide_pieces = False

    def process_widget_event(self, event):
        """
        Passes Pygame event to WidgetGroup to allow individual widgets to process
    events.

        Args:
            event (pygame.Event): Event to process.

        Returns:
            CustomEvent | None: A widget event.
        """
        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

```
import pygame
from data.helpers import bitboard_helpers as bb_helpers
from data.utils.enums import MoveType, Miscellaneous
from data.states.game.components.move import Move
from data.utils.event_types import GameEventType
from data.managers.logs import initialise_logger

logger = initialise_logger(__name__)

class GameController:
    def __init__(self, model, view, win_view, pause_view, to_menu, to_review,
    to_new_game):
        self._model = model
        self._view = view
        self._win_view = win_view
        self._pause_view = pause_view

        self._to_menu = to_menu
        self._to_review = to_review
```

```
        self._to_new_game = to_new_game

        self._view.initialise_timers()
        self._win_view.set_win_type('CAPTURE')

    def cleanup(self, next):
        """
        Handles game quit, either leaving to main menu or restarting a new game.

        Args:
            next (str): New state to switch to.
        """
        self._model.kill_thread()

        if next == 'menu':
            self._to_menu()
        elif next == 'game':
            self._to_new_game()
        elif next == 'review':
            self._to_review()

    def make_move(self, move):
        """
        Handles player move.

        Args:
            move (Move): Move to make.
        """
        self._model.make_move(move)
        self._view.set_overlay_coords([], None)

        if self._model.states['CPU_ENABLED']:
            self._model.make_cpu_move()

        if self._model.states['WINNER'] == Miscellaneous.DRAW:
            self._win_view.set_win_type('DRAW')

    def handle_pause_event(self, event):
        """
        Processes events when game is paused.

        Args:
            event (GameEventType): Event to process.

        Raises:
            Exception: If event type is unrecognised.
        """
        game_event = self._pause_view.convert_mouse_pos(event)

        if game_event is None:
            return

        match game_event.type:
            case GameEventType.PAUSE_CLICK:
                self._model.toggle_paused()

            case GameEventType.MENU_CLICK:
                self.cleanup('menu')

            case _:
                raise Exception('Unhandled event type (GameController.handle_event
    )')
```

```python

    def handle_winner_event(self, event):
        """
        Processes events when game is over.

        Args:
            event (GameEventType): Event to process.

        Raises:
            Exception: If event type is unrecognised.
        """
        game_event = self._win_view.convert_mouse_pos(event)

        if game_event is None:
            return

        match game_event.type:
            case GameEventType.MENU_CLICK:
                self.cleanup('menu')
                return

            case GameEventType.GAME_CLICK:
                self.cleanup('game')
                return

            case GameEventType.REVIEW_CLICK:
                self.cleanup('review')

            case _:
                raise Exception('Unhandled event type (GameController.handle_event
    )')

    def handle_game_widget_event(self, event):
        """
        Processes events for game GUI widgets.

        Args:
            event (GameEventType): Event to process.

        Raises:
            Exception: If event type is unrecognised.

        Returns:
            CustomEvent | None: A widget event.
        """
        widget_event = self._view.process_widget_event(event)

        if widget_event is None:
            return None

        match widget_event.type:
            case GameEventType.ROTATE_PIECE:
                src_coords = self._view.get_selected_coords()

                if src_coords is None:
                    logger.info('None square selected')
                    return

                move = Move.instance_from_coords(MoveType.ROTATE, src_coords,
    src_coords, rotation_direction=widget_event.rotation_direction)
                self.make_move(move)

```

```
            case GameEventType.RESIGN_CLICK:
                self._model.set_winner(self._model.states['ACTIVE_COLOUR'].get_flipped_colour())
                self._view.handle_game_end(play_sfx=False)
                self._win_view.set_win_type('RESIGN')

            case GameEventType.DRAW_CLICK:
                self._model.set_winner(Miscellaneous.DRAW)
                self._view.handle_game_end(play_sfx=False)
                self._win_view.set_win_type('DRAW')

            case GameEventType.TIMER_END:
                if self._model.states['TIME_ENABLED']:
                    self._model.set_winner(widget_event.active_colour.get_flipped_colour())
                    self._win_view.set_win_type('TIME')
                    self._view.handle_game_end(play_sfx=False)

            case GameEventType.MENU_CLICK:
                self.cleanup('menu')

            case GameEventType.HELP_CLICK:
                self._view.add_help_screen()

            case GameEventType.TUTORIAL_CLICK:
                self._view.add_tutorial_screen()

            case _:
                raise Exception('Unhandled event type (GameController.handle_event)')

        return widget_event.type

    def check_cpu(self):
        """
        Checks if CPU calculations are finished every frame.
        """
        if self._model.states['CPU_ENABLED'] and self._model.states['AWAITING_CPU'] is False:
            self._model.check_cpu()

    def handle_game_event(self, event):
        """
        Processes Pygame events for main game.

        Args:
            event (pygame.Event): If event type is unrecognised.

        Raises:
            Exception: If event type is unrecognised.
        """
        # Pass event for widgets to process
        widget_event = self.handle_game_widget_event(event)

        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))

            case GameEventType.PIECE_DROP:
                hovered_coords = game_event.coords

                # if piece is dropped onto the board
                if hovered_coords:
                    hovered_bitboard = bb_helpers.coords_to_bitboard(
```

```
hovered_coords)
                        selected_coords = self._view.get_selected_coords()
                        selected_bitboard = bb_helpers.coords_to_bitboard(selected_coords)
                        available_bitboard = self._model.get_available_moves(selected_bitboard)

                        if bb_helpers.is_occupied(hovered_bitboard, available_bitboard):
                            # Make a move if mouse is hovered over an empty surrounding square
                            move = Move.instance_from_coords(MoveType.MOVE, selected_coords, hovered_coords)
                            self.make_move(move)

                    if game_event.remove_overlay:
                        self._view.set_overlay_coords(None, None)

                    self._view.remove_dragged_piece()

                case _:
                    raise Exception('Unhandled event type (GameController.handle_event)', game_event.type)

    def handle_event(self, event):
        """
        Passes a Pygame event to the correct handling function according to the game state.

        Args:
            event (pygame.Event): Event to process.
        """
        if event.type in [pygame.MOUSEBUTTONDOWN, pygame.MOUSEBUTTONUP, pygame.MOUSEMOTION, pygame.KEYDOWN]:
            if self._model.states['PAUSED']:
                self.handle_pause_event(event)
            elif self._model.states['WINNER'] is not None:
                self.handle_winner_event(event)
            else:
                self.handle_game_event(event)

        if event.type == pygame.KEYDOWN:
            if event.key == pygame.K_ESCAPE:
                self._model.toggle_paused()
            # Debug shortcut to kill CPU
            elif event.key == pygame.K_l:
                logger.info('\nSTOPPING CPU')
                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

```
from collections import defaultdict
from data.utils.constants import A_FILE_MASK, J_FILE_MASK, ONE_RANK_MASK, EIGHT_RANK_MASK, EMPTY_BB
from data.utils.enums import Colour, Piece, Rank, File, MoveType, RotationDirection, Miscellaneous
```

```python
from data.states.game.components.bitboard_collection import BitboardCollection
from data.helpers import bitboard_helpers as bb_helpers
from data.states.game.components.laser import Laser
from data.states.game.components.move import Move


class Board:
    def __init__(self, fen_string="sc3ncfcncpb2/2pc7/3Pd6/pa1Pc1rbra1pb1Pd/pb1Pd1RaRb1pa1Pc/6pb3/7Pa2/2PdNaFaNa3Sa b"):
        self.bitboards = BitboardCollection(fen_string)
        self.hash_list = [self.bitboards.get_hash()]

    def __str__(self):
        """
        Returns a string representation of the board.

        Returns:
            str: Board formatted as string.
        """
        characters = '8  '
        pieces = defaultdict(int)

        for rank_idx, rank in enumerate(reversed(Rank)):
            for file_idx, file in enumerate(File):
                mask = 1 << (rank * 10 + file)
                blue_piece = self.bitboards.get_piece_on(mask, Colour.BLUE)
                red_piece = self.bitboards.get_piece_on(mask, Colour.RED)

                if blue_piece:
                    pieces[blue_piece.value.upper()] += 1
                    characters += f'{blue_piece.upper()}  '
                elif red_piece:
                    pieces[red_piece.value] += 1
                    characters += f'{red_piece}  '
                else:
                    characters += '.  '

            characters += f'\n\n{7 - rank_idx}  '
        characters += 'A  B  C  D  E  F  G  H  I  J\n\n'
        characters += str(dict(pieces))
        characters += f'\nCURRENT PLAYER TO MOVE: {self.bitboards.active_colour.name}\n'
        return characters

    def get_piece_list(self):
        """
        Converts the board bitboards to a list of pieces.

        Returns:
            list: List of Pieces.
        """
        return self.bitboards.convert_to_piece_list()

    def get_active_colour(self):
        """
        Gets the active colour.

        Returns:
            Colour: The active colour.
        """
        return self.bitboards.active_colour

```

```python
    def to_hash(self):
        """
        Gets the hash of the current board state.

        Returns:
            int: A Zobrist hash.
        """
        return self.bitboards.get_hash()

    def check_win(self):
        """
        Checks for a Pharaoh capture or threefold-repetition.

        Returns:
            Colour | Miscellaneous: The winning colour, or Miscellaneous.DRAW.
        """
        for colour in Colour:
            if self.bitboards.get_piece_bitboard(Piece.PHARAOH, colour) == EMPTY_BB:
                return colour.get_flipped_colour()

        if self.hash_list.count(self.hash_list[-1]) >= 3:
            return Miscellaneous.DRAW

        return None

    def apply_move(self, move, fire_laser=True, add_hash=False):
        """
        Applies a move to the board.

        Args:
            move (Move): The move to apply.
            fire_laser (bool): Whether to fire the laser after the move.
            add_hash (bool): Whether to add the board state hash to the hash list.

        Returns:
            Laser: The laser trajectory result.
        """
        piece_symbol = self.bitboards.get_piece_on(move.src, self.bitboards.active_colour)

        if piece_symbol is None:
            raise ValueError(f'Invalid move - no piece found on source square. {move}')
        elif piece_symbol == Piece.SPHINX:
            raise ValueError(f'Invalid move - sphinx piece is immovable. {move}')

        if move.move_type == MoveType.MOVE:
            possible_moves = self.get_valid_squares(move.src)
            if bb_helpers.is_occupied(move.dest, possible_moves) is False:
                raise ValueError('Invalid move - destination square is occupied')

            piece_rotation = self.bitboards.get_rotation_on(move.src)

            self.bitboards.update_move(move.src, move.dest)
            self.bitboards.update_rotation(move.src, move.dest, piece_rotation)

        elif move.move_type == MoveType.ROTATE:
            piece_symbol = self.bitboards.get_piece_on(move.src, self.bitboards.active_colour)
            piece_rotation = self.bitboards.get_rotation_on(move.src)

```

```python
            if move.rotation_direction == RotationDirection.CLOCKWISE:
                new_rotation = piece_rotation.get_clockwise()
            elif move.rotation_direction == RotationDirection.ANTICLOCKWISE:
                new_rotation = piece_rotation.get_anticlockwise()

            self.bitboards.update_rotation(move.src, move.src, new_rotation)

        laser = None
        if fire_laser:
            laser = self.fire_laser(add_hash)

        if add_hash:
            self.hash_list.append(self.bitboards.get_hash())

        self.bitboards.flip_colour()

        return laser

    def undo_move(self, move, laser_result):
        """
        Undoes a move on the board.

        Args:
            move (Move): The move to undo.
            laser_result (Laser): The laser trajectory result.
        """
        self.bitboards.flip_colour()

        if laser_result.hit_square_bitboard:
            # Get info of destroyed piece, and add it to the board again
            src = laser_result.hit_square_bitboard
            piece = laser_result.piece_hit
            colour = laser_result.piece_colour
            rotation = laser_result.piece_rotation

            self.bitboards.set_square(src, piece, colour)
            self.bitboards.clear_rotation(src)
            self.bitboards.set_rotation(src, rotation)

        # Create new Move object that is the inverse of the passed move
        if move.move_type == MoveType.MOVE:
            reversed_move = Move.instance_from_bitboards(MoveType.MOVE, move.dest, move.src)
        elif move.move_type == MoveType.ROTATE:
            reversed_move = Move.instance_from_bitboards(MoveType.ROTATE, move.src, move.src, move.rotation_direction.get_opposite())

        self.apply_move(reversed_move, fire_laser=False)
        self.bitboards.flip_colour()

    def remove_piece(self, square_bitboard):
        """
        Removes a piece from a given square.

        Args:
            square_bitboard (int): The bitboard representation of the square.
        """
        self.bitboards.clear_square(square_bitboard, Colour.BLUE)
        self.bitboards.clear_square(square_bitboard, Colour.RED)
        self.bitboards.clear_rotation(square_bitboard)

    def get_valid_squares(self, src_bitboard, colour=None):
```

```
        """
        Gets valid squares for a piece to move to.

        Args:
            src_bitboard (int): The bitboard representation of the source square.
            colour (Colour, optional): The active colour of the piece.

        Returns:
            int: The bitboard representation of valid squares.
        """
        target_top_left = (src_bitboard & A_FILE_MASK & EIGHT_RANK_MASK) << 9
        target_top_middle = (src_bitboard & EIGHT_RANK_MASK) << 10
        target_top_right = (src_bitboard & J_FILE_MASK & EIGHT_RANK_MASK) << 11
        target_middle_right = (src_bitboard & J_FILE_MASK) << 1

        target_bottom_right = (src_bitboard & J_FILE_MASK & ONE_RANK_MASK) >> 9
        target_bottom_middle = (src_bitboard & ONE_RANK_MASK) >> 10
        target_bottom_left = (src_bitboard & A_FILE_MASK & ONE_RANK_MASK)>> 11
        target_middle_left = (src_bitboard & A_FILE_MASK) >> 1

        possible_moves = target_top_left | target_top_middle | target_top_right | target_middle_right | target_bottom_right | target_bottom_middle | target_bottom_left | target_middle_left

        if colour is not None:
            valid_possible_moves = possible_moves & ~self.bitboards.combined_colour_bitboards[colour]
        else:
            valid_possible_moves = possible_moves & ~self.bitboards.combined_all_bitboard

        return valid_possible_moves

    def get_mobility(self, colour):
        """
        Gets all valid squares for a given colour.

        Args:
            colour (Colour): The colour of the pieces.

        Returns:
            int: The bitboard representation of all valid squares.
        """
        active_pieces = self.get_all_active_pieces(colour)
        possible_moves = 0

        for square in bb_helpers.occupied_squares(active_pieces):
            possible_moves += bb_helpers.pop_count(self.get_valid_squares(square))

        return possible_moves

    def get_all_active_pieces(self, colour=None):
        """
        Gets all active pieces for the current player.

        Args:
            colour (Colour): Active colour of pieces to retrieve. Defaults to None.

        Returns:
            int: The bitboard representation of all active pieces.
        """
```

```
        if colour is None:
            colour = self.bitboards.active_colour

        active_pieces = self.bitboards.combined_colour_bitboards[colour]
        sphinx_bitboard = self.bitboards.get_piece_bitboard(Piece.SPHINX, colour)
        return active_pieces ^ sphinx_bitboard

    def fire_laser(self, remove_hash):
        """
        Fires the laser and removes hit pieces.

        Args:
            remove_hash (bool): Whether to clear the hash list if a piece is hit.

        Returns:
            Laser: The result of firing the laser.
        """
        laser = Laser(self.bitboards)

        if laser.hit_square_bitboard:
            self.remove_piece(laser.hit_square_bitboard)

            if remove_hash:
                self.hash_list = [] # Remove all hashes for threefold repetition, as the position is impossible to be repeated after a piece is removed
        return laser

    def generate_square_moves(self, src):
        """
        Generates all valid moves for a piece on a given square.

        Args:
            src (int): The bitboard representation of the source square.

        Yields:
            Move: A valid move for the piece.
        """
        for dest in bb_helpers.occupied_squares(self.get_valid_squares(src)):
            yield Move(MoveType.MOVE, src, dest)

    def generate_all_moves(self, colour):
        """
        Generates all valid moves for a given colour.

        Args:
            colour (Colour): The colour of the pieces.

        Yields:
            Move: A valid move for the active colour.
        """
        sphinx_bitboard = self.bitboards.get_piece_bitboard(Piece.SPHINX, colour)
        # Remove source squares for Sphinx pieces, as they cannot be moved
        sphinx_masked_bitboard = self.bitboards.combined_colour_bitboards[colour] ^ sphinx_bitboard

        for square in bb_helpers.occupied_squares(sphinx_masked_bitboard):
            # Generate movement moves
            yield from self.generate_square_moves(square)

            # Generate rotational moves
            for rotation_direction in RotationDirection:
                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.

bitboard_collection.py

```
from data.utils.enums import Rank, File, Piece, Colour, Rotation, RotationIndex
from data.states.game.components.fen_parser import parse_fen_string
from data.states.game.cpu.zobrist_hasher import ZobristHasher
from data.helpers import bitboard_helpers as bb_helpers
from data.managers.logs import initialise_logger
from data.utils.constants import EMPTY_BB

logger = initialise_logger(__name__)

class BitboardCollection:
    def __init__(self, fen_string):
        self.piece_bitboards = [{char: EMPTY_BB for char in Piece}, {char:
    EMPTY_BB for char in Piece}]
        self.combined_colour_bitboards = [EMPTY_BB, EMPTY_BB]
        self.combined_all_bitboard = EMPTY_BB
        self.rotation_bitboards = [EMPTY_BB, EMPTY_BB]
        self.active_colour = Colour.BLUE
        self._hasher = ZobristHasher()

        try:
            if fen_string:
                self.piece_bitboards, self.combined_colour_bitboards, self.
    combined_all_bitboard, self.rotation_bitboards, self.active_colour =
    parse_fen_string(fen_string)
                self.initialise_hash()
        except ValueError as error:
            logger.error('Please input a valid FEN string:', error)
            raise error

    def __str__(self):
        """
        Returns a string representation of the bitboards.

        Returns:
            str: Bitboards formatted with piece type and colour shown.
        """
        characters = ''
        for rank in reversed(Rank):
            for file in File:
                bitboard = 1 << (rank * 10 + file)

                colour = self.get_colour_on(bitboard)
                piece = self.get_piece_on(bitboard, Colour.BLUE) or self.
    get_piece_on(bitboard, Colour.RED)

                if piece is not None:
                    characters += f'{piece.upper() if colour == Colour.BLUE
    else piece}  '
                else:
                    characters += '.  '

            characters += '\n\n'
```

```
        return characters

    def get_rotation_string(self):
        """
        Returns a string representation of the board rotations.

        Returns:
            str: Board formatted with only rotations shown.
        """
        characters = ''
        for rank in reversed(Rank):

            for file in File:
                mask = 1 << (rank * 10 + file)
                rotation = self.get_rotation_on(mask)
                has_piece = bb_helpers.is_occupied(self.combined_all_bitboard,
    mask)

                if has_piece:
                    characters += f'{rotation.upper()}  '
                else:
                    characters += '.  '

            characters += '\n\n'

        return characters

    def initialise_hash(self):
        """
        Initialises the Zobrist hash for the current board state.
        """
        for piece in Piece:
            for colour in Colour:
                piece_bitboard = self.get_piece_bitboard(piece, colour)

                for occupied_bitboard in bb_helpers.occupied_squares(
    piece_bitboard):
                    self._hasher.apply_piece_hash(occupied_bitboard, piece, colour
    )

        for bitboard in bb_helpers.loop_all_squares():
            rotation = self.get_rotation_on(bitboard)
            self._hasher.apply_rotation_hash(bitboard, rotation)

        if self.active_colour == Colour.RED:
            self._hasher.apply_red_move_hash()

    def flip_colour(self):
        """
        Flips the active colour and updates the Zobrist hash.
        """
        self.active_colour = self.active_colour.get_flipped_colour()

        if self.active_colour == Colour.RED:
            self._hasher.apply_red_move_hash()

    def update_move(self, src, dest):
        """
        Updates the bitboards for a move.

        Args:
```

```
            src (int): The bitboard representation of the source square.
            dest (int): The bitboard representation of the destination square.
        """
        piece = self.get_piece_on(src, self.active_colour)

        self.clear_square(src, Colour.BLUE)
        self.clear_square(dest, Colour.BLUE)
        self.clear_square(src, Colour.RED)
        self.clear_square(dest, Colour.RED)

        self.set_square(dest, piece, self.active_colour)

    def update_rotation(self, src, dest, new_rotation):
        """
        Updates the rotation bitboards for a move.

        Args:
            src (int): The bitboard representation of the source square.
            dest (int): The bitboard representation of the destination square.
            new_rotation (Rotation): The new rotation.
        """
        self.clear_rotation(src)
        self.set_rotation(dest, new_rotation)

    def clear_rotation(self, bitboard):
        """
        Clears the rotation for a given square.

        Args:
            bitboard (int): The bitboard representation of the square.
        """
        old_rotation = self.get_rotation_on(bitboard)
        rotation_1, rotation_2 = self.rotation_bitboards
        self.rotation_bitboards[RotationIndex.FIRSTBIT] = bb_helpers.clear_square(
    rotation_1, bitboard)
        self.rotation_bitboards[RotationIndex.SECONDBIT] = bb_helpers.clear_square
    (rotation_2, bitboard)

        self._hasher.apply_rotation_hash(bitboard, old_rotation)

    def clear_square(self, bitboard, colour):
        """
        Clears a square piece and rotation for a given colour.

        Args:
            bitboard (int): The bitboard representation of the square.
            colour (Colour): The colour to clear.
        """
        piece = self.get_piece_on(bitboard, colour)

        if piece is None:
            return

        piece_bitboard = self.get_piece_bitboard(piece, colour)
        colour_bitboard = self.combined_colour_bitboards[colour]
        all_bitboard = self.combined_all_bitboard

        self.piece_bitboards[colour][piece] = bb_helpers.clear_square(
    piece_bitboard, bitboard)
        self.combined_colour_bitboards[colour] = bb_helpers.clear_square(
    colour_bitboard, bitboard)
        self.combined_all_bitboard = bb_helpers.clear_square(all_bitboard,
```

```
bitboard)

        self._hasher.apply_piece_hash(bitboard, piece, colour)

    def set_rotation(self, bitboard, rotation):
        """
        Sets the rotation for a given square.

        Args:
            bitboard (int): The bitboard representation of the square.
            rotation (Rotation): The rotation to set.
        """
        rotation_1, rotation_2 = self.rotation_bitboards
        self._hasher.apply_rotation_hash(bitboard, rotation)

        match rotation:
            case Rotation.UP:
                return
            case Rotation.RIGHT:
                self.rotation_bitboards[RotationIndex.FIRSTBIT] = bb_helpers.set_square(rotation_1, bitboard)
                return
            case Rotation.DOWN:
                self.rotation_bitboards[RotationIndex.SECONDBIT] = bb_helpers.set_square(rotation_2, bitboard)
                return
            case Rotation.LEFT:
                self.rotation_bitboards[RotationIndex.FIRSTBIT] = bb_helpers.set_square(rotation_1, bitboard)
                self.rotation_bitboards[RotationIndex.SECONDBIT] = bb_helpers.set_square(rotation_2, bitboard)
                return
            case _:
                raise ValueError('Invalid rotation input (bitboard.py):', rotation)

    def set_square(self, bitboard, piece, colour):
        """
        Sets a piece on a given square.

        Args:
            bitboard (int): The bitboard representation of the square.
            piece (Piece): The piece to set.
            colour (Colour): The colour of the piece.
        """
        piece_bitboard = self.get_piece_bitboard(piece, colour)
        colour_bitboard = self.combined_colour_bitboards[colour]
        all_bitboard = self.combined_all_bitboard

        self.piece_bitboards[colour][piece] = bb_helpers.set_square(piece_bitboard, bitboard)
        self.combined_colour_bitboards[colour] = bb_helpers.set_square(colour_bitboard, bitboard)
        self.combined_all_bitboard = bb_helpers.set_square(all_bitboard, bitboard)

        self._hasher.apply_piece_hash(bitboard, piece, colour)

    def get_piece_bitboard(self, piece, colour):
        """
        Gets the bitboard for a piece type for a given colour.

        Args:
```

```
            piece (Piece): The piece bitboard to get.
            colour (Colour): The colour of the piece.

        Returns:
            int: The bitboard representation for all squares occupied by that piece type.
        """
        return self.piece_bitboards[colour][piece]

    def get_piece_on(self, target_bitboard, colour):
        """
        Gets the piece on a given square for a given colour.

        Args:
            target_bitboard (int): The bitboard representation of the square.
            colour (Colour): The colour of the piece.

        Returns:
            Piece: The piece on the square, or None if square is empty.
        """
        if not (bb_helpers.is_occupied(self.combined_colour_bitboards[colour], target_bitboard)):
            return None

        return next(
            (piece for piece in Piece if
                bb_helpers.is_occupied(self.get_piece_bitboard(piece, colour), target_bitboard)),
            None)

    def get_rotation_on(self, target_bitboard):
        """
        Gets the rotation on a given square.

        Args:
            target_bitboard (int): The bitboard representation of the square.

        Returns:
            Rotation: The rotation on the square.
        """
        rotationBits = [bb_helpers.is_occupied(self.rotation_bitboards[RotationIndex.SECONDBIT], target_bitboard), bb_helpers.is_occupied(self.rotation_bitboards[RotationIndex.FIRSTBIT], target_bitboard)]

        match rotationBits:
            case [False, False]:
                return Rotation.UP
            case [False, True]:
                return Rotation.RIGHT
            case [True, False]:
                return Rotation.DOWN
            case [True, True]:
                return Rotation.LEFT

    def get_colour_on(self, target_bitboard):
        """
        Gets the colour of the piece on a given square.

        Args:
            target_bitboard (int): The bitboard representation of the square.

        Returns:
```

```
            Colour: The colour of the piece on the square.
        """
        for piece in Piece:
            if self.get_piece_bitboard(piece, Colour.BLUE) & target_bitboard != EMPTY_BB:
                return Colour.BLUE
            elif self.get_piece_bitboard(piece, Colour.RED) & target_bitboard != EMPTY_BB:
                return Colour.RED

    def get_piece_count(self, piece, colour):
        """
        Gets the count of a given piece type and colour.

        Args:
            piece (Piece): The piece to count.
            colour (Colour): The colour of the piece.

        Returns:
            int: The number of that piece of that colour on the board.
        """
        return bb_helpers.pop_count(self.get_piece_bitboard(piece, colour))

    def get_hash(self):
        """
        Gets the Zobrist hash of the current board state.

        Returns:
            int: The Zobrist hash.
        """
        return self._hasher.hash

    def convert_to_piece_list(self):
        """
        Converts all bitboards to a list of pieces.

        Returns:
            list: Board represented as a 2D list of Piece and Rotation objects.
        """
        piece_list = []

        for i in range(80):
            if x := self.get_piece_on(1 << i, Colour.BLUE):
                rotation = self.get_rotation_on(1 << i)
                piece_list.append((x.upper(), rotation))
            elif y := self.get_piece_on(1 << i, Colour.RED):
                rotation = self.get_rotation_on(1 << i)
                piece_list.append((y, rotation))
            else:
                piece_list.append(None)

        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 to 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 return 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

```python
from random import choice
from data.states.game.cpu.base import BaseCPU
from data.utils.enums import Score, Colour

class MinimaxCPU(BaseCPU):
    def __init__(self, max_depth, callback, verbose=False):
        super().__init__(callback, verbose)
        self._max_depth = max_depth

    def find_move(self, board, stop_event):
        """
        Finds the best move for the current board state.

        Args:
            board (Board): The current board state.
            stop_event (threading.Event): Event used to kill search from an external class.
        """
        self.initialise_stats()
        best_score, best_move = self.search(board, self._max_depth, stop_event)

        if self._verbose:
            self.print_stats(best_score, best_move)

        self._callback(best_move)

    def search(self, board, depth, stop_event):
        """
        Recursively DFS through minimax tree with evaluation score.

        Args:
            board (Board): The current board state.
            depth (int): The current search depth.
            stop_event (threading.Event): Event used to kill search from an external class.
        Returns:
            tuple[int, Move]: The best score and the best move found.
        """
        if (base_case := super().search(board, depth, stop_event)):
            return base_case

        best_move = None

        # Blue is the maximising player
        if board.get_active_colour() == Colour.BLUE:
            max_score = -Score.INFINITE

            for move in board.generate_all_moves(Colour.BLUE):
```

```python
                laser_result = board.apply_move(move)


                new_score = self.search(board, depth - 1, stop_event)[0]

                # if depth < self._max_depth:
                #     print('DEPTH', depth, new_score, move)

                if new_score > max_score:
                    max_score = new_score
                    best_move = move

                    if new_score == (Score.CHECKMATE + self._max_depth):
                        board.undo_move(move, laser_result)
                        return max_score, best_move

                elif new_score == max_score:
                    # If evaluated scores are equal, pick a random move
                    best_move = choice([best_move, move])

                board.undo_move(move, laser_result)

            return max_score, best_move

        else:
            min_score = Score.INFINITE

            for move in board.generate_all_moves(Colour.RED):
                laser_result = board.apply_move(move)
                # print('DEPTH', depth, move)
                new_score = self.search(board, depth - 1, stop_event)[0]

                if new_score < min_score:
                    # print('setting new', new_score, move)
                    min_score = new_score
                    best_move = move

                    if new_score == (-Score.CHECKMATE - self._max_depth):
                        board.undo_move(move, laser_result)
                        return min_score, best_move

                elif new_score == min_score:
                    best_move = choice([best_move, move])

                board.undo_move(move, laser_result)

            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`

```python
from data.states.game.cpu.move_orderer import MoveOrderer
from data.states.game.cpu.base import BaseCPU
from data.utils.enums import Score, Colour

class ABMinimaxCPU(BaseCPU):
    def __init__(self, max_depth, callback, verbose=True):
```

```
        super().__init__(callback, verbose)
        self._max_depth = max_depth
        self._orderer = MoveOrderer()

    def initialise_stats(self):
        """
        Initialises the number of prunes to the statistics dictionary to be logged
    .
        """
        super().initialise_stats()
        self._stats['beta_prunes'] = 0
        self._stats['alpha_prunes'] = 0

    def find_move(self, board, stop_event):
        """
        Finds the best move for the current board state.

        Args:
            board (Board): The current board state.
            stop_event (threading.Event): Event used to kill search from an
    external class.
        """
        self.initialise_stats()
        best_score, best_move = self.search(board, self._max_depth, -Score.
    INFINITE, Score.INFINITE, stop_event)

        if self._verbose:
            self.print_stats(best_score, best_move)

        self._callback(best_move)

    def search(self, board, depth, alpha, beta, stop_event, hint=None,
    laser_coords=None):
        """
        Recursively DFS through minimax tree while pruning branches using the
    alpha and beta bounds.

        Args:
            board (Board): The current board state.
            depth (int): The current search depth.
            alpha (int): The upper bound value.
            beta (int): The lower bound value.
            stop_event (threading.Event): Event used to kill search from an
    external class.

        Returns:
            tuple[int, Move]: The best score and the best move found.
        """
        if (base_case := super().search(board, depth, stop_event)):
            return base_case

        best_move = None

        # Blue is the maximising player
        if board.get_active_colour() == Colour.BLUE:
            max_score = -Score.INFINITE

            for move in self._orderer.get_moves(board, hint=hint, laser_coords=
    laser_coords):
                laser_result = board.apply_move(move)
                new_score = self.search(board, depth - 1, alpha, beta, stop_event,
     laser_coords=laser_result.pieces_on_trajectory)[0]
```

```python

                if new_score > max_score:
                    max_score = new_score
                    best_move = move

                board.undo_move(move, laser_result)

                alpha = max(alpha, max_score)

                if beta <= alpha:
                    self._stats['alpha_prunes'] += 1
                    break

            return max_score, best_move

        else:
            min_score = Score.INFINITE

            for move in self._orderer.get_moves(board, hint=hint, laser_coords=laser_coords):
                laser_result = board.apply_move(move)
                new_score = self.search(board, depth - 1, alpha, beta, stop_event, laser_coords=laser_result.pieces_on_trajectory)[0]

                if new_score < min_score:
                    min_score = new_score
                    best_move = move

                board.undo_move(move, laser_result)

                beta = min(beta, min_score)
                if beta <= alpha:
                    self._stats['beta_prunes'] += 1
                    break

            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`

```python
from data.states.game.cpu.transposition_table import TranspositionTable
from data.states.game.cpu.engines.alpha_beta import ABMinimaxCPU

class TranspositionTableMixin:
    def __init__(self, *args, **kwargs):
        super().__init__(*args, **kwargs)
        self._table = TranspositionTable()

    def find_move(self, *args, **kwargs):
        self._table = TranspositionTable()
        super().find_move(*args, **kwargs)

    def search(self, board, depth, alpha, beta, stop_event, hint=None, laser_coords=None):
        """
```

```
        Searches transposition table for a cached move before running a full search if necessary.
        Caches the searched result.

        Args:
            board (Board): The current board state.
            depth (int): The current search depth.
            alpha (int): The upper bound value.
            beta (int): The lower bound value.
            stop_event (threading.Event): Event used to kill search from an external class.

        Returns:
            tuple[int, Move]: The best score and the best move found.
        """
        hash = board.to_hash()
        score, move = self._table.get_entry(hash, depth, alpha, beta)

        if score is not None:
            self._stats['cache_hits'] += 1
            self._stats['nodes'] += 1

            return score, move
        else:
            # If board hash entry not found in cache, run a full search
            score, move = super().search(board, depth, alpha, beta, stop_event, hint)
            self._table.insert_entry(score, move, hash, depth, alpha, beta)

            return score, move

class TTMinimaxCPU(TranspositionTableMixin, ABMinimaxCPU):
    def initialise_stats(self):
        """
        Initialises cache statistics to be logged.
        """
        super().initialise_stats()
        self._stats['cache_hits'] = 0

    def print_stats(self, score, move):
        """
        Logs the statistics for the search.

        Args:
            score (int): The best score found.
            move (Move): The best move found.
        """
        # Calculate number of cached entries retrieved as a percentage of all nodes
        self._stats['cache_hits_percentage'] = round(self._stats['cache_hits'] / self._stats['nodes'], 3)
        self._stats['cache_entries'] = len(self._table._table)
        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.

`iterative_deepening.py`

```python
from copy import deepcopy
from random import choice
from data.states.game.cpu.engines.transposition_table import
    TranspositionTableMixin
from data.states.game.cpu.engines.transposition_table import TranspositionTable
from data.states.game.cpu.engines.alpha_beta import ABMinimaxCPU
from data.managers.logs import initialise_logger
from data.utils.enums import Score

logger = initialise_logger(__name__)

class IterativeDeepeningMixin:
    def find_move(self, board, stop_event):
        """
        Iterates through increasing depths to find the best move.

        Args:
            board (Board): The current board state.
            stop_event (threading.Event): Event used to kill search from an
    external class.
        """
        self._table = TranspositionTable()

        best_move = None

        for depth in range(1, self._max_depth + 1):
            self.initialise_stats()

            # Use copy of board as search can be terminated before all tested
    moves are undone
            board_copy = deepcopy(board)

            try:
                best_score, best_move = self.search(board_copy, depth, -Score.
    INFINITE, Score.INFINITE, stop_event, hint=best_move)
            except TimeoutError:
                # If allocated time is up, use previous depth's best move
                logger.info(f'Terminated CPU search early at depth {depth}. Using
    existing best move: {best_move}')

                if best_move is None:
                    # If search is terminated at depth 0, use random move
                    best_move = choice(board_copy.generate_all_moves())
                    logger.warning('CPU terminated before any best move found!
    Using random move.')

                break

            self._stats['ID_depth'] = depth

        if self._verbose:
            self.print_stats(best_score, best_move)

        self._callback(best_move)

class IDMinimaxCPU(TranspositionTableMixin, IterativeDeepeningMixin, ABMinimaxCPU)
    :
    def initialise_stats(self):
        super().initialise_stats()
        self._stats['cache_hits'] = 0

    def print_stats(self, score, move):
```

```
        self._stats['cache_hits_percentage'] = round(self._stats['cache_hits'] /
    self._stats['nodes'], 3)
        self._stats['cache_entries'] = len(self._table._table)
        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`

```
from data.helpers.bitboard_helpers import pop_count, occupied_squares,
    bitboard_to_index
from data.states.game.components.psqt import PSQT, FLIP
from data.utils.enums import Colour, Piece, Score
from data.managers.logs import initialise_logger

logger = initialise_logger(__name__)

class Evaluator:
    def __init__(self, verbose=True):
        self._verbose = verbose

    def evaluate(self, board, absolute=False):
        """
        Evaluates and returns a numerical score for the board state.

        Args:
            board (Board): The current board state.
            absolute (bool): Whether to always return the absolute score from the
    active colour's perspective (for NegaMax).

        Returns:
            int: Score representing advantage/disadvantage for the player.
        """
        blue_score = (
            self.evaluate_material(board, Colour.BLUE),
            self.evaluate_position(board, Colour.BLUE),
            self.evaluate_mobility(board, Colour.BLUE),
            self.evaluate_pharaoh_safety(board, Colour.BLUE)
        )

        red_score = (
            self.evaluate_material(board, Colour.RED),
            self.evaluate_position(board, Colour.RED),
            self.evaluate_mobility(board, Colour.RED),
            self.evaluate_pharaoh_safety(board, Colour.RED)
        )

        if self._verbose:
            logger.info(f'Material: {blue_score[0]} | {red_score[0]}')
            logger.info(f'Position: {blue_score[1]} | {red_score[1]}')
            logger.info(f'Mobility: {blue_score[2]} | {red_score[2]}')
            logger.info(f'Safety: {blue_score[3]} | {red_score[3]}')
            logger.info(f'Overall score: {sum(blue_score) - sum(red_score)}\n')

        if absolute and board.get_active_colour() == Colour.RED:
            return sum(red_score) - sum(blue_score)
        else:
```

```python
            return sum(blue_score) - sum(red_score)

    def evaluate_material(self, board, colour):
        """
        Evaluates the material score for a given colour.

        Args:
            board (Board): The current board state.
            colour (Colour): The colour to evaluate.

        Returns:
            int: Sum of all piece scores.
        """
        return (
            Score.SPHINX * board.bitboards.get_piece_count(Piece.SPHINX, colour) +
            Score.PYRAMID * board.bitboards.get_piece_count(Piece.PYRAMID, colour)
 +
            Score.ANUBIS * board.bitboards.get_piece_count(Piece.ANUBIS, colour) +
            Score.SCARAB * board.bitboards.get_piece_count(Piece.SCARAB, colour)
        )

    def evaluate_position(self, board, colour):
        """
        Evaluates the positional score for a given colour.

        Args:
            board (Board): The current board state.
            colour (Colour): The colour to evaluate.

        Returns:
            int: Score representing positional advantage/disadvantage.
        """
        score = 0

        for piece in Piece:
            if piece == Piece.SPHINX:
                continue

            piece_bitboard = board.bitboards.get_piece_bitboard(piece, colour)

            for bitboard in occupied_squares(piece_bitboard):
                index = bitboard_to_index(bitboard)
                # Flip PSQT if using from blue player's perspective
                index = FLIP[index] if colour == Colour.BLUE else index

                score += PSQT[piece][index] * Score.POSITION

        return score

    def evaluate_mobility(self, board, colour):
        """
        Evaluates the mobility score for a given colour.

        Args:
            board (Board): The current board state.
            colour (Colour): The colour to evaluate.

        Returns:
            int: Score on numerical representation of mobility.
        """
        number_of_moves = board.get_mobility(colour)
        return number_of_moves * Score.MOVE
```

```

    def evaluate_pharaoh_safety(self, board, colour):
        """
        Evaluates the safety of the Pharaoh for a given colour.

        Args:
            board (Board): The current board state.
            colour (Colour): The colour to evaluate.

        Returns:
            int: Score representing mobility of the Pharaoh.
        """
        pharaoh_bitboard = board.bitboards.get_piece_bitboard(Piece.PHARAOH, colour)

        if pharaoh_bitboard:
            pharaoh_available_moves = pop_count(board.get_valid_squares(pharaoh_bitboard, colour))
            return (8 - pharaoh_available_moves) * Score.PHARAOH_SAFETY
        else:
            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

```
import threading
import time
from data.managers.logs import initialise_logger

logger = initialise_logger(__name__)

class CPUThread(threading.Thread):
    def __init__(self, cpu, verbose=False):
        super().__init__()
        self._stop_event = threading.Event()
        self._running = True
        self._verbose = verbose
        self.daemon = True

        self._board = None
        self._cpu = cpu
        self._id = None

    def kill_thread(self):
        """
        Kills the CPU and terminates the thread by stopping the run loop.
        """
        self.stop_cpu(force=True)
        self._running = False

    def stop_cpu(self, id=None, force=False):
        """
        Kills the CPU's move search.

```

```
        Args:
            id (int, optional): Id of search to kill, only kills if matching.
            force (bool, optional): Forcibly kill search regardless of id.
        """
        if self._id == id or force:
            self._stop_event.set()
            self._board = None

    def start_cpu(self, board, id=None):
        """
        Starts the CPU's move search.

        Args:
            board (Board): The current board state.
            id (int, optional): Id of current search.
        """
        self._stop_event.clear()
        self._board = board
        self._id = id

    def run(self):
        """
        Periodically checks if the board variable is set.
        If it is, then starts CPU search.
        """
        while self._running:
            if self._board and self._cpu:
                self._cpu.find_move(self._board, self._stop_event)
                self.stop_cpu()
            else:
                time.sleep(1)
                if self._verbose:
                    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 successivly **hash** a given board for every move played, with the initial hash being generated in the `Board` class.

zobrist_hasher.py

```
from random import randint
from data.helpers.bitboard_helpers import bitboard_to_index
from data.utils.enums import Piece, Colour, Rotation

# Initialise random values for each piece type on every square
# (5 x 2 colours) pieces + 4 rotations, for 80 squares
zobrist_table = [[randint(0, 2 ** 64) for i in range(14)] for j in range(80)]
# Hash for when the red player's move
red_move_hash = randint(0, 2 ** 64)

# Maps piece to the correct random value
piece_lookup = {
    Colour.BLUE: {
        piece: i for i, piece in enumerate(Piece)
    },
    Colour.RED: {
        piece: i + 5 for i, piece in enumerate(Piece)
    },
}
```

```

# Maps rotation to the correct random value
rotation_lookup = {
    rotation: i + 10 for i, rotation in enumerate(Rotation)
}

class ZobristHasher:
    def __init__(self):
        self.hash = 0

    def get_piece_hash(self, index, piece, colour):
        """
        Gets the random value for the piece type on the given square.

        Args:
            index (int): The index of the square.
            piece (Piece): The piece on the square.
            colour (Colour): The colour of the piece.

        Returns:
            int: A 64-bit value.
        """
        piece_index = piece_lookup[colour][piece]
        return zobrist_table[index][piece_index]

    def get_rotation_hash(self, index, rotation):
        """
        Gets the random value for the rotation on the given square.

        Args:
            index (int): The index of the square.
            rotation (Rotation): The rotation on the square.
            colour (Colour): The colour of the piece.

        Returns:
            int: A 64-bit value.
        """
        rotation_index = rotation_lookup[rotation]
        return zobrist_table[index][rotation_index]

    def apply_piece_hash(self, bitboard, piece, colour):
        """
        Updates the Zobrist hash with a new piece.

        Args:
            bitboard (int): The bitboard representation of the square.
            piece (Piece): The piece on the square.
            colour (Colour): The colour of the piece.
        """
        index = bitboard_to_index(bitboard)
        piece_hash = self.get_piece_hash(index, piece, colour)
        self.hash ^= piece_hash

    def apply_rotation_hash(self, bitboard, rotation):
        """Updates the Zobrist hash with a new rotation.

        Args:
            bitboard (int): The bitboard representation of the square.
            rotation (Rotation): The rotation on the square.
        """
        index = bitboard_to_index(bitboard)
        rotation_hash = self.get_rotation_hash(index, rotation)
```

```
        self.hash ^= rotation_hash

    def apply_red_move_hash(self):
        """
        Applies the Zobrist hash for the red player's move.
        """
        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`

```
from data.utils.enums import TranspositionFlag

class TranspositionEntry:
    def __init__(self, score, move, flag, hash_key, depth):
        self.score = score
        self.move = move
        self.flag = flag
        self.hash_key = hash_key
        self.depth = depth

class TranspositionTable:
    def __init__(self, max_entries=100000):
        self._max_entries = max_entries
        self._table = dict()

    def calculate_entry_index(self, hash_key):
        """
        Gets the dictionary key for a given Zobrist hash.

        Args:
            hash_key (int): A Zobrist hash.

        Returns:
            int: Key for the given hash.
        """
        return hash_key

    def insert_entry(self, score, move, hash_key, depth, alpha, beta):
        """
        Inserts an entry into the transposition table.

        Args:
            score (int): The evaluation score.
            move (Move): The best move found.
            hash_key (int): The Zobrist hash key.
            depth (int): The depth of the search.
            alpha (int): The upper bound value.
            beta (int): The lower bound value.

        Raises:
            Exception: Invalid depth or score.
        """
        if depth == 0 or alpha < score < beta:
            flag = TranspositionFlag.EXACT
```

```python
            score = score
        elif score <= alpha:
            flag = TranspositionFlag.UPPER
            score = alpha
        elif score >= beta:
            flag = TranspositionFlag.LOWER
            score = beta
        else:
            raise Exception('(TranspositionTable.insert_entry)')

        self._table[self.calculate_entry_index(hash_key)] = TranspositionEntry(score, move, flag, hash_key, depth)

        if len(self._table) > self._max_entries:
            # Removes the longest-existing entry to free up space for more up-to-date entries
            # Expression to remove leftmost item taken from https://docs.python.org/3/library/collections.html#ordereddict-objects
            (k := next(iter(self._table)), self._table.pop(k))

    def get_entry(self, hash_key, depth, alpha, beta):
        """
        Gets an entry from the transposition table.

        Args:
            hash_key (int): The Zobrist hash key.
            depth (int): The depth of the search.
            alpha (int): The alpha value for pruning.
            beta (int): The beta value for pruning.

        Returns:
            tuple[int, Move] | tuple[None, None]: The evaluation score and the best move found, if entry exists.
        """
        index = self.calculate_entry_index(hash_key)

        if index not in self._table:
            return None, None

        entry = self._table[index]

        if entry.hash_key == hash_key and entry.depth >= depth:
            if entry.flag == TranspositionFlag.EXACT:
                return entry.score, entry.move

            if entry.flag == TranspositionFlag.LOWER and entry.score >= beta:
                return entry.score, entry.move

            if entry.flag == TranspositionFlag.UPPER and entry.score <= alpha:
                return entry.score, entry.move

        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

```
import pygame
from collections import deque
from data.states.game.components.capture_draw import CaptureDraw
from data.states.game.components.piece_group import PieceGroup
from data.states.game.components.laser_draw import LaserDraw
from data.helpers.bitboard_helpers import bitboard_to_coords
from data.helpers.browser_helpers import get_winner_string
from data.states.review.widget_dict import REVIEW_WIDGETS
from data.states.game.components.board import Board
from data.utils.event_types import ReviewEventType
from data.components.game_entry import GameEntry
from data.managers.logs import initialise_logger
from data.utils.constants import ShaderType
from data.managers.window import window
from data.utils.assets import MUSIC
from data.utils.enums import Colour
from data.control import _State

logger = initialise_logger(__name__)

class Review(_State):
    def __init__(self):
        super().__init__()

        self._moves = deque()
        self._popped_moves = deque()
        self._game_info = {}

        self._board = None
        self._piece_group = None
        self._laser_draw = None
        self._capture_draw = None

    def cleanup(self):
        """
        Cleanup function. Clears shader effects.
        """
        super().cleanup()

        window.clear_apply_arguments(ShaderType.BLOOM)
        window.clear_effect(ShaderType.RAYS)

        return None

    def startup(self, persist):
        """
        Startup function. Initialises all objects, widgets and game data.
```

```python

        Args:
            persist (dict): Dict containing game entry data.
        """
        super().startup(REVIEW_WIDGETS, MUSIC['review'])

        window.set_apply_arguments(ShaderType.BASE, background_type=ShaderType.
    BACKGROUND_WAVES)
        window.set_apply_arguments(ShaderType.BLOOM, highlight_colours=[(pygame.
    Color('0x95e0cc')).rgb, pygame.Color('0xf14e52').rgb], colour_intensity=0.8)
        REVIEW_WIDGETS['help'].kill()

        self._moves = deque(GameEntry.parse_moves(persist.pop('moves', '')))
        self._popped_moves = deque()
        self._game_info = persist

        self._board = Board(self._game_info['start_fen_string'])
        self._piece_group = PieceGroup()
        self._laser_draw = LaserDraw(self.board_position, self.board_size)
        self._capture_draw = CaptureDraw(self.board_position, self.board_size)

        self.initialise_widgets()
        self.simulate_all_moves()
        self.refresh_pieces()
        self.refresh_widgets()

        self.draw()

    @property
    def board_position(self):
        return REVIEW_WIDGETS['chessboard'].position

    @property
    def board_size(self):
        return REVIEW_WIDGETS['chessboard'].size

    @property
    def square_size(self):
        return self.board_size[0] / 10

    def initialise_widgets(self):
        """
        Initializes the widgets for a new game.
        """
        REVIEW_WIDGETS['move_list'].reset_move_list()
        REVIEW_WIDGETS['move_list'].kill()
        REVIEW_WIDGETS['scroll_area'].set_image()

        REVIEW_WIDGETS['winner_text'].set_text(f'WINNER: {get_winner_string(self.
    _game_info["winner"])}')
        REVIEW_WIDGETS['blue_piece_display'].reset_piece_list()
        REVIEW_WIDGETS['red_piece_display'].reset_piece_list()

        if self._game_info['time_enabled']:
            REVIEW_WIDGETS['timer_disabled_text'].kill()
        else:
            REVIEW_WIDGETS['blue_timer'].kill()
            REVIEW_WIDGETS['red_timer'].kill()

    def refresh_widgets(self):
        """
        Refreshes the widgets after every move.
```

```
        """
        REVIEW_WIDGETS['move_number_text'].set_text(f'MOVE NO: {(len(self._moves)) / 2:.1f} / {(len(self._moves) + len(self._popped_moves)) / 2:.1f}')
        REVIEW_WIDGETS['move_colour_text'].set_text(f'{self.calculate_colour().name} TO MOVE')

        if self._game_info['time_enabled']:
            if len(self._moves) == 0:
                REVIEW_WIDGETS['blue_timer'].set_time(float(self._game_info['time']) * 60 * 1000)
                REVIEW_WIDGETS['red_timer'].set_time(float(self._game_info['time']) * 60 * 1000)
            else:
                REVIEW_WIDGETS['blue_timer'].set_time(float(self._moves[-1]['blue_time']) * 60 * 1000)
                REVIEW_WIDGETS['red_timer'].set_time(float(self._moves[-1]['red_time']) * 60 * 1000)

        REVIEW_WIDGETS['scroll_area'].set_image()

    def refresh_pieces(self):
        """
        Refreshes the pieces on the board.
        """
        self._piece_group.initialise_pieces(self._board.get_piece_list(), self.board_position, self.board_size)

    def simulate_all_moves(self):
        """
        Simulates all moves at the start of every game to obtain laser results and fill up piece display and move list widgets.
        """
        for index, move_dict in enumerate(self._moves):
            laser_result = self._board.apply_move(move_dict['move'], fire_laser=True)
            self._moves[index]['laser_result'] = laser_result

            if laser_result.hit_square_bitboard:
                if laser_result.piece_colour == Colour.BLUE:
                    REVIEW_WIDGETS['red_piece_display'].add_piece(laser_result.piece_hit)
                elif laser_result.piece_colour == Colour.RED:
                    REVIEW_WIDGETS['blue_piece_display'].add_piece(laser_result.piece_hit)

            REVIEW_WIDGETS['move_list'].append_to_move_list(move_dict['unparsed_move'])

    def calculate_colour(self):
        """
        Calculates the current active colour to move.

        Returns:
            Colour: The current colour to move.
        """
        if self._game_info['start_fen_string'][-1].lower() == 'b':
            initial_colour = Colour.BLUE
        elif self._game_info['start_fen_string'][-1].lower() == 'r':
            initial_colour = Colour.RED

        if len(self._moves) % 2 == 0:
            return initial_colour
```

```
        else:
            return initial_colour.get_flipped_colour()

    def handle_move(self, move, add_piece=True):
        """
        Handles applying or undoing a move.

        Args:
            move (dict): The move to handle.
            add_piece (bool): Whether to add the captured piece to the display. Defaults to True.
        """
        laser_result = move['laser_result']
        active_colour = self.calculate_colour()
        self._laser_draw.add_laser(laser_result, laser_colour=active_colour)

        if laser_result.hit_square_bitboard:
            if laser_result.piece_colour == Colour.BLUE:
                if add_piece:
                    REVIEW_WIDGETS['red_piece_display'].add_piece(laser_result.piece_hit)
                else:
                    REVIEW_WIDGETS['red_piece_display'].remove_piece(laser_result.piece_hit)
            elif laser_result.piece_colour == Colour.RED:
                if add_piece:
                    REVIEW_WIDGETS['blue_piece_display'].add_piece(laser_result.piece_hit)
                else:
                    REVIEW_WIDGETS['blue_piece_display'].remove_piece(laser_result.piece_hit)

            self._capture_draw.add_capture(
                laser_result.piece_hit,
                laser_result.piece_colour,
                laser_result.piece_rotation,
                bitboard_to_coords(laser_result.hit_square_bitboard),
                laser_result.laser_path[0][0],
                active_colour,
                shake=False
            )

    def update_laser_mask(self):
        """
        Updates the laser mask for the light rays effect.
        """
        temp_surface = pygame.Surface(window.size, pygame.SRCALPHA)
        self._piece_group.draw(temp_surface)
        mask = pygame.mask.from_surface(temp_surface, threshold=127)
        mask_surface = mask.to_surface(unsetcolor=(0, 0, 0, 255), setcolor=(255, 0, 0, 255))

        window.set_apply_arguments(ShaderType.RAYS, occlusion=mask_surface)

    def get_event(self, event):
        """
        Processes Pygame events.

        Args:
            event (pygame.event.Event): The event to handle.
        """
        if event.type in [pygame.MOUSEBUTTONUP, pygame.KEYDOWN]:
```

```
            REVIEW_WIDGETS['help'].kill()

        widget_event = self._widget_group.process_event(event)

        if widget_event is None:
            return

        match widget_event.type:
            case None:
                return

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

            case ReviewEventType.PREVIOUS_CLICK:
                if len(self._moves) == 0:
                    return

                # Pop last applied move off first stack
                move = self._moves.pop()
                # Pushed onto second stack
                self._popped_moves.append(move)

                # Undo last applied move
                self._board.undo_move(move['move'], laser_result=move['
    laser_result'])
                self.handle_move(move, add_piece=False)
                REVIEW_WIDGETS['move_list'].pop_from_move_list()

                self.refresh_pieces()
                self.refresh_widgets()
                self.update_laser_mask()

            case ReviewEventType.NEXT_CLICK:
                if len(self._popped_moves) == 0:
                    return

                # Peek at second stack to get last undone move
                move = self._popped_moves[-1]

                # Reapply last undone move
                self._board.apply_move(move['move'])
                self.handle_move(move, add_piece=True)
                REVIEW_WIDGETS['move_list'].append_to_move_list(move['
    unparsed_move'])

                # Pop last undone move from second stack
                self._popped_moves.pop()
                # Push onto first stack
                self._moves.append(move)

                self.refresh_pieces()
                self.refresh_widgets()
                self.update_laser_mask()

            case ReviewEventType.HELP_CLICK:
                self._widget_group.add(REVIEW_WIDGETS['help'])
                self._widget_group.handle_resize(window.size)

    def handle_resize(self):
        """
```

```
        Handles resizing of the window.
        """
        super().handle_resize()
        self._piece_group.handle_resize(self.board_position, self.board_size)
        self._laser_draw.handle_resize(self.board_position, self.board_size)
        self._capture_draw.handle_resize(self.board_position, self.board_size)

        if self._laser_draw.firing:
            self.update_laser_mask()

    def draw(self):
        """
        Draws all components onto the window screen.
        """
        self._capture_draw.update()
        self._widget_group.draw()
        self._piece_group.draw(window.screen)
        self._laser_draw.draw(window.screen)
        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

```
import sqlite3
from pathlib import Path

database_path = (Path(__file__).parent / '../database.db').resolve()

def upgrade():
    """
    Upgrade function to create games table.
    """
    connection = sqlite3.connect(database_path)
    cursor = connection.cursor()

    cursor.execute('''
        CREATE TABLE games(
            id INTEGER PRIMARY KEY,
            cpu_enabled INTEGER NOT NULL,
            cpu_depth INTEGER,
            winner INTEGER,
            time_enabled INTEGER NOT NULL,
            time REAL,
            number_of_ply INTEGER NOT NULL,
            moves TEXT NOT NULL
        )
    ''')

    connection.commit()
    connection.close()
```

```

def downgrade():
    """
    Downgrade function to revert table creation.
    """
    connection = sqlite3.connect(database_path)
    cursor = connection.cursor()

    cursor.execute('''
        DROP TABLE games
    ''')

    connection.commit()
    connection.close()

upgrade()
# downgrade()
```

Using the ALTER command allows me to rename table columns.

change_fen_string_column_name_23122024.py

```
import sqlite3
from pathlib import Path

database_path = (Path(__file__).parent / '../database.db').resolve()

def upgrade():
    """
    Upgrade function to rename fen_string column.
    """
    connection = sqlite3.connect(database_path)
    cursor = connection.cursor()

    cursor.execute('''
        ALTER TABLE games RENAME COLUMN fen_string TO final_fen_string
    ''')

    connection.commit()
    connection.close()

def downgrade():
    """
    Downgrade function to revert fen_string column renaming.
    """
    connection = sqlite3.connect(database_path)
    cursor = connection.cursor()

    cursor.execute('''
        ALTER TABLE games RENAME COLUMN final_fen_string TO fen_string
    ''')

    connection.commit()
    connection.close()

upgrade()
# 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`

```python
import sqlite3
from pathlib import Path
from datetime import datetime

database_path = (Path(__file__).parent / '../database/database.db').resolve()

def insert_into_games(game_entry):
    """
    Inserts a new row into games table.

    Args:
        game_entry (GameEntry): GameEntry object containing game information.
    """
    connection = sqlite3.connect(database_path, detect_types=sqlite3.PARSE_DECLTYPES)
    connection.row_factory = sqlite3.Row
    cursor = connection.cursor()

    # Datetime added for created_dt column
    game_entry = (*game_entry, datetime.now())

    cursor.execute('''
        INSERT INTO games (cpu_enabled, cpu_depth, winner, time_enabled, time,
    number_of_ply, moves, start_fen_string, final_fen_string, created_dt)
        VALUES (?, ?, ?, ?, ?, ?, ?, ?, ?, ?)
    ''', game_entry)

    connection.commit()

    # Return inserted row
    cursor.execute('''
        SELECT * FROM games WHERE id = LAST_INSERT_ROWID()
    ''')
    inserted_row = cursor.fetchone()

    connection.close()

    return dict(inserted_row)

def get_all_games():
    """
    Get all rows in games table.

    Returns:
        list[dict]: List of game entries represented as dictionaries.
    """
    connection = sqlite3.connect(database_path, detect_types=sqlite3.PARSE_DECLTYPES)
    connection.row_factory = sqlite3.Row
    cursor = connection.cursor()

    cursor.execute('''
        SELECT * FROM games
    ''')
    games = cursor.fetchall()

```

```python
    connection.close()

    return [dict(game) for game in games]

def delete_all_games():
    """
    Delete all rows in games table.
    """
    connection = sqlite3.connect(database_path)
    cursor = connection.cursor()

    cursor.execute('''
        DELETE FROM games
    ''')

    connection.commit()
    connection.close()

def delete_game(id):
    """
    Deletes specific row in games table using id attribute.

    Args:
        id (int): Primary key for row.
    """
    connection = sqlite3.connect(database_path)
    cursor = connection.cursor()

    cursor.execute('''
        DELETE FROM games WHERE id = ?
    ''', (id,))

    connection.commit()
    connection.close()

def get_ordered_games(column, ascend=True, start_row=1, end_row=10):
    """
    Get specific number of rows from games table ordered by a specific column(s).

    Args:
        column (_type_): Column to sort by.
        ascend (bool, optional): Sort ascending or descending. Defaults to True.
        start_row (int, optional): First row returned. Defaults to 1.
        end_row (int, optional): Last row returned. Defaults to 10.

    Raises:
        ValueError: If ascend argument or column argument are invalid types.

    Returns:
        list[dict]: List of ordered game entries represented as dictionaries.
    """
    if not isinstance(ascend, bool) or not isinstance(column, str):
        raise ValueError('(database_helpers.get_ordered_games) Invalid input
    arguments!')

    connection = sqlite3.connect(database_path, detect_types=sqlite3.
    PARSE_DECLTYPES)
    connection.row_factory = sqlite3.Row
    cursor = connection.cursor()

    # Match ascend bool to correct SQL keyword
    if ascend:
```

```
        ascend_arg = 'ASC'
    else:
        ascend_arg = 'DESC'

    # Partition by winner, then order by time and number_of_ply
    if column == 'winner':
        cursor.execute(f'''
            SELECT * FROM
                (SELECT ROW_NUMBER() OVER (
                    PARTITION BY winner
                    ORDER BY time {ascend_arg}, number_of_ply {ascend_arg}
                ) AS row_num, * FROM games)
            WHERE row_num >= ? AND row_num <= ?
        ''', (start_row, end_row))
    else:
    # Order by time or number_of_ply only
        cursor.execute(f'''
            SELECT * FROM
                (SELECT ROW_NUMBER() OVER (
                    ORDER BY {column} {ascend_arg}
                ) AS row_num, * FROM games)
            WHERE row_num >= ? AND row_num <= ?
        ''', (start_row, end_row))

    games = cursor.fetchall()

    connection.close()

    return [dict(game) for game in games]

def get_number_of_games():
    """
    Returns:
        int: Number of rows in the games.
    """
    connection = sqlite3.connect(database_path)
    cursor = connection.cursor()

    cursor.execute("""
        SELECT COUNT(ROWID) FROM games
    """)

    result = cursor.fetchall()[0][0]

    connection.close()

    return result

# 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 `SMProtocol` 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 appropiate 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

```
from pathlib import Path
from array import array
import moderngl
from data.shaders.classes import shader_pass_lookup
from data.shaders.protocol import SMProtocol
from data.utils.constants import ShaderType

shader_path = (Path(__file__).parent / '../shaders/').resolve()

SHADER_PRIORITY = [
    ShaderType.CRT,
    ShaderType.SHAKE,
    ShaderType.BLOOM,
    ShaderType.CHROMATIC_ABBREVIATION,
    ShaderType.RAYS,
    ShaderType.GRAYSCALE,
    ShaderType.BASE,
]

pygame_quad_array = array('f', [
    -1.0, 1.0, 0.0, 0.0,
    1.0, 1.0, 1.0, 0.0,
    -1.0, -1.0, 0.0, 1.0,
    1.0, -1.0, 1.0, 1.0,
])

opengl_quad_array = array('f', [
    -1.0, -1.0, 0.0, 0.0,
    1.0, -1.0, 1.0, 0.0,
    -1.0, 1.0, 0.0, 1.0,
    1.0, 1.0, 1.0, 1.0,
])

class ShaderManager(SMProtocol):
    def __init__(self, ctx: moderngl.Context, screen_size):
        self._ctx = ctx
        self._ctx.gc_mode = 'auto'

        self._screen_size = screen_size
        self._opengl_buffer = self._ctx.buffer(data=opengl_quad_array)
        self._pygame_buffer = self._ctx.buffer(data=pygame_quad_array)
        self._shader_list = [ShaderType.BASE]

        self._vert_shaders = {}
        self._frag_shaders = {}
        self._programs = {}
        self._vaos = {}
        self._textures = {}
        self._shader_passes = {}
        self.framebuffers = {}

        self.load_shader(ShaderType.BASE)
        self.load_shader(ShaderType._CALIBRATE)
        self.create_framebuffer(ShaderType._CALIBRATE)
```

```python

    def load_shader(self, shader_type, **kwargs):
        """
        Loads a given shader by creating a VAO reading the corresponding .frag file.

        Args:
            shader_type (ShaderType): The type of shader to load.
            **kwargs: Additional arguments passed when initialising the fragment shader class.
        """
        self._shader_passes[shader_type] = shader_pass_lookup[shader_type](self, **kwargs)
        self.create_vao(shader_type)

    def clear_shaders(self):
        """
        Clears the shader list, leaving only the base shader.
        """
        self._shader_list = [ShaderType.BASE]

    def create_vao(self, shader_type):
        """
        Creates a vertex array object (VAO) for the given shader type.

        Args:
            shader_type (ShaderType): The type of shader.
        """
        frag_name = shader_type[1:] if shader_type[0] == '_' else shader_type
        vert_path = Path(shader_path / 'vertex/base.vert').resolve()
        frag_path = Path(shader_path / f'fragments/{frag_name}.frag').resolve()

        self._vert_shaders[shader_type] = vert_path.read_text()
        self._frag_shaders[shader_type] = frag_path.read_text()

        program = self._ctx.program(vertex_shader=self._vert_shaders[shader_type], fragment_shader=self._frag_shaders[shader_type])
        self._programs[shader_type] = program

        if shader_type == ShaderType._CALIBRATE:
            self._vaos[shader_type] = self._ctx.vertex_array(self._programs[shader_type], [(self._pygame_buffer, '2f 2f', 'vert', 'texCoords')])
        else:
            self._vaos[shader_type] = self._ctx.vertex_array(self._programs[shader_type], [(self._opengl_buffer, '2f 2f', 'vert', 'texCoords')])

    def create_framebuffer(self, shader_type, size=None, filter=moderngl.NEAREST):
        """
        Creates a framebuffer for the given shader type.

        Args:
            shader_type (ShaderType): The type of shader.
            size (tuple[int, int], optional): The size of the framebuffer. Defaults to screen size.
            filter (moderngl.Filter, optional): The texture filter. Defaults to NEAREST.
        """
        texture_size = size or self._screen_size
        texture = self._ctx.texture(size=texture_size, components=4)
        texture.filter = (filter, filter)

        self._textures[shader_type] = texture
```

```
        self.framebuffers[shader_type] = self._ctx.framebuffer(color_attachments=[
    self._textures[shader_type]])

    def render_to_fbo(self, shader_type, texture, output_fbo=None, program_type=
    None, use_image=True, **kwargs):
        """
        Applies the shaders and renders the resultant texture to a framebuffer
    object (FBO).

        Args:
            shader_type (ShaderType): The type of shader.
            texture (moderngl.Texture): The texture to render.
            output_fbo (moderngl.Framebuffer, optional): The output framebuffer.
    Defaults to None.
            program_type (ShaderType, optional): The program type. Defaults to
    None.
            use_image (bool, optional): Whether to use the image uniform. Defaults
     to True.
            **kwargs: Additional uniforms for the fragment shader.
        """
        fbo = output_fbo or self.framebuffers[shader_type]
        program = self._programs[program_type] if program_type else self._programs
    [shader_type]
        vao= self._vaos[program_type] if program_type else self._vaos[shader_type]

        fbo.use()
        texture.use(0)

        if use_image:
            program['image'] = 0
        for uniform, value in kwargs.items():
            program[uniform] = value

        vao.render(mode=moderngl.TRIANGLE_STRIP)

    def apply_shader(self, shader_type, **kwargs):
        """
        Applies a shader of the given type and adds it to the list.

        Args:
            shader_type (ShaderType): The type of shader to apply.

        Raises:
            ValueError: If the shader is already being applied.
        """
        if shader_type in self._shader_list:
            return

        self.load_shader(shader_type, **kwargs)
        self._shader_list.append(shader_type)

        # Sort shader list based on the order in SHADER_PRIORITY, so that more
    important shaders are applied first
        self._shader_list.sort(key=lambda shader: -SHADER_PRIORITY.index(shader))

    def remove_shader(self, shader_type):
        """
        Removes a shader of the given type from the list.

        Args:
            shader_type (ShaderType): The type of shader to remove.
        """
```

```
        if shader_type in self._shader_list:
            self._shader_list.remove(shader_type)

    def render_output(self):
        """
        Renders the final output to the screen.
        """
        # Render to the screen framebuffer
        self._ctx.screen.use()

        # Take the texture of the last framebuffer to be rendered to, and render
    that to the screen framebuffer
        output_shader_type = self._shader_list[-1]
        self.get_fbo_texture(output_shader_type).use(0)
        self._programs[output_shader_type]['image'] = 0

        self._vaos[output_shader_type].render(mode=moderngl.TRIANGLE_STRIP)

    def get_fbo_texture(self, shader_type):
        """
        Gets the texture from the specified shader type's FBO.

        Args:
            shader_type (ShaderType): The type of shader.

        Returns:
            moderngl.Texture: The texture from the FBO.
        """
        return self.framebuffers[shader_type].color_attachments[0]

    def calibrate_pygame_surface(self, pygame_surface):
        """
        Converts the Pygame window surface into an OpenGL texture.

        Args:
            pygame_surface (pygame.Surface): The finished Pygame surface.

        Returns:
            moderngl.Texture: The calibrated texture.
        """
        texture = self._ctx.texture(pygame_surface.size, 4)
        texture.filter = (moderngl.NEAREST, moderngl.NEAREST)
        texture.swizzle = 'BGRA'
        # Take the Pygame surface's pixel array and draw it to the new texture
        texture.write(pygame_surface.get_view('1'))

        # ShaderType._CALIBRATE has a VAO containing the pygame_quad_array
    coordinates, as Pygame uses different texture coordinates than ModernGL
    textures
        self.render_to_fbo(ShaderType._CALIBRATE, texture)
        return self.get_fbo_texture(ShaderType._CALIBRATE)

    def draw(self, surface, arguments):
        """
        Draws the Pygame surface with shaders applied to the screen.

        Args:
            surface (pygame.Surface): The final Pygame surface.
            arguments (dict): A dict of { ShaderType: Args } items, containing
    keyword arguments for every fragment shader.
        """
        self._ctx.viewport = (0, 0, *self._screen_size)
```

```python
        texture = self.calibrate_pygame_surface(surface)

        for shader_type in self._shader_list:
            self._shader_passes[shader_type].apply(texture, **arguments.get(
    shader_type, {}))
            texture = self.get_fbo_texture(shader_type)

        self.render_output()

    def __del__(self):
        """
        Cleans up ModernGL resources when the ShaderManager object is deleted.
        """
        self.cleanup()

    def cleanup(self):
        """
        Cleans up resources used by the ModernGL.
        Probably unnecessary as the 'auto' garbage collection mode is used.
        """
        self._pygame_buffer.release()
        self._opengl_buffer.release()
        for program in self._programs:
            self._programs[program].release()
        for texture in self._textures:
            self._textures[texture].release()
        for vao in self._vaos:
            self._vaos[vao].release()
        for framebuffer in self.framebuffers:
            self.framebuffers[framebuffer].release()

    def handle_resize(self, new_screen_size):
        """
        Handles resizing of the screen.

        Args:
            new_screen_size (tuple[int, int]): The new screen size.
        """
        self._screen_size = new_screen_size

        # Recreate all framebuffers to prevent scaling issues
        for shader_type in self.framebuffers:
            filter = self._textures[shader_type].filter[0]
            self.create_framebuffer(shader_type, size=self._screen_size, filter=
    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`

```
# version 330 core

in vec2 uvs;
out vec4 f_colour;

uniform sampler2D image;
uniform float threshold;
uniform float intensity;

void main() {
    vec4 pixel = texture(image, uvs);
    // Dot product used to calculate brightness of a pixel from its RGB values
    // Values taken from https://en.wikipedia.org/wiki/Relative_luminance
    float brightness = dot(pixel.rgb, vec3(0.2126, 0.7152, 0.0722));
    float isBright = step(threshold, brightness);

    f_colour = vec4(vec3(pixel.rgb * intensity) * isBright, 1.0);
}
```

### 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`

```
from data.shaders.protocol import SMProtocol
from data.utils.constants import ShaderType

BLUR_ITERATIONS = 4

class _Blur:
    def __init__(self, shader_manager: SMProtocol):
        self._shader_manager = shader_manager

        shader_manager.create_framebuffer(ShaderType._BLUR)

        shader_manager.create_framebuffer("blurPing")
        shader_manager.create_framebuffer("blurPong")

    def apply(self, texture):
        """
        Applies Gaussian blur to a given texture.

        Args:
            texture (moderngl.Texture): Texture to blur.
        """
        self._shader_manager.get_fbo_texture("blurPong").write(texture.read())

        for _ in range(BLUR_ITERATIONS):
            # Apply horizontal blur
            self._shader_manager.render_to_fbo(
```

```
                ShaderType._BLUR,
                texture=self._shader_manager.get_fbo_texture("blurPong"),
                output_fbo=self._shader_manager.framebuffers["blurPing"],
                passes=5,
                horizontal=True
            )
            # Apply vertical blur
            self._shader_manager.render_to_fbo(
                ShaderType._BLUR,
                texture=self._shader_manager.get_fbo_texture("blurPing"), # Use horizontal blur result as input texture
                output_fbo=self._shader_manager.framebuffers["blurPong"],
                passes=5,
                horizontal=False
            )

        self._shader_manager.render_to_fbo(ShaderType._BLUR, self._shader_manager.get_fbo_texture("blurPong"))
```

blur.frag

```
// Modified from https://learnopengl.com/Advanced-Lighting/Bloom
#version 330 core

in vec2 uvs;
out vec4 f_colour;

uniform sampler2D image;
uniform bool horizontal;
uniform int passes;
uniform float weight[5] = float[] (0.227027, 0.1945946, 0.1216216, 0.054054, 0.016216);

void main() {
    vec2 offset = 1.0 / textureSize(image, 0);
    vec3 result = texture(image, uvs).rgb * weight[0];

    if (horizontal) {
        for (int i = 1 ; i < passes ; ++i) {
            result += texture(image, uvs + vec2(offset.x * i, 0.0)).rgb * weight[i];
            result += texture(image, uvs - vec2(offset.x * i, 0.0)).rgb * weight[i];
        }
    }
    else {
        for (int i = 1 ; i < passes ; ++i) {
            result += texture(image, uvs + vec2(0.0, offset.y * i)).rgb * weight[i];
            result += texture(image, uvs - vec2(0.0, offset.y * i)).rgb * weight[i];
        }
    }

    f_colour = vec4(result, 1.0);
}
```

### 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`

```python
from data.shaders.classes.highlight_brightness import _HighlightBrightness
from data.shaders.classes.highlight_colour import _HighlightColour
from data.shaders.protocol import SMProtocol
from data.shaders.classes.blur import _Blur
from data.utils.constants import ShaderType

BLOOM_INTENSITY = 0.6

class Bloom:
    def __init__(self, shader_manager: SMProtocol):
        self._shader_manager = shader_manager

        shader_manager.load_shader(ShaderType._BLUR)
        shader_manager.load_shader(ShaderType._HIGHLIGHT_BRIGHTNESS)
        shader_manager.load_shader(ShaderType._HIGHLIGHT_COLOUR)

        shader_manager.create_framebuffer(ShaderType.BLOOM)
        shader_manager.create_framebuffer(ShaderType._BLUR)
        shader_manager.create_framebuffer(ShaderType._HIGHLIGHT_BRIGHTNESS)
        shader_manager.create_framebuffer(ShaderType._HIGHLIGHT_COLOUR)

    def apply(self, texture, highlight_surface=None, highlight_colours=[], surface_intensity=BLOOM_INTENSITY, brightness_intensity=BLOOM_INTENSITY, colour_intensity=BLOOM_INTENSITY):
        """
        Applies a bloom effect to a given texture.

        Args:
            texture (moderngl.Texture): Texture to apply bloom to.
            highlight_surface (pygame.Surface, optional): Surface to use as the highlights. Defaults to None.
            highlight_colours (list[list[int, int, int], ...], optional): Colours to use as the highlights. Defaults to [].
            surface_intensity (_type_, optional): Intensity of bloom applied to the highlight surface. Defaults to BLOOM_INTENSITY.
            brightness_intensity (_type_, optional): Intensity of bloom applied to the highlight brightness. Defaults to BLOOM_INTENSITY.
            colour_intensity (_type_, optional): Intensity of bloom applied to the highlight colours. Defaults to BLOOM_INTENSITY.
        """
        if highlight_surface:
            # Calibrate Pygame surface and apply blur
            glare_texture = self._shader_manager.calibrate_pygame_surface(highlight_surface)
            _Blur(self._shader_manager).apply(glare_texture)

            self._shader_manager.get_fbo_texture(ShaderType._BLUR).use(1)
            self._shader_manager.render_to_fbo(ShaderType.BLOOM, texture, blurredImage=1, intensity=surface_intensity)

            # Set bloom-applied texture as the base texture
            texture = self._shader_manager.get_fbo_texture(ShaderType.BLOOM)

        # Extract bright colours (highlights) from the texture
        _HighlightBrightness(self._shader_manager).apply(texture, intensity=brightness_intensity)
```

```
        highlight_texture = self._shader_manager.get_fbo_texture(ShaderType._HIGHLIGHT_BRIGHTNESS)

        # Use colour as highlights
        for colour in highlight_colours:
            _HighlightColour(self._shader_manager).apply(texture, old_highlight=highlight_texture, colour=colour, intensity=colour_intensity)
            highlight_texture = self._shader_manager.get_fbo_texture(ShaderType._HIGHLIGHT_COLOUR)

        # Apply Gaussian blur to highlights
        _Blur(self._shader_manager).apply(highlight_texture)

        # Add the pixel values for the highlights onto the base texture
        self._shader_manager.get_fbo_texture(ShaderType._BLUR).use(1)
        self._shader_manager.render_to_fbo(ShaderType.BLOOM, texture, blurredImage=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`

```
# version 330 core

in vec2 uvs;
out vec4 f_colour;

uniform sampler2D image;
uniform vec3 checkColour;

void main() {
    vec4 pixel = texture(image, uvs);

    // If pixel is occluding colour, set pixel to white
    if (pixel.rgb == checkColour) {
        f_colour = vec4(1.0, 1.0, 1.0, 1.0);
    // Else, set pixel to black
    } else {
        f_colour = vec4(vec3(0.0), 1.0);
    }
}
```

#### Shadowmap

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

```
# version 330 core

#define PI 3.1415926536;
```

```

in vec2 uvs;
out vec4 f_colour;

uniform sampler2D image;
uniform float resolution;
uniform float THRESHOLD=0.99;

void main() {
  float maxDistance = 1.0;

    for (float y = 0.0 ; y < resolution ; y += 1.0) {
        //rectangular to polar filter
        float currDistance = y / resolution;

        vec2 norm = vec2(uvs.x, currDistance) * 2.0 - 1.0; // Range from [0, 1] -> [-1, 1]
        float angle = (1.5 - norm.x) * PI; // Range from [-1, 1] -> [0.5PI, 2.5PI]
        float radius = (1.0 + norm.y) * 0.5; // Range from [-1, 1] -> [0, 1]

        //coord which we will sample from occlude map
        vec2 coords = vec2(radius * -sin(angle), radius * -cos(angle)) / 2.0 + 0.5;

        // Sample occlusion map
        vec4 occluding = texture(image, coords);

        // If pixel is not occluding (Red channel value below threshold), set maxDistance to current distance
    // If pixel is occluding, don't change distance
    // maxDistance therefore is the distance from the center to the nearest occluding pixel
        maxDistance = max(maxDistance * step(occluding.r, THRESHOLD), min(maxDistance, currDistance));
    }

    f_colour = vec4(vec3(maxDistance), 1.0);
}
```

### Lightmap

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

`lightmap.frag`

```
# version 330 core

#define PI 3.14159265

in vec2 uvs;
out vec4 f_colour;

uniform float softShadow;
uniform float resolution;
uniform float falloff;
uniform vec3 lightColour;
uniform vec2 angleClamp;
uniform sampler2D occlusionMap;
uniform sampler2D image;

vec3 normLightColour = lightColour / 255;
```

```
vec2 radiansClamp = angleClamp * (PI / 180);

float sample(vec2 coord, float r) {
  /*
  Sample from the 1D distance map.

  Returns:
    float: 1.0 if sampled radius is greater than the passed radius, 0.0 if not.
  */
  return step(r, texture(image, coord).r);
}

void main() {
  // Cartesian to polar transformation
  // Range from [0, 1] -> [-1, 1]
  vec2 norm = uvs.xy * 2.0 - 1.0;
  float angle = atan(norm.y, norm.x);
  float r = length(norm);

  // The texture coordinates to sample our 1D lookup texture
  // Always 0.0 on y-axis, as the texture is 1D
  float x = (angle + PI) / (2.0 * PI); // Normalise angle to [0, 1]
  vec2 tc = vec2(x, 0.0);

  // Sample the 1D lookup texture to check if pixel is in light or in shadow
  // Gives us hard shadows
  // 1.0 -> in light, 0.0, -> in shadow
  float inLight = sample(tc, r);
  // Clamp angle so that only pixels within the range are in light
  inLight = inLight * step(angle, radiansClamp.y) * step(radiansClamp.x, angle);

  // Multiply the blur amount by the distance from the center
  // So that the blurring increases as distance increases
  float blur = (1.0 / resolution) * smoothstep(0.0, 0.1, r);

  // Use gaussian blur to apply blur effecy
  float sum = 0.0;

  sum += sample(vec2(tc.x - blur * 4.0, tc.y), r) * 0.05;
  sum += sample(vec2(tc.x - blur * 3.0, tc.y), r) * 0.09;
  sum += sample(vec2(tc.x - blur * 2.0, tc.y), r) * 0.12;
  sum += sample(vec2(tc.x - blur * 1.0, tc.y), r) * 0.15;

  sum += inLight * 0.16;

  sum += sample(vec2(tc.x + blur * 1.0, tc.y), r) * 0.15;
  sum += sample(vec2(tc.x + blur * 2.0, tc.y), r) * 0.12;
  sum += sample(vec2(tc.x + blur * 3.0, tc.y), r) * 0.09;
  sum += sample(vec2(tc.x + blur * 4.0, tc.y), r) * 0.05;

  // Mix with the softShadow uniform to toggle degree of softShadows
  float finalLight = mix(inLight, sum, softShadow);

  // Multiply the final light value with the distance, to give a radial falloff
  // Use as the alpha value, with the light colour being the RGB values
  f_colour = vec4(normLightColour, finalLight * smoothstep(1.0, falloff, r));
}
```

### 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

```python
from data.shaders.classes.lightmap import _Lightmap
from data.shaders.classes.blend import _Blend
from data.shaders.protocol import SMProtocol
from data.shaders.classes.crop import _Crop
from data.utils.constants import ShaderType

class Rays:
    def __init__(self, shader_manager: SMProtocol, lights):
        self._shader_manager = shader_manager
        self._lights = lights

        # Load all necessary shaders
        shader_manager.load_shader(ShaderType._LIGHTMAP)
        shader_manager.load_shader(ShaderType._BLEND)
        shader_manager.load_shader(ShaderType._CROP)
        shader_manager.create_framebuffer(ShaderType.RAYS)

    def apply(self, texture, occlusion=None, softShadow=0.3):
        """
        Applies the light rays effect to a given texture.

        Args:
            texture (moderngl.Texture): The texture to apply the effect to.
            occlusion (pygame.Surface, optional): A Pygame mask surface to use as the occlusion texture. Defaults to None.
        """
        final_texture = texture

        # Iterate through array containing light information
        for pos, radius, colour, *args in self._lights:
            # Topleft of light source square
            light_topleft = (pos[0] - (radius * texture.size[1] / texture.size[0]), pos[1] - radius)
            # Relative size of light compared to texture
            relative_size = (radius * 2 * texture.size[1] / texture.size[0], radius * 2)

            # Crop texture to light source diameter, and to position light source at the center
            _Crop(self._shader_manager).apply(texture, relative_pos=light_topleft, relative_size=relative_size)
            cropped_texture = self._shader_manager.get_fbo_texture(ShaderType._CROP)

            if occlusion:
                # Calibrate Pygame mask surface and crop it
                occlusion_texture = self._shader_manager.calibrate_pygame_surface(occlusion)
                _Crop(self._shader_manager).apply(occlusion_texture, relative_pos=light_topleft, relative_size=relative_size)
                occlusion_texture = self._shader_manager.get_fbo_texture(ShaderType._CROP)
            else:
                occlusion_texture = None

            # 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)

            # Blend the final result with the original texture
            _Blend(self._shader_manager).apply(final_texture, light_map,
light_topleft)
            final_texture = self._shader_manager.get_fbo_texture(ShaderType._BLEND
)

        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

```
    def print_stats(self, score, move):
        """
        Prints statistics after traversing tree.

        Args:
            score (int): Final score obtained after traversal.
            move (Move): Best move obtained after traversal.
        """
        if self._verbose is False:
            return

        self._stats['time_taken'] = round(1000 * (time.time() - self._stats['time_taken']), 3)
        self._stats['ms_per_node'] = round(self._stats['time_taken'] / self._stats['nodes'], 3)

        # Prints stats across multiple lines
        if self._verbose is True:
            logger.info(f'\n\n'
                        f'{self.__str__()} Search Results:\n'
                        f'{printer.pformat(self._stats)}\n'
                        f'Best score: {score}   Best move: {move}\n'
                        )

        # Prints stats in a compacted format
        elif self._verbose.lower() == 'compact':
            logger.info(self._stats)
```

```
            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 | `sc9/10/10/4paPa4/5Pa4/10/10/9Sa b` | 124 | ✓ |
| Position | `sc9/4nanana3/10/10/10/4NaNaNa3/10/9Sa b` | 66 | ✓ |
| Mobility | See footnote[1] | 196 | ✓ |
| King Safety | `sc4fa3pa/10/10/10/10/10/5FaPa2Sa b` | 3 | ✓ |
| Combined | See footnote[2] | 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 | `sc9/pafa8/Fa9/10/10/10/10/9Sa b` | Rotate J3 clockwise | ✓ |
| Mate in 1 | `sc9/10/10/10/8faRb/8FaRb/10/9Sa b` | Move J3 to J2 | ✓ |
| Mate in 3 | `sc9/10/10/8Ra1/7FaRafa/8RaRa/9Ra/9Sa b` | Move J2 to I1...[3] | ✓ |
| Mate in 3 | `sc5fcnc2/4Pa4Pc/3pb6/2Pc2ra1pb2/10/pb9/7Pa2 /2PdNaFa4Sa b` | Move E7 to F7...[4] | ✓ |
| Mate in 3 | `sc2pdfc5/2Ra1ra5/pa3Pc4Rb/pb1rd1Pdra4/7Rd2/3 Ra1Pa4/4Fa5/3PdNaPa3Sa b` | Move J6 to J7...[5] | ✓ |

[1] scpapa7/papapa7/papapa1Pa1Pa1Pa1/10/4Pa1Pa1Pa1/10/4Pa1Pa3/9Sa b
[2] scnc1fcncpbpb3/pa9/pb1pc1rbpa3Pd/1Pc2Pd4Pc/2Pd1RaRb4/10/7Pa2/2PdNaFaNa3Sa b
[3] `2. Move J4 to J5 3. Move J3 to I2`
[4] `2. Rotate anticlockwise H8 3. Move F7 to G7`
[5] `2. Move E7 to F8 3. Move E4 to E5`

| Description | FEN string | Best Move | Passed |
|---|---|---|---|
| Win Material | `sc9/2fa7/5NaPb3/pa2ra1Pd4/3pcnd1pd2Rd/3pc6/10/8FaSa b` | Move F6 to G7...[6] | ✓ |

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.

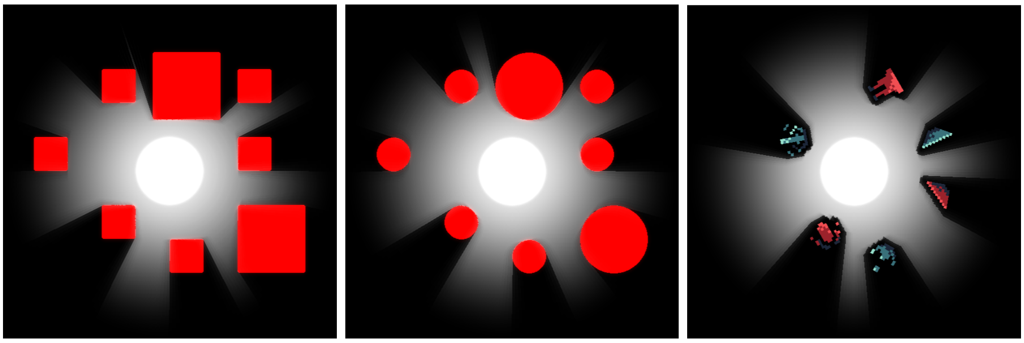


Figure 4.1: Shadow mapping algorithm test (softShadow=0.5, radius=0.5)

## 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 | ✓ |

[6] `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 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 | ✓ |
| 5 | 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 final tests:
Link to video demonstrating unit tests:

# 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 improve the immersiveness of the game, as well as 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.s

## 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 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://jdsherbert.itch.io/ultimate-ui-sfx-pack
- https://jdwasabi.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/

# Appendix A

# Screenshots


Figure A.1: Main menu screen

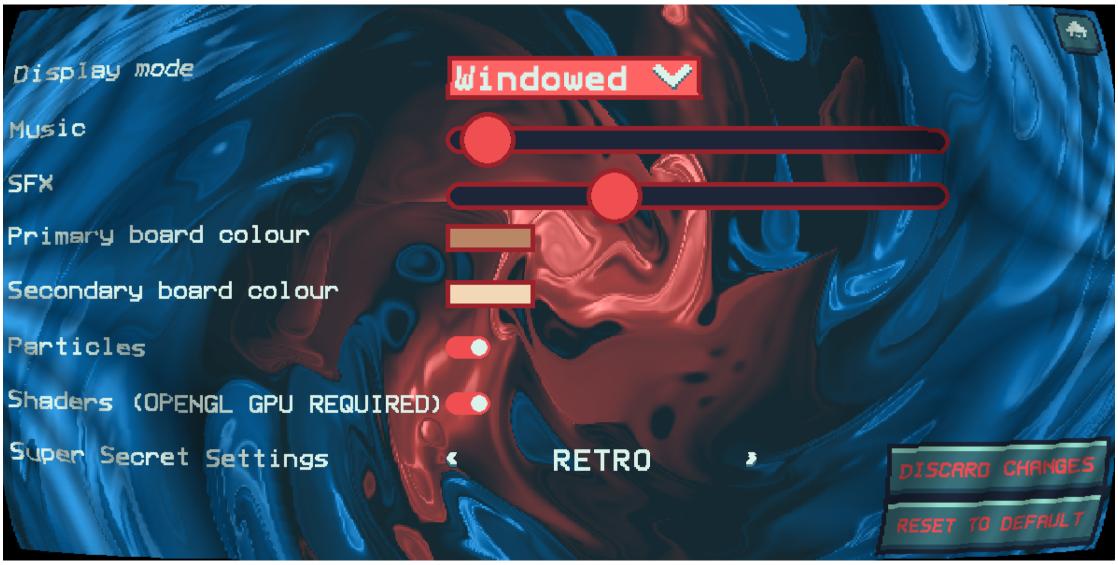



Figure A.2: Settings screen


Figure A.3: Config screen

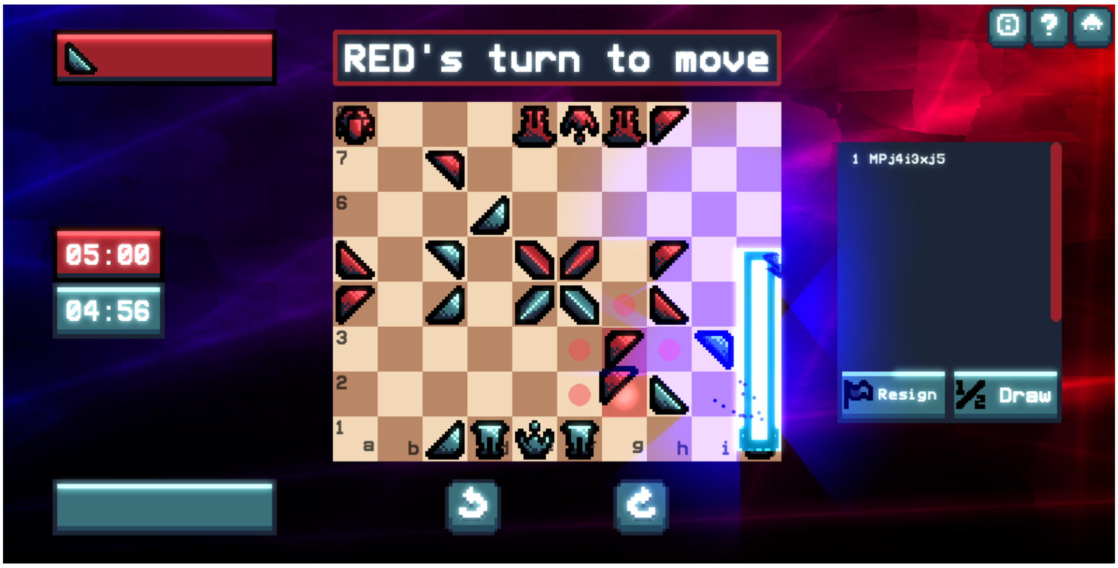



Figure A.4: Game screen

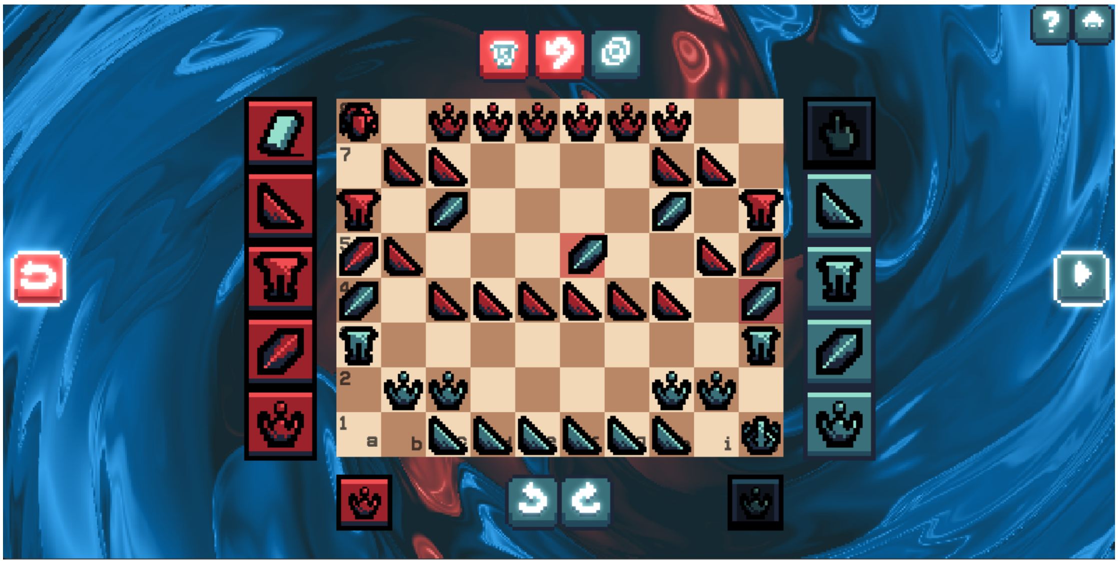


Figure A.5: Editor screen


Figure A.6: Browser screen

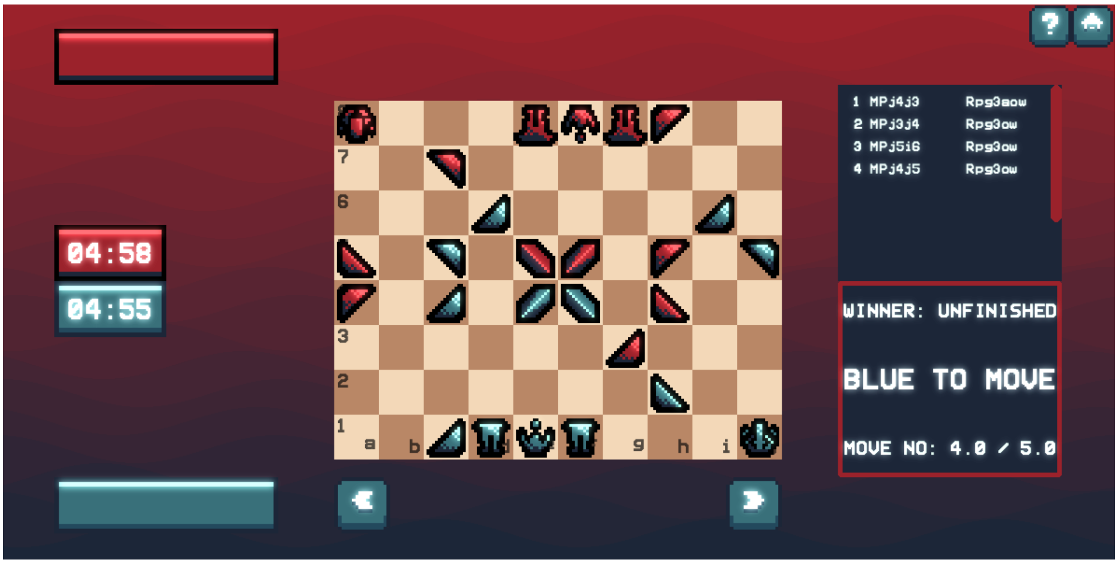



Figure A.7: Review screen

# Appendix B

# Source Code

## B.1 data

### B.1.1 control.py

```
import pygame
from data.components.widget_group import WidgetGroup
from data.managers.logs import initialise_logger
from data.managers.cursor import CursorManager
from data.managers.animation import animation
from data.utils.assets import DEFAULT_FONT
from data.managers.window import window
from data.managers.audio import audio
from data.managers.theme import theme

logger = initialise_logger(__file__)

FPS = 60
SHOW_FPS = False
start_ticks = pygame.time.get_ticks()

# Control class for managing state machine
class Control:
    def __init__(self):
        self.done = False
        self._clock = pygame.time.Clock()

    def setup_states(self, state_dict, start_state):
        self.state_dict = state_dict
        self.state_name = start_state

        self.state = self.state_dict[self.state_name]
        self.state.startup()

    # Method to cleanup previous state and startup new state.
    def flip_state(self):
        self.state.done = False
        persist = self.state.cleanup()

        previous, self.state_name = self.state_name, self.state.next

        self.state = self.state_dict[self.state_name]
        self.state.previous = previous
```

```
        self.state.startup(persist)

    def update(self):
        if self.state.quit:
            self.done = True
        elif self.state.done:
            self.flip_state()

        self._clock.tick(FPS)
        animation.set_delta_time()

        self.state.update()

        if SHOW_FPS:
            self.draw_fps()

        window.update()

    def main_game_loop(self):
        while not self.done:
            self.event_loop()
            self.update()

    def update_window(self, resize=False):
        if resize:
            self.update_native_window_size()
            window.handle_resize()
            self.state.handle_resize()

        self.update()

    # Debug method to render framerate.
    def draw_fps(self):
        fps = str(int(self._clock.get_fps()))
        DEFAULT_FONT.strength = 0.1
        DEFAULT_FONT.render_to(window.screen, (0, 0), fps, fgcolor=theme['
    textError'], size=15)

    # Used to limit window dimensions when resizing application window
    def update_native_window_size(self):
        x, y = window.size

        max_window_x = 100000
        max_window_y = x / 1.4
        min_window_x = 400
        min_window_y = min_window_x / 1.4

        # If aspect ratio is less than 1.4, stop allowing width rescaling
        if x / y < 1.4:
            min_window_x = x

        window.minimum_size = (min_window_x, min_window_y)
        window.maximum_size = (max_window_x, max_window_y)

    def event_loop(self):
        for event in pygame.event.get():
            if event.type == pygame.QUIT:
                self.done = True

            # Only allow left-click for mouse presses
            if event.type == pygame.MOUSEBUTTONDOWN and event.button != 1:
                return
```

```python

            self.state.get_event(event)

class _State:
    def __init__(self):
        self.next = None
        self.previous = None
        self.done = False
        self.quit = False
        self.persist = {}

        self._cursor = CursorManager()
        self._widget_group = None

    def startup(self, widgets=None, music=None):
        if widgets:
            self._widget_group = WidgetGroup(widgets)
            self._widget_group.handle_resize(window.size)

        if music:
            audio.play_music(music)

        logger.info(f'starting {self.__class__.__name__.lower()}.py')

    def cleanup(self):
        logger.info(f'cleaning {self.__class__.__name__.lower()}.py')

    def draw(self):
        raise NotImplementedError

    def get_event(self, event):
        raise NotImplementedError

    def handle_resize(self):
        self._widget_group.handle_resize(window.size)

    def update(self, **kwargs):
        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

```python
import pygame

# Initialise Pygame
pygame.mixer.init()
pygame.init()

# Initialise OpenGL for Pygame with version 330
pygame.display.gl_set_attribute(pygame.GL_CONTEXT_MAJOR_VERSION, 3)
pygame.display.gl_set_attribute(pygame.GL_CONTEXT_MINOR_VERSION, 3)
pygame.display.gl_set_attribute(pygame.GL_CONTEXT_PROFILE_MASK, pygame.
    GL_CONTEXT_PROFILE_CORE)
```

```
pygame.display.gl_set_attribute(pygame.GL_CONTEXT_FORWARD_COMPATIBLE_FLAG, True)
```

### B.1.5 windows_setup.py

```python
import win32gui
import win32con
import ctypes
import sys
import os

def wndProc(oldWndProc, draw_callback, hWnd, message, wParam, lParam):
    # Run window update function whenever window is being resized
    if message == win32con.WM_SIZING or message == win32con.WM_TIMER:
        draw_callback(resize=True)
        win32gui.RedrawWindow(hWnd, None, None, win32con.RDW_INVALIDATE | win32con
.RDW_ERASE)
    # Run window update function whenever window is being dragged
    elif message == win32con.WM_MOVE:
        draw_callback(resize=False)

    return win32gui.CallWindowProc(oldWndProc, hWnd, message, wParam, lParam)

def set_win_resize_func(resize_function):
    oldWndProc = win32gui.SetWindowLong(win32gui.GetForegroundWindow(), win32con.
    GWL_WNDPROC, lambda *args: wndProc(oldWndProc, resize_function, *args))

user32 = ctypes.windll.user32
user32.SetProcessDPIAware() # To deal with Windows High Text Size / Low Display
    Resolution Settings

# Only allow Windows Version >= 7
if os.name != 'nt' or sys.getwindowsversion()[0] < 6:
    raise NotImplementedError("Incompatible OS!")
```

## B.2 data\app_data

### B.2.1 default_settings.json

```json
{
    "primaryBoardColour": "0xB98766",
    "secondaryBoardColour": "0xF3D8B8",
    "laserColourBlue": "0x0000ff",
    "laserColourRed": "0xff0000",
    "displayMode": "windowed",
    "musicVolume": 0.5,
    "sfxVolume": 0.5,
    "particles": true,
    "opengl": true,
    "shader": "default"
}
```

### B.2.2 logs_config.json

```json
{
    "version": 1,
    "disable_existing_loggers": false,
    "formatters": {
      "simple": {
        "format": "%(asctime)s - %(name)s - %(levelname)s - %(message)s",
```

```
        "datefmt": "%Y-%m-%d %H:%M:%S"
      }
    },

    "handlers": {
      "console": {
        "class": "logging.StreamHandler",
        "formatter": "simple",
        "stream": "ext://sys.stdout"
      }
    },

    "root": {
      "level": "INFO",
      "handlers": ["console"],
      "propagate": false
    }
  }
```

### B.2.3 logs_config_prod.json

```
{
    "version": 1,
    "disable_existing_loggers": false,
    "formatters": {
      "simple": {
        "format": "%(asctime)s - %(name)s - %(levelname)s - %(message)s"
      }
    },

    "handlers": {
      "console": {
        "class": "logging.StreamHandler",
        "level": "DEBUG",
        "formatter": "simple",
        "stream": "ext://sys.stdout"
      },

      "info_file_handler": {
        "class": "logging.handlers.RotatingFileHandler",
        "level": "INFO",
        "formatter": "simple",
        "filename": "info.log",
        "maxBytes": 10485760,
        "backupCount": 20,
        "encoding": "utf8"
      },

      "error_file_handler": {
        "class": "logging.handlers.RotatingFileHandler",
        "level": "ERROR",
        "formatter": "simple",
        "filename": "errors.log",
        "maxBytes": 10485760,
        "backupCount": 20,
        "encoding": "utf8"
      }
    },

    "loggers": {
      "my_module": {
        "level": "ERROR",
```

```
        "handlers": ["console"],
        "propagate": false
      }
    },

    "root": {
      "level": "INFO",
      "handlers": ["console", "info_file_handler", "error_file_handler"]
    }
  }
```


### B.2.4 themes.json


```
{
    "colours": {
        "text": {
            "primary": "0xdaf2e9",
            "secondary": "0xf14e52",
            "error": "0xf14e52"
        },
        "fill": {
            "primary": "0x1c2638",
            "secondary": "0xf14e52",
            "tertiary": "0xdaf2e9",
            "error": "0x9b222b"
        },
        "border": {
            "primary": "0x9b222b",
            "secondary": "0xdaf2e9"
        }
    },
    "dimensions": {
        "borderRadius": 3,
        "borderWidth": 5,
        "margin": 10
    }
}
```


### B.2.5 user_settings.json


```
{
    "primaryBoardColour": "0xB98766",
    "secondaryBoardColour": "0xF3D8B8",
    "laserColourBlue": "0x0000ff",
    "laserColourRed": "0xff0000",
    "displayMode": "windowed",
    "musicVolume": 0.013,
    "sfxVolume": 0.085,
    "particles": true,
    "opengl": true,
    "shader": "default"
}
```


## B.3 data\components

### B.3.1 circular_linked_list.py

See Section 3.4.3.

### B.3.2 cursor.py

```
import pygame

class Cursor(pygame.sprite.Sprite):
    def __init__(self):
        super().__init__()
        self.image = pygame.Surface((1, 1))
        self.image.fill((255, 0, 0))
        self.rect = self.image.get_rect()

    # def update(self):
    #     self.rect.center = pygame.mouse.get_pos()

    def get_sprite_collision(self, mouse_pos, square_group):
        self.rect.center = mouse_pos
        sprite = pygame.sprite.spritecollideany(self, square_group)

        return sprite
```

### B.3.3 custom_event.py

See Section 3.4.4.

### B.3.4 game_entry.py

```
from data.states.game.components.move import Move
from data.utils.enums import Colour

class GameEntry:
    def __init__(self, game_states, final_fen_string):
        self._game_states = game_states
        self._final_fen_string = final_fen_string

    # Debug method used to print GameEntry row
    def __str__(self):
        return f'''
<GameEntry>:>
    CPU_ENABLED: {self._game_states['CPU_ENABLED']}
    CPU_DEPTH: {self._game_states['CPU_DEPTH']},
    WINNER: {self._game_states['WINNER']},
    TIME_ENABLED: {self._game_states['TIME_ENABLED']},
    TIME: {self._game_states['TIME']},
    NUMBER_OF_PLY: {len(self._game_states['MOVES'])},
    MOVES: {self.convert_moves(self._game_states['MOVES'])}
    FINAL FEN_STRING: {self._final_fen_string}
    START FEN STRING: {self._game_states['START_FEN_STRING']}
</GameEntry>
        '''

    def convert_to_row(self):
        return (self._game_states['CPU_ENABLED'], self._game_states['CPU_DEPTH'], self._game_states['WINNER'], self._game_states['TIME_ENABLED'], self._game_states['TIME'], len(self._game_states['MOVES']), self.convert_moves(self._game_states['MOVES']), self._game_states['START_FEN_STRING'], self._final_fen_string)

    # List comprehension used to format move dictionary into string
    def convert_moves(self, moves):
        return '|'.join([
```

```
            f'{round(move['time'][Colour.BLUE], 4)};{round(move['time'][Colour.RED
    ], 4)};{move['move']}'
            for move in moves
        ])

    # Inverse method of convert_moves, converts string into dictionary of moves
    @staticmethod
    def parse_moves(move_str):
        moves = move_str.split('|')
        return [
            {
                'blue_time': move.split(';')[0],
                'red_time': move.split(';')[1],
                'move': Move.instance_from_notation(move.split(';')[2]),
                'unparsed_move': move.split(';')[2],
            } for move in moves if move != ''
        ]
```

### B.3.5 widget_group.py

```
import pygame
from data.managers.window import window

# Overriding Pygame widget group to handle own widget system
class WidgetGroup(pygame.sprite.Group):
    def __init__(self, widget_dict):
        super().__init__()

        # Add widgets from WIDGET_DICT
        for value in widget_dict.values():
            if isinstance(value, list):
                for widget in value:
                    self.add(widget)
            elif isinstance(value, dict):
                for widget in value.values():
                    self.add(widget)
            else:
                self.add(value)

    def handle_resize(self, new_surface_size):
        for sprite in self.sprites():
            sprite.set_surface_size(new_surface_size)
            sprite.set_image()
            sprite.set_geometry()

    def process_event(self, event):
        for sprite in self.sprites():
            widget_event = sprite.process_event(event)

            if widget_event:
                return widget_event

        return None

    def draw(self):
        sprites = self.sprites()
        for spr in sprites:
            surface = spr._surface or window.screen
            self.spritedict[spr] = surface.blit(spr.image, spr.rect)
        self.lostsprites = []
        dirty = self.lostsprites

```

```
        return dirty

    # Returns True if mouse cursor is hovering over a widget
    def on_widget(self, mouse_pos):
        test_sprite = pygame.sprite.Sprite()
        test_sprite.rect = pygame.FRect(*mouse_pos, 1, 1)
        return pygame.sprite.spritecollideany(test_sprite, self)
```

## B.4 data\database

## B.5 data\database\migrations

### B.5.1 add_created_dt_column27112024.py

```
import sqlite3
from pathlib import Path

database_path = (Path(__file__).parent / '../database.db').resolve()

# Upgrade function used to update games table schema
def upgrade():
    connection = sqlite3.connect(database_path)
    cursor = connection.cursor()

    cursor.execute('''
        ALTER TABLE games ADD COLUMN created_dt TIMESTAMP NOT NULL
    ''')

    connection.commit()
    connection.close()

# Downgrade function used to revert changes
def downgrade():
    connection = sqlite3.connect(database_path)
    cursor = connection.cursor()

    cursor.execute('''
        ALTER TABLE games DROP COLUMN created_dt
    ''')

    connection.commit()
    connection.close()

upgrade()
# downgrade()
```

### B.5.2 add_fen_string_column_22112024.py

```
import sqlite3
from pathlib import Path

database_path = (Path(__file__).parent / '../database.db').resolve()

def upgrade():
    connection = sqlite3.connect(database_path)
    cursor = connection.cursor()

    cursor.execute('''
        ALTER TABLE games ADD COLUMN fen_string TEXT NOT NULL
```

```
    ''')

    connection.commit()
    connection.close()

def downgrade():
    connection = sqlite3.connect(database_path)
    cursor = connection.cursor()

    cursor.execute('''
        ALTER TABLE games DROP COLUMN fen_string
    ''')

    connection.commit()
    connection.close()

upgrade()
```

### B.5.3 add_start_fen_string_column_23122024.py

```
import sqlite3
from pathlib import Path

database_path = (Path(__file__).parent / '../database.db').resolve()

def upgrade():
    connection = sqlite3.connect(database_path)
    cursor = connection.cursor()

    cursor.execute('''
        ALTER TABLE games ADD COLUMN start_fen_string TEXT NOT NULL
    ''')

    connection.commit()
    connection.close()

def downgrade():
    connection = sqlite3.connect(database_path)
    cursor = connection.cursor()

    cursor.execute('''
        ALTER TABLE games DROP COLUMN start_fen_string
    ''')

    connection.commit()
    connection.close()

upgrade()
# 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

```python
from data.managers.logs import initialise_logger
from data.utils.constants import EMPTY_BB
from data.utils.enums import Rank, File

logger = initialise_logger(__name__)

# Debug function to return string representation of bitboard
def print_bitboard(bitboard):
    if (bitboard >= (2 ** 80)):
        raise ValueError('Invalid bitboard: too many bits')

    characters = ''
    for rank in reversed(Rank):

        for file in File:
            mask = 1 << (rank * 10 + file)
            if (bitboard & mask) != 0:
                characters += '1  '
            else:
                characters += '.  '

        characters += '\n\n'

    logger.info('\n' + characters + '\n')

def is_occupied(bitboard, target_bitboard):
    return (target_bitboard & bitboard) != EMPTY_BB

def clear_square(bitboard, target_bitboard):
    return (~target_bitboard & bitboard)

def set_square(bitboard, target_bitboard):
    return (target_bitboard | bitboard)

def index_to_bitboard(index):
    return (1 << index)

def coords_to_bitboard(coords):
    index = coords[1] * 10 + coords[0]
    return index_to_bitboard(index)

# Converts bitboard square to algebraic board notation
def bitboard_to_notation(bitboard):
    index = bitboard_to_index(bitboard)
    x = index // 10
    y = index % 10

    return chr(y + 97) + str(x + 1)

def notation_to_bitboard(notation):
    index = (int(notation[1]) - 1) * 10 + int(ord(notation[0])) - 97

```

```
    return index_to_bitboard(index)

def bitboard_to_index(bitboard):
    return bitboard.bit_length() - 1

def bitboard_to_coords(bitboard):
    list_position = bitboard_to_index(bitboard)
    x = list_position % 10
    y = list_position // 10

    return x, y

# Converts every occupied bit in bitboard to tuple of integers in a list
def bitboard_to_coords_list(bitboard):
    list_positions = []

    for square in occupied_squares(bitboard):
        list_positions.append(bitboard_to_coords(square))

    return list_positions

# Yields all individual occupied squares in the form of a bitboard
def occupied_squares(bitboard):
    while bitboard:
        lsb_square = bitboard & -bitboard
        bitboard = bitboard ^ lsb_square

        yield lsb_square

# Returns number of occupied squares in bitboard
def pop_count(bitboard):
    count = 0
    while bitboard:
        count += 1
        # Find least significant occupied bit
        lsb_square = bitboard & -bitboard
        bitboard = bitboard ^ lsb_square

    return count

def loop_all_squares():
    for i in range(80):
        yield 1 << i
```

### B.6.3 board_helpers.py

```
import pygame
from data.helpers.data_helpers import get_user_settings
from data.utils.assets import DEFAULT_FONT

user_settings = get_user_settings()

def create_board(board_size, primary_colour, secondary_colour, font=DEFAULT_FONT):
    square_size = board_size[0] / 10
    board_surface = pygame.Surface(board_size)

    for i in range(80):
        x = i % 10
        y = i // 10

        if (x + y) % 2 == 0:
            square_colour = primary_colour
```

```python
        else:
            square_colour = secondary_colour

        square_x = x * square_size
        square_y = y * square_size

        pygame.draw.rect(board_surface, square_colour, (square_x, square_y, square_size + 1, square_size + 1)) # +1 to fill in black lines

        if y == 7:
            text_position = (square_x + square_size * 0.7, square_y + square_size * 0.55)
            text_size = square_size / 3
            font.render_to(board_surface, text_position, str(chr(x + 1 + 96)), fgcolor=(10, 10, 10, 175), size=text_size)
        if x == 0:
            text_position = (square_x + square_size * 0.1, square_y + square_size * 0.1)
            text_size = square_size / 3
            font.render_to(board_surface, text_position, str(7-y + 1), fgcolor=(10, 10, 10, 175), size=text_size)

    return board_surface

def create_square_overlay(square_size, colour):
    overlay = pygame.Surface((square_size, square_size), pygame.SRCALPHA)
    overlay.fill(colour)

    return overlay

def create_circle_overlay(square_size, colour):
    overlay = pygame.Surface((square_size, square_size), pygame.SRCALPHA)
    pygame.draw.circle(overlay, colour, (square_size / 2, square_size / 2), square_size / 4)

    return overlay

def coords_to_screen_pos(coords, board_position, square_size):
    x = board_position[0] + (coords[0] * square_size)
    y = board_position[1] + ((7 - coords[1]) * square_size)

    return (x, y)

def screen_pos_to_coords(mouse_position, board_position, board_size):
    if (board_position[0] <= mouse_position[0] <= board_position[0] + board_size[0]) and (board_position[1] <= mouse_position[1] <= board_position[1] + board_size[1]):
        x = (mouse_position[0] - board_position[0]) // (board_size[0] / 10)
        y = (board_size[1] - (mouse_position[1] - board_position[1])) // (board_size[0] / 10)
        return (int(x), int(y))

    return None
```

### B.6.4 browser_helpers.py

```python
from data.utils.enums import Miscellaneous, Colour

def get_winner_string(winner):
    if winner is None:
        return 'UNFINISHED'
    elif winner == Miscellaneous.DRAW:
```

```
        return 'DRAW'
    else:
        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

```
def height_to_font_size(font, target_height):
    test_size = 1
    while True:
        glyph_metrics = font.get_metrics('j', size=test_size)
        descender = font.get_sized_descender(test_size)
        test_height = abs(glyph_metrics[0][3] - glyph_metrics[0][2]) - descender
        if test_height > target_height:
            return test_size - 1

        test_size += 1

def width_to_font_size(font, target_width):
    test_size = 1
    while True:
        glyph_metrics = font.get_metrics(' ', size=test_size)

        if (glyph_metrics[0][4] * 8) > target_width:
            return (test_size - 1)

        test_size += 1

def text_width_to_font_size(text, font, target_width):
    test_size = 1
    if len(text) == 0:
        # print('(text_width_to_font_size) Text must have length greater than 1!')
        text = " "

    while True:
        text_rect = font.get_rect(text, size=test_size)

        if text_rect.width > target_width:
            return (test_size - 1)

        test_size += 1

def text_height_to_font_size(text, font, target_height):
    test_size = 1

    if ('(' in text) or (')' in text):
        text = text.replace('(', 'j') # Pygame freetype thinks '(' or ')' is
    taller for some reason
        text = text.replace(')', 'j')

    if len(text) == 0:
        # print('(text_height_to_font_size) Text must have length greater than
    1!')
```

```
        text = "j"

    while True:
        text_rect = font.get_rect(text, size=test_size)

        if text_rect.height > target_height:
            return (test_size - 1)

        test_size += 1

def get_font_height(font, font_size):
    glyph_metrics = font.get_metrics('j', size=font_size)
    descender = font.get_sized_descender(font_size)
    return abs(glyph_metrics[0][3] - glyph_metrics[0][2]) - descender
```

### B.6.8 input_helpers.py

```
from data.utils.enums import MoveType, Rotation

def parse_move_type(move_type):
    if move_type.isalpha() is False:
        raise ValueError('Invalid move type - move type must be a string!')
    if move_type.lower() not in MoveType:
        raise ValueError('Invalid move - type - move type must be m or r!')

    return MoveType(move_type.lower())

def parse_notation(notation):
    if (notation[0].isalpha() is False) or (notation[1].isnumeric() is False):
        raise ValueError('Invalid notation - invalid notation input types!')
    if not (97 <= ord(notation[0]) <= 106):
        raise ValueError('Invalid notation - file is out of range!')
    elif not (0 <= int(notation[1]) <= 10):
        raise ValueError('Invalid notation - rank is out of range!')

    return notation

def parse_rotation(rotation):
    if rotation == '':
        return None
    if rotation.isalpha() is False:
        raise ValueError('Invalid rotation - rotation must be a string!')
    if rotation.lower() not in Rotation:
        raise ValueError('Invalid rotation - rotation is invalid!')

    return Rotation(rotation.lower())
```

### B.6.9 load_helpers.py

```
import pygame
import pygame.freetype
from pathlib import Path
from data.helpers.asset_helpers import gif_to_frames, pil_image_to_surface

def convert_gfx_alpha(image, colorkey=(0, 0, 0)):
    # if image.get_alpha():
        return image.convert_alpha()
    # else:
    #     image = image.convert_alpha()
    #     image.set_colorkey(colorkey)

```

```
    #     return image

def load_gfx(path, colorkey=(0, 0, 0), accept=(".svg", ".png", ".jpg", ".gif")):
    file_path = Path(path)
    name, extension = file_path.stem, file_path.suffix

    if extension.lower() in accept:
        if extension.lower() == '.gif':
            frames_list = []

            for frame in gif_to_frames(path):
                image_surface = pil_image_to_surface(frame)
                frames_list.append(image_surface)

            return frames_list

        if extension.lower() == '.svg':
            low_quality_image = pygame.image.load_sized_svg(path, (200, 200))
            image = pygame.image.load(path)
            image = convert_gfx_alpha(image, colorkey)

            return [image, low_quality_image]

        else:
            image = pygame.image.load(path)
            return convert_gfx_alpha(image, colorkey)

def load_all_gfx(directory, colorkey=(0, 0, 0), accept=(".svg", ".png", ".jpg", ".
    gif")):
    graphics = {}

    for file in Path(directory).rglob('*'):
        name, extension = file.stem, file.suffix
        path = Path(directory / file)

        if extension.lower() in accept and 'old' not in name:
            if name == 'piece_spritesheet':
                data = load_spritesheet(
                    path,
                    (16, 16),
                    ['pyramid_1', 'scarab_1', 'anubis_1', 'pharaoh_1', 'sphinx_1',
      'pyramid_0', 'scarab_0', 'anubis_0', 'pharaoh_0', 'sphinx_0'],
                    ['_a', '_b', '_c', '_d'])

                graphics = graphics | data
                continue

            data = load_gfx(path, colorkey, accept)

            if isinstance(data, list):
                graphics[name] = data[0]
                graphics[f'{name}_lq'] = data[1]
            else:
                graphics[name] = data

    return graphics

def load_spritesheet(path, sprite_size, col_names, row_names):
    spritesheet = load_gfx(path)
    col_count = int(spritesheet.width / sprite_size[0])
    row_count = int(spritesheet.height / sprite_size[1])

```

```
    sprite_dict = {}

    for column in range(col_count):
        for row in range(row_count):
            surface = pygame.Surface(sprite_size, pygame.SRCALPHA)
            name = col_names[column] + row_names[row]

            surface.blit(spritesheet, (0, 0), (column * sprite_size[0], row *
    sprite_size[1], *sprite_size))
            sprite_dict[name] = surface

    return sprite_dict

def load_all_fonts(directory, accept=(".ttf", ".otf")):
    fonts = {}

    for file in Path(directory).rglob('*'):
        name, extension = file.stem, file.suffix
        path = Path(directory / file)

        if extension.lower() in accept:
            font = pygame.freetype.Font(path)
            fonts[name] = font

    return fonts

def load_all_sfx(directory, accept=(".mp3", ".wav", ".ogg")):
    sound_effects = {}

    for file in Path(directory).rglob('*'):
        name, extension = file.stem, file.suffix
        path = Path(directory / file)

        if extension.lower() in accept and 'old' not in name:
            sound_effects[name] = load_sfx(path)

    return sound_effects

def load_sfx(path, accept=(".mp3", ".wav", ".ogg")):
    file_path = Path(path)
    name, extension = file_path.stem, file_path.suffix

    if extension.lower() in accept:
        sfx = pygame.mixer.Sound(path)
        return sfx

def load_all_music(directory, accept=(".mp3", ".wav", ".ogg")):
    music_paths = {}
    for file in Path(directory).rglob('*'):
        name, extension = file.stem, file.suffix
        path = Path(directory / file)

        if extension.lower() in accept:
            music_paths[name] = path

    return music_paths
```

### B.6.10 widget_helpers.py

See Section 3.3.3.

# B.7 data\managers

## B.7.1 animation.py

```
import pygame
from data.helpers.asset_helpers import scale_and_cache

FPS = 60

class AnimationManager:
    def __init__(self):
        self._current_ms = 0
        self._timers = []

    def set_delta_time(self):
        self._current_ms = pygame.time.get_ticks()

        for timer in self._timers:
            start_ms, target_ms, callback = timer
            if self._current_ms - start_ms >= target_ms:
                callback()
                self._timers.remove(timer)

    def calculate_frame_index(self, start_index, end_index, fps):
        ms_per_frame = int(1000 / fps)
        return start_index + ((self._current_ms // ms_per_frame) % (end_index - start_index))

    def draw_animation(self, screen, animation, position, size, fps=8):
        frame_index = self.calculate_frame_index(0, len(animation), fps)
        scaled_animation = scale_and_cache(animation[frame_index], size)
        screen.blit(scaled_animation, position)

    def draw_image(self, screen, image, position, size):
        scaled_background = scale_and_cache(image, size)
        screen.blit(scaled_background, position)

    def set_timer(self, target_ms, callback):
        self._timers.append((self._current_ms, target_ms, callback))

animation = AnimationManager()
```

## B.7.2 audio.py

```
import pygame
from data.helpers.data_helpers import get_user_settings
from data.managers.logs import initialise_logger

logger = initialise_logger(__name__)
user_settings = get_user_settings()

class AudioManager:
    def __init__(self, num_channels=16):
        pygame.mixer.set_num_channels(num_channels)

        self._music_volume = user_settings['musicVolume']
        self._sfx_volume = user_settings['sfxVolume']

        self._current_song = None
        self._current_channels = []

```

```
    def set_sfx_volume(self, volume):
        self._sfx_volume = volume

        for channel in self._current_channels:
            channel.set_volume(self._sfx_volume)

    def set_music_volume(self, volume):
        self._music_volume = volume

        pygame.mixer.music.set_volume(self._music_volume)

    def pause_sfx(self):
        pygame.mixer.pause()

    def unpause_sfx(self):
        pygame.mixer.unpause()

    def stop_sfx(self, fadeout=0):
        pygame.mixer.fadeout(fadeout)

    def remove_unused_channels(self):
        unused_channels = []
        for channel in self._current_channels:
            if channel.get_busy() is False:
                unused_channels.append(channel)

        return unused_channels

    def play_sfx(self, sfx, loop=False):
        unused_channels = self.remove_unused_channels()

        if len(unused_channels) == 0:
            channel = pygame.mixer.find_channel()
        else:
            channel = unused_channels.pop(0)

        if channel is None:
            logger.warning('No available channel for SFX')
            return

        self._current_channels.append(channel)
        channel.set_volume(self._sfx_volume)

        if loop:
            channel.play(sfx, loops=-1)
        else:
            channel.play(sfx)

    def play_music(self, music_path):
        if 'menu' in str(music_path) and 'menu' in str(self._current_song):
            return

        if music_path == self._current_song:
            return

        pygame.mixer.music.stop()
        pygame.mixer.music.unload()
        pygame.mixer.music.load(music_path)
        pygame.mixer.music.set_volume(self._music_volume)
        pygame.mixer.music.play(loops=-1)

        self._current_song = music_path
```

```python

audio = AudioManager()
```

### B.7.3 cursor.py

```python
import pygame
from data.utils.enums import CursorMode
from data.utils.assets import GRAPHICS

# Manager to change mouse cursor iconss
class CursorManager:
    def __init__(self):
        self._mode = CursorMode.ARROW
        self.set_mode(CursorMode.ARROW)

    def set_mode(self, mode):
        pygame.mouse.set_visible(True)

        match mode:
            case CursorMode.ARROW:
                pygame.mouse.set_cursor((7, 5), pygame.transform.scale(GRAPHICS['
    arrow'], (32, 32)))
            case CursorMode.IBEAM:
                pygame.mouse.set_cursor((15, 5), pygame.transform.scale(GRAPHICS['
    ibeam'], (32, 32)))
            case CursorMode.OPENHAND:
                pygame.mouse.set_cursor((17, 5), pygame.transform.scale(GRAPHICS['
    hand_open'], (32, 32)))
            case CursorMode.CLOSEDHAND:
                pygame.mouse.set_cursor((17, 5), pygame.transform.scale(GRAPHICS['
    hand_closed'], (32, 32)))
            case CursorMode.NO:
                pygame.mouse.set_visible(False)

        self._mode = mode

    def get_mode(self):
        return self._mode

cursor = CursorManager()
```

### B.7.4 logs.py

```python
import logging.config
from data.helpers.data_helpers import load_json
from pathlib import Path
import logging

config_path = (Path(__file__).parent / '../app_data/logs_config.json').resolve()
config = load_json(config_path)
logging.config.dictConfig(config)

def initialise_logger(file_path):
    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

```python
import pygame
import moderngl
from data.utils.constants import ShaderType, SCREEN_SIZE, SHADER_MAP
from data.helpers.data_helpers import get_user_settings
from data.helpers.asset_helpers import draw_background
from data.managers.shader import ShaderManager

user_settings = get_user_settings()
is_opengl = user_settings['opengl']
is_fullscreen = user_settings['displayMode'] == 'fullscreen'

class WindowManager(pygame.Window):
    def __init__(self, **kwargs):
        super().__init__(**kwargs)
        self._native_screen = self.get_surface() # Initialise convert format
        self.screen = pygame.Surface(self.size, pygame.SRCALPHA)

        if is_opengl:
            self._ctx = moderngl.create_context()
            self._shader_manager = ShaderManager(self._ctx, screen_size=self.size)

            # Each ShaderType contains a dictionary of kwargs, used as arguments when running the apply method on the corresponding shader class
            self.shader_arguments = {
                ShaderType.BASE: {},
                ShaderType.SHAKE: {},
                ShaderType.BLOOM: {},
                ShaderType.GRAYSCALE: {},
                ShaderType.CRT: {},
                ShaderType.RAYS: {}
            }

            # For the secret settings option in the settings menu, apply shaders for the selected option
            if (selected_shader := get_user_settings()['shader']) is not None:
                for shader_type in SHADER_MAP[selected_shader]:
                    self.set_effect(shader_type)
        else:
            # If shaders disabled, use temporary image as background
            from data.utils.assets import GRAPHICS
            self._background_image = GRAPHICS['temp_background']

    def set_effect(self, effect, **kwargs):
        if is_opengl:
            self._shader_manager.apply_shader(effect, **kwargs)

    def set_apply_arguments(self, effect, **kwargs):
        if is_opengl:
            self.shader_arguments[effect] = kwargs

    def clear_apply_arguments(self, effect):
        if is_opengl:
            self.shader_arguments[effect] = {}

    def clear_effect(self, effect):
```

```
        if is_opengl:
            self._shader_manager.remove_shader(effect)
            self.clear_apply_arguments(effect)

    def clear_all_effects(self, clear_arguments=False):
        if is_opengl:
            self._shader_manager.clear_shaders()

            if clear_arguments:
                for shader_type in self.shader_arguments:
                    self.shader_arguments[shader_type] = {}

    def draw(self):
        if is_opengl:
            self._shader_manager.draw(self.screen, self.shader_arguments)
        else:
            self._native_screen.blit(self.screen, (0, 0))

        self.flip()

        if is_opengl:
            self.screen.fill((0, 0, 0, 0))
        else:
            self.screen.fill((0, 0, 0))
            draw_background(self.screen, self._background_image)

    def update(self):
        self.draw()

    def handle_resize(self):
        self.screen = pygame.Surface(self.size, pygame.SRCALPHA)
        if is_opengl:
            self._shader_manager.handle_resize(self.size)
        else:
            draw_background(self.screen, self._background_image)

window = WindowManager(size=SCREEN_SIZE, resizable=True, opengl=is_opengl,
    fullscreen_desktop=is_fullscreen)
```

## B.8 data\shaders

### B.8.1 protocol.py

```
import pygame
import moderngl
from typing import Protocol, Optional
from data.utils.constants import ShaderType

class SMProtocol(Protocol):
    def load_shader(self, shader_type: ShaderType, **kwargs) -> None: ...
    def clear_shaders(self) -> None: ...
    def create_vao(self, shader_type: ShaderType) -> None: ...
    def create_framebuffer(self, shader_type: ShaderType, size: Optional[tuple[int
    ]]=None, filter: Optional[int]=moderngl.NEAREST) -> None: ...
    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: ...
    def apply_shader(self, shader_type: ShaderType, **kwargs) -> None: ...
    def remove_shader(self, shader_type: ShaderType) -> None: ...
    def render_output(self, texture: moderngl.Texture) -> None: ...
    def get_fbo_texture(self, shader_type: ShaderType) -> moderngl.Texture: ...
```

```
    def calibrate_pygame_surface(self, pygame_surface: pygame.Surface) -> moderngl
    .Texture: ...
    def draw(self, surface: pygame.Surface, arguments: dict) -> None: ...
    def __del__(self) -> None: ...
    def cleanup(self) -> None: ...
    def handle_resize(self, new_screen_size: tuple[int]) -> None: ...

    _ctx: moderngl.Context
    _screen_size: tuple[int]
    _opengl_buffer: moderngl.Buffer
    _pygame_buffer: moderngl.Buffer
    _shader_stack: list[ShaderType]

    _vert_shaders: dict
    _frag_shaders: dict
    _programs: dict
    _vaos: dict
    _textures: dict
    _shader_passes: dict
    framebuffers: dict
```

## B.9 data\shaders\classes

### B.9.1 base.py

```
import pygame
from data.shaders.protocol import SMProtocol
from data.utils.constants import ShaderType

class Base:
    def __init__(self, shader_manager: SMProtocol):
        self._shader_manager = shader_manager

        self._shader_manager.create_framebuffer(ShaderType.BASE)
        self._shader_manager.create_vao(ShaderType.BACKGROUND_WAVES)
        self._shader_manager.create_vao(ShaderType.BACKGROUND_BALATRO)
        self._shader_manager.create_vao(ShaderType.BACKGROUND_LASERS)
        self._shader_manager.create_vao(ShaderType.BACKGROUND_GRADIENT)
        self._shader_manager.create_vao(ShaderType.BACKGROUND_NONE)

    def apply(self, texture, background_type=None):
        base_texture = self._shader_manager.get_fbo_texture(ShaderType.BASE)

        # Draws background to ShaderType.BASE framebuffer
        match background_type:
            case ShaderType.BACKGROUND_WAVES:
                self._shader_manager.render_to_fbo(
                    ShaderType.BASE,
                    texture=base_texture,
                    program_type=ShaderType.BACKGROUND_WAVES,
                    use_image=False,
                    time=pygame.time.get_ticks() / 1000
                )
            case ShaderType.BACKGROUND_BALATRO:
                self._shader_manager.render_to_fbo(
                    ShaderType.BASE,
                    texture=base_texture,
                    program_type=ShaderType.BACKGROUND_BALATRO,
                    use_image=False,
                    time=pygame.time.get_ticks() / 1000,
                    screenSize=base_texture.size
```

```
                )
            case ShaderType.BACKGROUND_LASERS:
                self._shader_manager.render_to_fbo(
                    ShaderType.BASE,
                    texture=base_texture,
                    program_type=ShaderType.BACKGROUND_LASERS,
                    use_image=False,
                    time=pygame.time.get_ticks() / 1000,
                   screenSize=base_texture.size
                )
            case ShaderType.BACKGROUND_GRADIENT:
                self._shader_manager.render_to_fbo(
                    ShaderType.BASE,
                    texture=base_texture,
                    program_type=ShaderType.BACKGROUND_GRADIENT,
                    use_image=False,
                    time=pygame.time.get_ticks() / 1000,
                   screenSize=base_texture.size
                )
            case None:
                self._shader_manager.render_to_fbo(
                    ShaderType.BASE,
                    texture=base_texture,
                    program_type=ShaderType.BACKGROUND_NONE,
                    use_image=False,
                )
            case _:
                raise ValueError('(shader.py) Unknown background type:',
    background_type)

        # Draws background using texture in ShaderType.BASE framebuffer, on pixels
     in the Pygame texture that have no alpha
        self._shader_manager.get_fbo_texture(ShaderType.BASE).use(1)
        self._shader_manager.render_to_fbo(ShaderType.BASE, texture, background=1)
```

### B.9.2 blend.py

```
import moderngl
from data.shaders.protocol import SMProtocol
from data.utils.constants import ShaderType

class _Blend:
    def __init__(self, shader_manager: SMProtocol):
        self._shader_manager = shader_manager

        self._shader_manager.create_framebuffer(ShaderType._BLEND)

    # Blend two textures, while positioning textures relative to each other if not
     the same size
    def apply(self, texture, texture_2, texture_2_pos):
        self._shader_manager._ctx.blend_func = (moderngl.SRC_ALPHA, moderngl.ONE)

        relative_size = (texture_2.size[0] / texture.size[0], texture_2.size[1] /
    texture.size[1])
        # Convert position of smaller texture within big texture into OpenGL
    coordinates
        opengl_pos = (texture_2_pos[0], 1 - texture_2_pos[1] - relative_size[1])

        texture_2.use(1)
        self._shader_manager.render_to_fbo(ShaderType._BLEND, texture, image2=1,
    image2Pos=opengl_pos, relativeSize=relative_size)
        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

```python
import pygame
from data.utils.constants import ShaderType
from data.shaders.protocol import SMProtocol

CHROMATIC_ABBREVIATION_INTENSITY = 2.0

class ChromaticAbbreviation:
    def __init__(self, shader_manager: SMProtocol):
        self._shader_manager = shader_manager

        self._shader_manager.create_framebuffer(ShaderType.CHROMATIC_ABBREVIATION)

    def apply(self, texture):
        mouse_pos = (pygame.mouse.get_pos()[0] / texture.size[0], pygame.mouse.
    get_pos()[1] / texture.size[1])
        self._shader_manager.render_to_fbo(ShaderType.CHROMATIC_ABBREVIATION,
    texture, mouseFocusPoint=mouse_pos, enabled=pygame.mouse.get_pressed()[0],
    intensity=CHROMATIC_ABBREVIATION_INTENSITY)
```

### B.9.6 crop.py

```python
from data.utils.constants import ShaderType
from data.shaders.protocol import SMProtocol

class _Crop:
    def __init__(self, shader_manager: SMProtocol):
        self._shader_manager = shader_manager

    def apply(self, texture, relative_pos, relative_size):
        opengl_pos = (relative_pos[0], 1 - relative_pos[1] - relative_size[1])
        pixel_size = (int(relative_size[0] * texture.size[0]), int(relative_size
    [1] * texture.size[1]))

        self._shader_manager.create_framebuffer(ShaderType._CROP, size=pixel_size)

        self._shader_manager.render_to_fbo(ShaderType._CROP, texture, relativePos=
    opengl_pos, relativeSize=relative_size)
```

### B.9.7 crt.py

```python
from data.utils.constants import ShaderType
from data.shaders.protocol import SMProtocol

class CRT:
    def __init__(self, shader_manager: SMProtocol):
        self._shader_manager = shader_manager

        shader_manager.create_framebuffer(ShaderType.CRT)

```

```
    def apply(self, texture):
        self._shader_manager.render_to_fbo(ShaderType.CRT, texture)
```

### B.9.8 grayscale.py

```
from data.utils.constants import ShaderType
from data.shaders.protocol import SMProtocol

class Grayscale:
    def __init__(self, shader_manager: SMProtocol):
        self._shader_manager = shader_manager

        shader_manager.create_framebuffer(ShaderType.GRAYSCALE)

    def apply(self, texture):
        self._shader_manager.render_to_fbo(ShaderType.GRAYSCALE, texture)
```

### B.9.9 highlight_brightness.py

```
from data.utils.constants import ShaderType
from data.shaders.protocol import SMProtocol

HIGHLIGHT_THRESHOLD = 0.9

class _HighlightBrightness:
    def __init__(self, shader_manager: SMProtocol):
        self._shader_manager = shader_manager

        shader_manager.create_framebuffer(ShaderType._HIGHLIGHT_BRIGHTNESS)

    def apply(self, texture, intensity):
        self._shader_manager.render_to_fbo(ShaderType._HIGHLIGHT_BRIGHTNESS,
    texture, threshold=HIGHLIGHT_THRESHOLD, intensity=intensity)
```

### B.9.10 highlight_colour.py

```
from data.utils.constants import ShaderType
from data.shaders.protocol import SMProtocol

class _HighlightColour:
    def __init__(self, shader_manager: SMProtocol):
        self._shader_manager = shader_manager

        shader_manager.create_framebuffer(ShaderType._HIGHLIGHT_COLOUR)

    def apply(self, texture, old_highlight, colour, intensity):
        old_highlight.use(1)
        self._shader_manager.render_to_fbo(ShaderType._HIGHLIGHT_COLOUR, texture,
    highlight=1, colour=colour, threshold=0.1, intensity=intensity)
```

### B.9.11 lightmap.py

```
from data.utils.constants import ShaderType
from data.shaders.protocol import SMProtocol
from data.shaders.classes.shadowmap import _Shadowmap

LIGHT_RESOLUTION = 256

class _Lightmap:
    def __init__(self, shader_manager: SMProtocol):
```

```
        self._shader_manager = shader_manager

        shader_manager.load_shader(ShaderType._SHADOWMAP)

    def apply(self, texture, colour, softShadow, occlusion=None, falloff=0.0, clamp=(-180, 180)):
        self._shader_manager.create_framebuffer(ShaderType._LIGHTMAP, size=texture.size)
        self._shader_manager._ctx.enable(self._shader_manager._ctx.BLEND)

        _Shadowmap(self._shader_manager).apply(texture, occlusion)
        shadow_map = self._shader_manager.get_fbo_texture(ShaderType._SHADOWMAP)

        self._shader_manager.render_to_fbo(ShaderType._LIGHTMAP, shadow_map, resolution=LIGHT_RESOLUTION, lightColour=colour, falloff=falloff, angleClamp=clamp, softShadow=softShadow)

        self._shader_manager._ctx.disable(self._shader_manager._ctx.BLEND)
```

### B.9.12 occlusion.py

```
from data.utils.constants import ShaderType
from data.shaders.protocol import SMProtocol

class _Occlusion:
    def __init__(self, shader_manager: SMProtocol):
        self._shader_manager = shader_manager

    def apply(self, texture, occlusion_colour=(255, 0, 0)):
        self._shader_manager.create_framebuffer(ShaderType._OCCLUSION, size=texture.size)
        self._shader_manager.render_to_fbo(ShaderType._OCCLUSION, texture, checkColour=tuple(num / 255 for num in occlusion_colour))
```

### B.9.13 rays.py

See Section 3.9.3.

### B.9.14 shadowmap.py

```
import moderngl
from data.utils.constants import ShaderType
from data.shaders.protocol import SMProtocol
from data.shaders.classes.occlusion import _Occlusion

LIGHT_RESOLUTION = 256

class _Shadowmap:
    def __init__(self, shader_manager: SMProtocol):
        self._shader_manager = shader_manager

        shader_manager.load_shader(ShaderType._OCCLUSION)

    def apply(self, texture, occlusion_texture=None):
        self._shader_manager.create_framebuffer(ShaderType._SHADOWMAP, size=(texture.size[0], 1), filter=moderngl.LINEAR)

        if occlusion_texture is None:
            _Occlusion(self._shader_manager).apply(texture)
            occlusion_texture = self._shader_manager.get_fbo_texture(ShaderType._OCCLUSION)
```

```python

        self._shader_manager.render_to_fbo(ShaderType._SHADOWMAP, occlusion_texture, resolution=LIGHT_RESOLUTION)
```

### B.9.15 shake.py

```python
from data.utils.constants import ShaderType
from data.shaders.protocol import SMProtocol
from random import randint

SHAKE_INTENSITY = 3

class Shake:
    def __init__(self, shader_manager: SMProtocol):
        self._shader_manager = shader_manager

        self._shader_manager.create_framebuffer(ShaderType.SHAKE)

    def apply(self, texture, intensity=SHAKE_INTENSITY):
        displacement = (randint(-intensity, intensity) / 1000, randint(-intensity, intensity) / 1000)
        self._shader_manager.render_to_fbo(ShaderType.SHAKE, texture, displacement=displacement)
```

### B.9.16 __init__.py

```python
from data.shaders.classes.chromatic_abbreviation import ChromaticAbbreviation
from data.shaders.classes.highlight_brightness import _HighlightBrightness
from data.shaders.classes.highlight_colour import _HighlightColour
from data.shaders.classes.shadowmap import _Shadowmap
from data.shaders.classes.occlusion import _Occlusion
from data.shaders.classes.grayscale import Grayscale
from data.shaders.classes.lightmap import _Lightmap
from data.shaders.classes.blend import _Blend
from data.shaders.classes.shake import Shake
from data.shaders.classes.bloom import Bloom
from data.shaders.classes.blur import _Blur
from data.shaders.classes.crop import _Crop
from data.shaders.classes.rays import Rays
from data.shaders.classes.base import Base
from data.shaders.classes.crt import CRT

from data.utils.constants import ShaderType

shader_pass_lookup = {
    ShaderType.CHROMATIC_ABBREVIATION: ChromaticAbbreviation,
    ShaderType.GRAYSCALE: Grayscale,
    ShaderType.SHAKE: Shake,
    ShaderType.BLOOM: Bloom,
    ShaderType.BASE: Base,
    ShaderType.RAYS: Rays,
    ShaderType.CRT: CRT,

    ShaderType._HIGHLIGHT_BRIGHTNESS: _HighlightBrightness,
    ShaderType._HIGHLIGHT_COLOUR: _HighlightColour,
    ShaderType._CALIBRATE: lambda *args: None,
    ShaderType._OCCLUSION: _Occlusion,
    ShaderType._SHADOWMAP: _Shadowmap,
    ShaderType._LIGHTMAP: _Lightmap,
    ShaderType._BLEND: _Blend,
    ShaderType._BLUR: _Blur,
```

```
    ShaderType._CROP: _Crop,
}
```

## B.10 data\shaders\fragments

### B.10.1 background_balatro.frag

```
// Original by localthunk (https://www.playbalatro.com)
// Modified from https://godotshaders.com/shader/balatro-background-shader/

# version 330 core

// Configuration (modify these values to change the effect)
#define SPIN_ROTATION -2.0
#define SPIN_SPEED 7.0
#define OFFSET vec2(0.0)
#define COLOUR_2 vec4(0.871, 0.267, 0.231, 1.0)
#define COLOUR_1 vec4(0.0, 0.42, 0.706, 1.0)
#define COLOUR_3 vec4(0.086, 0.137, 0.145, 1.0)
#define CONTRAST 3.5
#define LIGTHING 0.4
#define SPIN_AMOUNT 0.25
#define PIXEL_FILTER 745.0
#define SPIN_EASE 1.0
#define PI 3.14159265359
#define IS_ROTATE false

uniform float time;
uniform vec2 screenSize;

in vec2 uvs;
out vec4 f_colour;

vec4 effect(vec2 screenSize, vec2 screen_coords) {
    float pixel_size = length(screenSize.xy) / PIXEL_FILTER;
    vec2 uv = (floor(screen_coords.xy*(1./pixel_size))*pixel_size - 0.5*screenSize.xy)/length(screenSize.xy) - OFFSET;
    float uv_len = length(uv);

    float speed = (SPIN_ROTATION*SPIN_EASE*0.2);
    if(IS_ROTATE){
       speed = time * speed;
    }
    speed += 302.2;
    float new_pixel_angle = atan(uv.y, uv.x) + speed - SPIN_EASE*20.*(1.*SPIN_AMOUNT*uv_len + (1. - 1.*SPIN_AMOUNT));
    vec2 mid = (screenSize.xy/length(screenSize.xy))/2.;
    uv = (vec2((uv_len * cos(new_pixel_angle) + mid.x), (uv_len * sin(new_pixel_angle) + mid.y)) - mid);

    uv *= 30.;
    speed = time*(SPIN_SPEED);
    vec2 uv2 = vec2(uv.x+uv.y);

    for(int i=0; i < 5; i++) {
        uv2 += sin(max(uv.x, uv.y)) + uv;
        uv  += 0.5*vec2(cos(5.1123314 + 0.353*uv2.y + speed*0.131121),sin(uv2.x - 0.113*speed));
        uv  -= 1.0*cos(uv.x + uv.y) - 1.0*sin(uv.x*0.711 - uv.y);
    }

```

```
    float contrast_mod = (0.25*CONTRAST + 0.5*SPIN_AMOUNT + 1.2);
    float paint_res = min(2., max(0.,length(uv)*(0.035)*contrast_mod));
    float c1p = max(0.,1. - contrast_mod*abs(1.-paint_res));
    float c2p = max(0.,1. - contrast_mod*abs(paint_res));
    float c3p = 1. - min(1., c1p + c2p);
    float light = (LIGTHING - 0.2)*max(c1p*5. - 4., 0.) + LIGTHING*max(c2p*5. - 4., 0.);
    return (0.3/CONTRAST)*COLOUR_1 + (1. - 0.3/CONTRAST)*(COLOUR_1*c1p + COLOUR_2*c2p + vec4(c3p*COLOUR_3.rgb, c3p*COLOUR_1.a)) + light;
}

void main() {
    f_colour = effect(screenSize.xy, uvs* screenSize.xy);
}
```

### B.10.2 background_gradient.frag

```
// Modified from https://www.shadertoy.com/view/wdyczG

#version 330 core

uniform float time;
uniform vec2 screenSize;

in vec2 uvs;
out vec4 f_colour;

#define S(a,b,t) smoothstep(a,b,t)

mat2 Rot(float a)
{
    float s = sin(a);
    float c = cos(a);
    return mat2(c, -s, s, c);
}

// Created by inigo quilez - iq/2014
// License Creative Commons Attribution-NonCommercial-ShareAlike 3.0 Unported License.
vec2 hash( vec2 p )
{
    p = vec2( dot(p,vec2(2127.1,81.17)), dot(p,vec2(1269.5,283.37)) );
  return fract(sin(p)*43758.5453);
}

float noise( in vec2 p )
{
    vec2 i = floor( p );
    vec2 f = fract( p );

  vec2 u = f*f*(3.0-2.0*f);

    float n = mix( mix( dot( -1.0+2.0*hash( i + vec2(0.0,0.0) ), f - vec2(0.0,0.0) ),
                        dot( -1.0+2.0*hash( i + vec2(1.0,0.0) ), f - vec2(1.0,0.0) ), u.x),
                   mix( dot( -1.0+2.0*hash( i + vec2(0.0,1.0) ), f - vec2(0.0,1.0) ),
                        dot( -1.0+2.0*hash( i + vec2(1.0,1.0) ), f - vec2(1.0,1.0) ), u.x), u.y);
  return 0.5 + 0.5*n;
}
```

```

void main() {
    float ratio = screenSize.x / screenSize.y;

    vec2 tuv = uvs;
    tuv -= .5;

    // rotate with Noise
    float degree = noise(vec2(time*.1, tuv.x*tuv.y));

    tuv.y *= 1./ratio;
    tuv *= Rot(radians((degree-.5)*720.+180.));
  tuv.y *= ratio;

    // Wave warp with sin
    float frequency = 5.;
    float amplitude = 30.;
    float speed = time * 2.;
    tuv.x += sin(tuv.y*frequency+speed)/amplitude;
    tuv.y += sin(tuv.x*frequency*1.5+speed)/(amplitude*.5);

    // draw the image
    vec3 colorYellow = vec3(.957, .804, .623);
    vec3 colorDeepBlue = vec3(.192, .384, .933);
    vec3 layer1 = mix(colorYellow, colorDeepBlue, S(-.3, .2, (tuv*Rot(radians(-5.)
    )).x));

    vec3 colorRed = vec3(.910, .510, .8);
    vec3 colorBlue = vec3(0.350, .71, .953);
    vec3 layer2 = mix(colorRed, colorBlue, S(-.3, .2, (tuv*Rot(radians(-5.))).x));

    vec3 finalComp = mix(layer1, layer2, S(.5, -.3, tuv.y));

    vec3 col = finalComp;

    f_colour = vec4(col,1.0);
}
```

### B.10.3 background_lasers.frag

```
// Modified from https://www.shadertoy.com/view/7tBSR1
// rand [0,1] https://www.shadertoy.com/view/4djSRW

#version 330 core

uniform float time;
uniform vec2 screenSize;

in vec2 uvs;
out vec4 f_colour;

float rand(vec2 p) {
    p *= 500.0;
  vec3 p3  = fract(vec3(p.xyx) * .1031);
    p3 += dot(p3, p3.yzx + 33.33);
    return fract((p3.x + p3.y) * p3.z);
}

// value noise
float noise(vec2 p) {
  vec2 f = smoothstep(0.0, 1.0, fract(p));
  vec2 i = floor(p);
```

```
  float a = rand(i);
  float b = rand(i+vec2(1.0,0.0));
  float c = rand(i+vec2(0.0,1.0));
  float d = rand(i+vec2(1.0,1.0));
  return mix(mix(a, b, f.x), mix(c, d, f.x), f.y);
}

// fractal noise
float fbm(vec2 p) {
    float a = 0.5;
    float r = 0.0;
    for (int i = 0; i < 8; i++) {
        r += a*noise(p);
        a *= 0.5;
        p *= 2.0;
    }
    return r;
}

// lasers originating from a central point
float laser(vec2 p, int num) {
  float r = atan(p.x, p.y);
  float sn = sin(r*float(num)+time);
    float lzr = 0.5+0.5*sn;
    lzr = lzr*lzr*lzr*lzr*lzr;
    float glow = pow(clamp(sn, 0.0, 1.0),100.0);
  return lzr+glow;
}

// mix of fractal noises to simulate fog
float clouds(vec2 uv) {
    vec2 t = vec2(0,time);
  float c1 = fbm(fbm(uv*3.0)*0.75+uv*3.0+t/3.0);
  float c2 = fbm(fbm(uv*2.0)*0.5+uv*7.0+t/3.0);
  float c3 = fbm(fbm(uv*10.0-t)*0.75+uv*5.0+t/6.0);
    float r = mix(c1, c2, c3*c3);
  return r*r;
}

void main() {
    vec2 hs = screenSize.xy/screenSize.y*0.5;
    vec2 uvc = uvs-hs;
  float l = (1.0 + 3.0*noise(vec2(15.0-time)))
        * laser(vec2(uvs.x+0.5, uvs.y*(0.5 + 10.0*noise(vec2(time/5.0))) + 0.1),
    15);
  l += fbm(vec2(2.0*time))
        * laser(vec2(hs.x-uvc.x-0.2, uvs.y+0.1), 25);
  l += noise(vec2(time-73.0))
        * laser(vec2(uvc.x, 1.0-uvs.y+0.5), 30);
    float c = clouds(uvs);
    vec4 col = vec4(uvs.x, 0.0, 1-uvs.x, 1.0)*(uvs.y*l+uvs.y*uvs.y)*c;

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

### B.10.4 background_none.frag

```
# version 330 core

in vec2 uvs;
out vec4 f_colour;

```

```
void main() {
    f_colour = vec4(vec3(0.0 + uvs.x * 0.001), 1.0);
}
```

### B.10.5 background_waves.frag

```
// Modified from https://godotshaders.com/shader/discrete-ocean/

# version 330 core

uniform float wave_amp=1.0;
uniform float wave_size=4.0;
uniform float wave_time_mul=0.2;

uniform int total_phases=20;

uniform vec4 bottom_color=vec4(0.608, 0.133, 0.167, 1.0);
uniform vec4 top_color=vec4(0.110, 0.149, 0.220, 1.0);

// uniform vec4 bottom_color=vec4(0.38, 0.04, 0.71, 1.0);
// uniform vec4 top_color=vec4(0.15, 0.02, 0.49, 1.0);

uniform float time;

in vec2 uvs;
out vec4 f_colour;

#define PI 3.14159

float rand (float n) {
    return fract(sin(n) * 43758.5453123);
}
float noise (float p){
  float fl = floor(p);
    float fc = fract(p);
  return mix(rand(fl), rand(fl + 1.0), fc);
}
float fmod(float x, float y) {
  return x - floor(x / y) * y;
}
vec4 lerp(vec4 a, vec4 b, float w) {
  return a + w * (b - a);
}

void main() {
  float t = float(total_phases);
  float effective_wave_amp = min(wave_amp, 0.5 / t);
  float d = fmod(uvs.y, 1.0 / t);
  float i = floor(uvs.y * t);
  float vi = floor(uvs.y * t + t * effective_wave_amp);
  float s = effective_wave_amp * sin((uvs.x + time * max(1.0 / t, noise(vi)) *
    wave_time_mul * vi / t) * 2.0 * PI * wave_size);

  if (d < s) i--;
  if (d > s + 1.0 / t) i++;
  i = clamp(i, 0.0, t - 1.0);

  f_colour = lerp(top_color, bottom_color, i / (t - 1.0));
}
```

### B.10.6 base.frag

```
#version 330 core

uniform sampler2D image;
uniform sampler2D background;

in vec2 uvs;
out vec4 f_colour;

void main() {
    vec4 colour = texture(image, uvs);

  if (colour.a == 1.0) {
    f_colour = colour;
  } else {
    f_colour = texture(background, uvs);
  }
}
```

### B.10.7 blend.frag

```
#version 330 core

uniform sampler2D image;
uniform sampler2D image2;
uniform vec2 relativeSize;
uniform vec2 image2Pos;

in vec2 uvs;
out vec4 f_colour;

void main() {
    vec3 colour = texture(image, uvs).rgb;

    vec2 image2Coords = vec2((uvs.x - image2Pos.x) / relativeSize.x, (uvs.y -
    image2Pos.y) / relativeSize.y);

    float withinBounds = step(image2Pos.x, uvs.x) * step(uvs.x, (image2Pos.x +
    relativeSize.x)) * step(image2Pos.y, uvs.y) * step(uvs.y, (image2Pos.y +
    relativeSize.y));

    f_colour = vec4(colour + (texture(image2, image2Coords).rgb * withinBounds),
    1.0);
}
```

### B.10.8 bloom.frag

```
#version 330 core

in vec2 uvs;
out vec4 f_colour;

uniform sampler2D image;
uniform sampler2D blurredImage;
uniform float intensity;

void main() {
    vec3 baseColour = texture(image, uvs).rgb;
    vec3 bloomColor = texture(blurredImage, uvs).rgb;

    baseColour += bloomColor * intensity;
    f_colour = vec4(baseColour, 1.0);
}
```

### B.10.9 bloom_old.frag

```
#version 330 core

in vec2 uvs;
out vec4 f_colour;

uniform sampler2D image;
uniform float bloom_spread = 0.1;
uniform float bloom_intensity = 0.5;

void main() {
  ivec2 size = textureSize(image, 0);

    float uv_x = uvs.x * size.x;
    float uv_y = uvs.y * size.y;

    vec4 sum = vec4(0.0);

    for (int n = 0; n < 9; ++n) {
        uv_y = (uvs.y * size.y) + (bloom_spread * float(n - 4));
        vec4 h_sum = vec4(0.0);
        h_sum += texelFetch(image, ivec2(uv_x - (4.0 * bloom_spread), uv_y), 0);
        h_sum += texelFetch(image, ivec2(uv_x - (3.0 * bloom_spread), uv_y), 0);
        h_sum += texelFetch(image, ivec2(uv_x - (2.0 * bloom_spread), uv_y), 0);
        h_sum += texelFetch(image, ivec2(uv_x - bloom_spread, uv_y), 0);
        h_sum += texelFetch(image, ivec2(uv_x, uv_y), 0);
        h_sum += texelFetch(image, ivec2(uv_x + bloom_spread, uv_y), 0);
        h_sum += texelFetch(image, ivec2(uv_x + (2.0 * bloom_spread), uv_y), 0);
        h_sum += texelFetch(image, ivec2(uv_x + (3.0 * bloom_spread), uv_y), 0);
        h_sum += texelFetch(image, ivec2(uv_x + (4.0 * bloom_spread), uv_y), 0);
        sum += h_sum / 9.0;
    }

    f_colour = texture(image, uvs) + ((sum / 9.0) * bloom_intensity);
}
```

### B.10.10 blur.frag

See Section 3.9.2.

### B.10.11 box_blur.frag

```
# version 330 core

uniform sampler2D image;

uniform int size=1;
uniform int separation=1;

in vec2 uvs;
out vec4 f_colour;

vec2 textureSize = textureSize(image, 0);

void main() {
    if (size <= 0) {
        return;
    }

```

```
    float count = 0.0;

    for (int i = -size ; i <= size ; ++i) {
        for (int j = -size ; j <= size ; ++j) {
            f_colour += texture(image, uvs + (vec2(i, j) * separation) /
    textureSize).rgba;

            count += 1.0;
        }
    }

    f_colour.rgb /= count;
}
```

### B.10.12 calibrate.frag

```
#version 330 core

uniform sampler2D image;

in vec2 uvs;
out vec4 f_colour;

void main() {
    f_colour = vec4(texture(image, uvs).rgba);
}
```

### B.10.13 chromatic_abbreviation.frag

```
#version 330 core

in vec2 uvs;
out vec4 f_colour;

uniform sampler2D image;

uniform bool enabled;
uniform vec2 mouseFocusPoint;
uniform float intensity;

void main() {
  if (!enabled) {
    f_colour = texture(image, uvs);
    return;
  }

  float redOffset = 0.009 * intensity;
  float greenOffset = 0.006 * intensity;
  float blueOffset = -0.006 * intensity;

  vec2 texSize = textureSize(image, 0).xy;
  vec2 direction = uvs - mouseFocusPoint;

  f_colour = texture(image, uvs);

  f_colour.r = texture(image, uvs + (direction * vec2(redOffset))).r;
  f_colour.g = texture(image, uvs + (direction * vec2(greenOffset))).g;
  f_colour.b = texture(image, uvs + (direction * vec2(blueOffset))).b;
}
```

### B.10.14 crop.frag

```
#version 330 core

uniform sampler2D image;
uniform vec2 relativeSize;
uniform vec2 relativePos;

in vec2 uvs;
out vec4 f_colour;

void main() {
    vec2 sampleCoords = relativeSize.xy * uvs.xy + relativePos.xy;

    float withinBounds = step(0.0, sampleCoords.x) * step(sampleCoords.x, 1.0) *
    step(0.0, sampleCoords.y) * step(sampleCoords.y, 1.0);

    vec3 colour = texture(image, sampleCoords).rgb * withinBounds;
    colour.r += (1 - withinBounds);

    f_colour = vec4(colour, 1.0);
}
```

### B.10.15 crt.frag

```
#version 330 core

uniform sampler2D image;
uniform int mode = 1;

in vec2 uvs;
out vec4 f_colour;

void main() {
  if (mode == 0){
    f_colour = vec4(texture(image, uvs).rgb, 1.0);
  } else {
    float flatness = 1.0;

    if (mode == 1) flatness = 5.0;
    else if (mode == 2) flatness = 10.0;

    vec2 center = vec2(0.5, 0.5);
    vec2 off_center = uvs - center;

    // Calculate offset of bulged pixels, increases with distance from center
    off_center *= 1.0 + 0.8 * pow(abs(off_center.yx), vec2(flatness));

    vec2 uvs_2 = center + off_center;

    if (uvs_2.x > 1.0 || uvs_2.x < 0.0 || uvs_2.y > 1.0 || uvs_2.y < 0.0) {
      f_colour = vec4(0.0, 0.0, 0.0, 1.0);
    } else {
      f_colour = vec4(texture(image, uvs_2).rgb, 1.0);

      // Draw horizontal lines
      float fv = fract(uvs_2.y * float(textureSize(image, 0).y));
      fv = min(1.0, 0.8 + 0.5 * min(fv, 1.0 - fv));
      f_colour.rgb *= fv;
    }
  }
}
```

### B.10.16 flashlight.frag

```
#version 330 core

uniform sampler2D image;
uniform vec2 center;

in vec2 uvs;
out vec4 f_colour;

vec2 resolution = textureSize(image, 0);
float radius = 100.0; // radius in pixel

float getDistance(vec2 pixelCoord, vec2 playerCoord) {
    return distance(pixelCoord*resolution, playerCoord);
}

void main() {
    float distance = getDistance(uvs, center);
    float a = 0;
    float b = 1;

    // if (distance < radius)
    float factor = 1.0 / (pow((distance / 100), 2) + 1);
    float isLit = step(distance, 10000);

    f_colour = vec4(texture(image, uvs).rgb + factor * isLit, 1.0);

    // if (distance < 10000) {
    //     float factor = 1.0 / (pow((distance / 100), 2) + 1);
    //     f_colour = vec4(texture(image, uvs).rgb + factor, 1.0);
    // }
    // else {
    //     f_colour = vec4(texture(image, uvs).rgb, 1.0);
    // }
}
```

### B.10.17 grayscale.frag

```
#version 330 core

uniform sampler2D image;

in vec2 uvs;
out vec4 f_colour;

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

### B.10.18 highlight_brightness.frag

See Section 3.9.2.

### B.10.19 highlight_colour.frag

```
# version 330 core

```

```
uniform sampler2D image;
uniform sampler2D highlight;

uniform vec3 colour;
uniform float threshold;
uniform float intensity;

in vec2 uvs;
out vec4 f_colour;

vec3 normColour = colour / 255;

void main() {
    vec4 pixel = texture(image, uvs);
    float isClose = step(abs(pixel.r - normColour.r), threshold) * step(abs(pixel.
    g - normColour.g), threshold) * step(abs(pixel.b - normColour.b), threshold);

    if (isClose == 1.0) {
        f_colour = vec4(vec3(pixel.rgb * intensity), 1.0);
    } else {
        f_colour = vec4(texture(highlight, uvs).rgb, 1.0);
    }
}
```

### 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

```
#version 330 core

uniform sampler2D image;

in vec2 uvs;
out vec4 f_colour;

void main() {
    f_colour = vec4(texture(image, uvs).rgb, 1.0);
}
```

### B.10.23 shadowmap.frag

See Section 3.9.3.

### B.10.24 shake.frag

```
#version 330 core

uniform sampler2D image;
uniform vec2 displacement;

in vec2 uvs;
out vec4 f_colour;
```

```

void main() {
    f_colour = vec4(texture(image, uvs + displacement).rgb, 1.0);
}
```

## B.11 data\shaders\vertex

### B.11.1 base.vert

```
#version 330 core

in vec2 vert;
in vec2 texCoords;
out vec2 uvs;

void main() {
    uvs = texCoords;
    gl_Position = vec4(vert, 0.0, 1.0);
}
```

## B.12 data\states

## B.13 data\states\browser

### B.13.1 browser.py

```python
import pygame
import pyperclip
from data.helpers.database_helpers import delete_game, get_ordered_games
from data.states.browser.widget_dict import BROWSER_WIDGETS
from data.utils.event_types import BrowserEventType
from data.managers.logs import initialise_logger
from data.utils.constants import GAMES_PER_PAGE
from data.managers.window import window
from data.utils.enums import ShaderType
from data.utils.assets import MUSIC
from data.control import _State
from random import randint

logger = initialise_logger(__name__)

class Browser(_State):
    def __init__(self):
        super().__init__()

        self._selected_index = None
        self._filter_column = 'number_of_ply'
        self._filter_ascend = False
        self._games_list = []
        self._page_number = 1

    def cleanup(self):
        super().cleanup()

        if self._selected_index is not None:
            return self._games_list[self._selected_index]

        return None
```

```python

    def startup(self, persist=None):
        self.refresh_games_list() # BEFORE RESIZE TO FILL WIDGET BEFORE RESIZING
        super().startup(BROWSER_WIDGETS, music=MUSIC[f'menu_{randint(1, 3)}'])

        self._filter_column = 'number_of_ply'
        self._filter_ascend = False

        window.set_apply_arguments(ShaderType.BASE, background_type=ShaderType.
    BACKGROUND_BALATRO)

        BROWSER_WIDGETS['help'].kill()
        BROWSER_WIDGETS['browser_strip'].kill()

        self.draw()

    def refresh_games_list(self):
        column_map = {
            'moves': 'number_of_ply',
            'winner': 'winner',
            'time': 'created_dt'
        }

        ascend_map = {
            'asc': True,
            'desc': False
        }

        filter_column = BROWSER_WIDGETS['filter_column_dropdown'].
    get_selected_word()
        filter_ascend = BROWSER_WIDGETS['filter_ascend_dropdown'].
    get_selected_word()

        self._selected_index = None

        start_row = (self._page_number - 1) * GAMES_PER_PAGE + 1
        end_row = (self._page_number) * GAMES_PER_PAGE
        self._games_list = get_ordered_games(column_map[filter_column], ascend_map
    [filter_ascend], start_row=start_row, end_row=end_row)

        BROWSER_WIDGETS['browser_strip'].initialise_games_list(self._games_list)
        BROWSER_WIDGETS['browser_strip'].set_surface_size(window.size)
        BROWSER_WIDGETS['scroll_area'].set_image()

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

        if event.type in [pygame.MOUSEBUTTONUP, pygame.KEYDOWN]:
            BROWSER_WIDGETS['help'].kill()

        if widget_event is None:
            return

        match widget_event.type:
            case BrowserEventType.MENU_CLICK:
                self.next = 'menu'
                self.done = True

            case BrowserEventType.BROWSER_STRIP_CLICK:
                self._selected_index = widget_event.selected_index

            case BrowserEventType.COPY_CLICK:
```

```
                if self._selected_index is None:
                    return
                logger.info(f'COPYING TO CLIPBOARD: {self._games_list[self._selected_index]['final_fen_string']}')
                pyperclip.copy(self._games_list[self._selected_index]['final_fen_string'])

            case BrowserEventType.DELETE_CLICK:
                if self._selected_index is None:
                    return
                delete_game(self._games_list[self._selected_index]['id'])
                self.refresh_games_list()

            case BrowserEventType.REVIEW_CLICK:
                if self._selected_index is None:
                    return

                self.next = 'review'
                self.done = True

            case BrowserEventType.FILTER_COLUMN_CLICK:
                selected_word = BROWSER_WIDGETS['filter_column_dropdown'].get_selected_word()

                if selected_word is None:
                    return

                self.refresh_games_list()

            case BrowserEventType.FILTER_ASCEND_CLICK:
                selected_word = BROWSER_WIDGETS['filter_ascend_dropdown'].get_selected_word()

                if selected_word is None:
                    return

                self.refresh_games_list()

            case BrowserEventType.PAGE_CLICK:
                self._page_number = widget_event.data

                self.refresh_games_list()

            case BrowserEventType.HELP_CLICK:
                self._widget_group.add(BROWSER_WIDGETS['help'])
                self._widget_group.handle_resize(window.size)

    def draw(self):
        self._widget_group.draw()
```

### B.13.2 widget_dict.py

```
from data.helpers.database_helpers import get_number_of_games
from data.components.custom_event import CustomEvent
from data.utils.event_types import BrowserEventType
from data.utils.constants import GAMES_PER_PAGE
from data.utils.assets import GRAPHICS
from data.widgets import *

BROWSER_HEIGHT = 0.6

browser_strip = BrowserStrip(
```

```
    relative_position=(0.0, 0.0),
    relative_height=BROWSER_HEIGHT,
    games_list=[]
)

number_of_pages = get_number_of_games() // GAMES_PER_PAGE + 1

carousel_widgets = {
    i: Text(
        relative_position=(0, 0),
        relative_size=(0.3, 0.1),
        text=f"PAGE {i} OF {number_of_pages}",
        fill_colour=(0, 0, 0, 0),
        fit_vertical=False,
        border_width=0,
    )
    for i in range(1, number_of_pages + 1)
}

sort_by_container = Rectangle(
    relative_size=(0.5, 0.1),
    relative_position=(0.01, 0.77),
    anchor_x='right',
    visible=True
)

buttons_container = Rectangle(
    relative_position=(0, 0.025),
    relative_size=(0.5, 0.1),
    scale_mode='height',
    anchor_x='center'
)

top_right_container = Rectangle(
    relative_position=(0, 0),
    relative_size=(0.15, 0.075),
    fixed_position=(5, 5),
    anchor_x='right',
    scale_mode='height'
)

BROWSER_WIDGETS = {
    'help':
    Icon(
        relative_position=(0, 0),
        relative_size=(1.02, 1.02),
        icon=GRAPHICS['browser_help'],
        anchor_x='center',
        anchor_y='center',
        border_width=0,
        fill_colour=(0, 0, 0, 0)
    ),
    'default': [
        buttons_container,
        sort_by_container,
        top_right_container,
        ReactiveIconButton(
            parent=top_right_container,
            relative_position=(0, 0),
            relative_size=(1, 1),
            anchor_x='right',
            scale_mode='height',
```

```
            base_icon=GRAPHICS['home_base'],
            hover_icon=GRAPHICS['home_hover'],
            press_icon=GRAPHICS['home_press'],
            event=CustomEvent(BrowserEventType.MENU_CLICK)
        ),
        ReactiveIconButton(
            parent=top_right_container,
            relative_position=(0, 0),
            relative_size=(1, 1),
            scale_mode='height',
            base_icon=GRAPHICS['help_base'],
            hover_icon=GRAPHICS['help_hover'],
            press_icon=GRAPHICS['help_press'],
            event=CustomEvent(BrowserEventType.HELP_CLICK)
        ),
        ReactiveIconButton(
            parent=buttons_container,
            relative_position=(0, 0),
            relative_size=(1, 1),
            scale_mode='height',
            base_icon=GRAPHICS['copy_base'],
            hover_icon=GRAPHICS['copy_hover'],
            press_icon=GRAPHICS['copy_press'],
            event=CustomEvent(BrowserEventType.COPY_CLICK),
        ),
        ReactiveIconButton(
            parent=buttons_container,
            relative_position=(0, 0),
            relative_size=(1, 1),
            scale_mode='height',
            anchor_x='center',
            base_icon=GRAPHICS['delete_base'],
            hover_icon=GRAPHICS['delete_hover'],
            press_icon=GRAPHICS['delete_press'],
            event=CustomEvent(BrowserEventType.DELETE_CLICK),
        ),
        ReactiveIconButton(
            parent=buttons_container,
            relative_position=(0, 0),
            relative_size=(1, 1),
            scale_mode='height',
            anchor_x='right',
            base_icon=GRAPHICS['review_base'],
            hover_icon=GRAPHICS['review_hover'],
            press_icon=GRAPHICS['review_press'],
            event=CustomEvent(BrowserEventType.REVIEW_CLICK),
        ),
        Text(
            parent=sort_by_container,
            relative_position=(0, 0),
            relative_size=(0.3, 1),
            fit_vertical=False,
            text='SORT BY:',
            border_width=0,
            fill_colour=(0, 0, 0, 0)
        )
    ],
    'browser_strip':
        browser_strip,
    'scroll_area':
    ScrollArea(
        relative_position=(0.0, 0.15),
```

```
        relative_size=(1, BROWSER_HEIGHT),
        vertical=False,
        widget=browser_strip
    ),
    'filter_column_dropdown':
    Dropdown(
        parent=sort_by_container,
        relative_position=(0.3, 0),
        relative_height=0.75,
        anchor_x='right',
        word_list=['time', 'moves', 'winner'],
        fill_colour=(255, 100, 100),
        event=CustomEvent(BrowserEventType.FILTER_COLUMN_CLICK)
    ),
    'filter_ascend_dropdown':
    Dropdown(
        parent=sort_by_container,
        relative_position=(0, 0),
        relative_height=0.75,
        anchor_x='right',
        word_list=['desc', 'asc'],
        fill_colour=(255, 100, 100),
        event=CustomEvent(BrowserEventType.FILTER_ASCEND_CLICK)
    ),
    'page_carousel':
    Carousel(
        relative_position=(0.01, 0.77),
        margin=5,
        widgets_dict=carousel_widgets,
        event=CustomEvent(BrowserEventType.PAGE_CLICK),
    )
}
```

## B.14 data\states\config

### B.14.1 config.py

```
import pygame
from data.states.config.default_config import default_config
from data.states.config.widget_dict import CONFIG_WIDGETS
from data.utils.event_types import ConfigEventType
from data.managers.logs import initialise_logger
from data.managers.animation import animation
from data.utils.constants import ShaderType
from data.utils.assets import MUSIC, SFX
from data.managers.window import window
from data.managers.audio import audio
from data.managers.theme import theme
from data.utils.enums import Colour
from data.control import _State
from random import randint

logger = initialise_logger(__name__)

class Config(_State):
    def __init__(self):
        super().__init__()

        self._config = None
        self._valid_fen = True
        self._selected_preset = None
```

```python

    def cleanup(self):
        super().cleanup()

        window.clear_apply_arguments(ShaderType.BLOOM)

        return self._config

    def startup(self, persist=None):
        super().startup(CONFIG_WIDGETS, music=MUSIC[f'menu_{randint(1, 3)}'])
        window.set_apply_arguments(ShaderType.BLOOM, highlight_colours=[(pygame.
    Color('0x95e0cc')).rgb, pygame.Color('0xf14e52').rgb], colour_intensity=0.9)

        CONFIG_WIDGETS['invalid_fen_string'].kill()
        CONFIG_WIDGETS['help'].kill()

        self._config = default_config

        if persist:
            self._config['FEN_STRING'] = persist

        self.set_fen_string(self._config['FEN_STRING'])
        self.toggle_pvc(self._config['CPU_ENABLED'])
        self.set_active_colour(self._config['COLOUR'])

        CONFIG_WIDGETS['cpu_depth_carousel'].set_to_key(self._config['CPU_DEPTH'])
        if self._config['CPU_ENABLED']:
            self.create_depth_picker()
        else:
            self.remove_depth_picker()

        self.draw()

    def create_depth_picker(self):
        # CONFIG_WIDGETS['start_button'].update_relative_position((0.5, 0.8))
        # CONFIG_WIDGETS['start_button'].set_image()
        CONFIG_WIDGETS['cpu_depth_carousel'].set_surface_size(window.size)
        CONFIG_WIDGETS['cpu_depth_carousel'].set_image()
        CONFIG_WIDGETS['cpu_depth_carousel'].set_geometry()
        self._widget_group.add(CONFIG_WIDGETS['cpu_depth_carousel'])

    def remove_depth_picker(self):
        # CONFIG_WIDGETS['start_button'].update_relative_position((0.5, 0.7))
        # CONFIG_WIDGETS['start_button'].set_image()

        CONFIG_WIDGETS['cpu_depth_carousel'].kill()

    def toggle_pvc(self, pvc_enabled):
        if pvc_enabled:
            CONFIG_WIDGETS['pvc_button'].set_locked(True)
            CONFIG_WIDGETS['pvp_button'].set_locked(False)
        else:
            CONFIG_WIDGETS['pvp_button'].set_locked(True)
            CONFIG_WIDGETS['pvc_button'].set_locked(False)

        self._config['CPU_ENABLED'] = pvc_enabled

        if self._config['CPU_ENABLED']:
            self.create_depth_picker()
        else:
            self.remove_depth_picker()

```

```
    def set_fen_string(self, new_fen_string):
        CONFIG_WIDGETS['fen_string_input'].set_text(new_fen_string)
        self._config['FEN_STRING'] = new_fen_string

        self.set_preset_overlay(new_fen_string)

        try:
            CONFIG_WIDGETS['board_thumbnail'].initialise_board(new_fen_string)
            CONFIG_WIDGETS['invalid_fen_string'].kill()

            if new_fen_string[-1].lower() == 'r':
                self.set_active_colour(Colour.RED)
            else:
                self.set_active_colour(Colour.BLUE)

            self._valid_fen = True
        except:
            CONFIG_WIDGETS['board_thumbnail'].initialise_board('')
            self._widget_group.add(CONFIG_WIDGETS['invalid_fen_string'])

            window.set_effect(ShaderType.SHAKE)
            animation.set_timer(500, lambda: window.clear_effect(ShaderType.SHAKE)
    )

            audio.play_sfx(SFX['error_1'])
            audio.play_sfx(SFX['error_2'])

            self._valid_fen = False

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

        if event.type in [pygame.MOUSEBUTTONUP, pygame.KEYDOWN]:
            CONFIG_WIDGETS['help'].kill()

        if widget_event is None:
            return

        match widget_event.type:
            case ConfigEventType.GAME_CLICK:
                if self._valid_fen:
                    self.next = 'game'
                    self.done = True

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

            case ConfigEventType.TIME_CLICK:
                self._config['TIME_ENABLED'] = not(widget_event.data)
                CONFIG_WIDGETS['timer_button'].set_next_icon()

            case ConfigEventType.PVP_CLICK:
                self.toggle_pvc(False)

            case ConfigEventType.PVC_CLICK:
                self.toggle_pvc(True)

            case ConfigEventType.FEN_STRING_TYPE:
                self.set_fen_string(widget_event.text)

            case ConfigEventType.TIME_TYPE:
```

```
                if widget_event.text == '':
                    self._config['TIME'] = 5
                else:
                    self._config['TIME'] = float(widget_event.text)

            case ConfigEventType.CPU_DEPTH_CLICK:
                self._config['CPU_DEPTH'] = int(widget_event.data)

            case ConfigEventType.PRESET_CLICK:
                self.set_fen_string(widget_event.fen_string)

            case ConfigEventType.SETUP_CLICK:
                if self._valid_fen:
                    self.next = 'editor'
                    self.done = True

            case ConfigEventType.COLOUR_CLICK:
                self.set_active_colour(widget_event.data.get_flipped_colour())

            case ConfigEventType.HELP_CLICK:
                self._widget_group.add(CONFIG_WIDGETS['help'])
                self._widget_group.handle_resize(window.size)

    def set_preset_overlay(self, fen_string):
        fen_string_widget_map = {
            'sc3ncfcncpb2/2pc7/3Pd6/pa1Pc1rbra1pb1Pd/pb1Pd1RaRb1pa1Pc/6pb3/7Pa2/2PdNaFaNa3Sa b': 'preset_1',
            'sc3ncfcncra2/10/3Pd2pa3/paPc2Pbra2pbPd/pbPd2Rapd2paPc/3Pc2pb3/10/2RaNaFaNa3Sa b': 'preset_2',
            'sc3pcncpb3/5fc4/pa3pcncra3/pb1rd1Pd1Pb3/3pd1pb1Rd1Pd/3RaNaPa3Pc/4Fa5/3PdNaPa3Sa b': 'preset_3'
        }

        if fen_string in fen_string_widget_map:
            self._selected_preset = CONFIG_WIDGETS[fen_string_widget_map[fen_string]]
        else:
            self._selected_preset = None

    def set_active_colour(self, colour):
        if self._config['COLOUR'] != colour:
            CONFIG_WIDGETS['to_move_button'].set_next_icon()

        self._config['COLOUR'] = colour

        if colour == Colour.BLUE:
            CONFIG_WIDGETS['to_move_text'].set_text('BLUE TO MOVE')
        elif colour == Colour.RED:
            CONFIG_WIDGETS['to_move_text'].set_text('RED TO MOVE')

        if self._valid_fen:
            self._config['FEN_STRING'] = self._config['FEN_STRING'][:-1] + colour.name[0].lower()
            CONFIG_WIDGETS['fen_string_input'].set_text(self._config['FEN_STRING'])

    def draw(self):
        self._widget_group.draw()

        if self._selected_preset:
            pygame.draw.rect(window.screen, theme['borderPrimary'], (*self._selected_preset.position, *self._selected_preset.size), width=int(theme['
```

```
    borderWidth']))

    def update(self, **kwargs):
        self._widget_group.update()
        super().update(**kwargs)
```

### B.14.2 default_config.py

```
from data.utils.enums import Colour

default_config = {
    'FEN_STRING': 'sc3ncfcncpb2/2pc7/3Pd6/pa1Pc1rbra1pb1Pd/pb1Pd1RaRb1pa1Pc/6pb3/7Pa2/2PdNaFaNa3Sa b',
    'COLOUR': Colour.BLUE,
    'TIME_ENABLED': True,
    'CPU_ENABLED': False,
    'CPU_DEPTH': 2,
    'TIME': 5,
}
```

### B.14.3 widget_dict.py

```
from data.widgets import *
from data.states.config.default_config import default_config
from data.helpers.asset_helpers import get_highlighted_icon
from data.components.custom_event import CustomEvent
from data.utils.event_types import ConfigEventType
from data.utils.assets import GRAPHICS
from data.managers.theme import theme
from data.utils.enums import Colour

def float_validator(num_string):
    try:
        float(num_string)
        return True
    except:
        return False

if default_config['CPU_ENABLED']:
    pvp_icons = {False: GRAPHICS['swords'], True: GRAPHICS['swords']}
    pvc_icons = {True: GRAPHICS['robot'], False: GRAPHICS['robot']}
    pvc_locked = True
    pvp_locked = False
else:
    pvp_icons = {True: GRAPHICS['swords'], False: GRAPHICS['swords']}
    pvc_icons = {False: GRAPHICS['robot'], True: GRAPHICS['robot']}
    pvc_locked = False
    pvp_locked = True

if default_config['TIME_ENABLED']:
    time_enabled_icons = {True: GRAPHICS['timer'], False: get_highlighted_icon(GRAPHICS['timer'])}
else:
    time_enabled_icons = {False: get_highlighted_icon(GRAPHICS['timer']), True: GRAPHICS['timer']}

if default_config['COLOUR'] == Colour.BLUE:
    colour_icons = {Colour.BLUE: GRAPHICS['pharaoh_0_a'], Colour.RED: GRAPHICS['pharaoh_1_a']}
else:
```

```
    colour_icons = {Colour.RED: GRAPHICS['pharaoh_1_a'], Colour.BLUE: GRAPHICS['
    pharaoh_0_a']}

preview_container = Rectangle(
    relative_position=(-0.15, 0),
    relative_size=(0.65, 0.9),
    anchor_x='center',
    anchor_y='center',
)

config_container = Rectangle(
    relative_position=(0.325, 0),
    relative_size=(0.3, 0.9),
    anchor_x='center',
    anchor_y='center',
)

to_move_container = Rectangle(
    parent=config_container,
    relative_size=(0.9, 0.15),
    relative_position=(0, 0.1),
    anchor_x='center'
)

board_thumbnail = BoardThumbnail(
    parent=preview_container,
    relative_position=(0, 0),
    relative_width=0.7,
    scale_mode='width',
    anchor_x='right',
)

top_right_container = Rectangle(
    relative_position=(0, 0),
    relative_size=(0.15, 0.075),
    fixed_position=(5, 5),
    anchor_x='right',
    scale_mode='height'
)

CONFIG_WIDGETS = {
    'help':
    Icon(
        relative_position=(0, 0),
        relative_size=(1.02, 1.02),
        icon=GRAPHICS['config_help'],
        anchor_x='center',
        anchor_y='center',
        border_width=0,
        fill_colour=(0, 0, 0, 0)
    ),
    'default': [
        preview_container,
        config_container,
        to_move_container,
        top_right_container,
        ReactiveIconButton(
            parent=top_right_container,
            relative_position=(0, 0),
            relative_size=(1, 1),
            anchor_x='right',
            scale_mode='height',
```

```
            base_icon=GRAPHICS['home_base'],
            hover_icon=GRAPHICS['home_hover'],
            press_icon=GRAPHICS['home_press'],
            event=CustomEvent(ConfigEventType.MENU_CLICK)
        ),
        ReactiveIconButton(
            parent=top_right_container,
            relative_position=(0, 0),
            relative_size=(1, 1),
            scale_mode='height',
            base_icon=GRAPHICS['help_base'],
            hover_icon=GRAPHICS['help_hover'],
            press_icon=GRAPHICS['help_press'],
            event=CustomEvent(ConfigEventType.HELP_CLICK)
        ),
        TextInput(
            parent=config_container,
            relative_position=(0.3, 0.3),
            relative_size=(0.65, 0.15),
            fit_vertical=True,
            placeholder='TIME CONTROL (DEFAULT 5)',
            default=str(default_config['TIME']),
            border_width=5,
            margin=20,
            validator=float_validator,
            event=CustomEvent(ConfigEventType.TIME_TYPE)
        ),
        Text(
            parent=config_container,
            fit_vertical=False,
            relative_position=(0.75, 0.3),
            relative_size=(0.2, 0.15),
            text='MINS',
            border_width=0,
            fill_colour=(0, 0, 0, 0)
        ),
        TextButton(
            parent=preview_container,
            relative_position=(0.3, 0),
            relative_size=(0.15, 0.15),
            text='CUSTOM',
            anchor_y='bottom',
            fit_vertical=False,
            margin=10,
            event=CustomEvent(ConfigEventType.SETUP_CLICK)
        )
    ],
    'board_thumbnail':
        board_thumbnail,
    'fen_string_input':
    TextInput(
        parent=preview_container,
        relative_position=(0, 0),
        relative_size=(0.55, 0.15),
        fit_vertical=False,
        placeholder='ENTER FEN STRING',
        default='sc3ncfcncpb2/2pc7/3Pd7/pa1Pc1rbra1pb1Pd/pb1Pd1RaRb1pa1Pc/6pb3/7
    Pa2/2PdNaFaNa3Sa b',
        border_width=5,
        anchor_y='bottom',
        anchor_x='right',
        margin=20,
```

```
            event=CustomEvent(ConfigEventType.FEN_STRING_TYPE)
        ),
        'start_button':
        TextButton(
            parent=config_container,
            relative_position=(0, 0),
            relative_size=(0.9, 0.3),
            anchor_y='bottom',
            anchor_x='center',
            text='START NEW GAME',
            strength=0.1,
            text_colour=theme['textSecondary'],
            margin=20,
            fit_vertical=False,
            event=CustomEvent(ConfigEventType.GAME_CLICK)
        ),
        'timer_button':
        MultipleIconButton(
            parent=config_container,
            scale_mode='height',
            relative_position=(0.05, 0.3),
            relative_size=(0.15, 0.15),
            margin=10,
            border_width=5,
            border_radius=5,
            icons_dict=time_enabled_icons,
            event=CustomEvent(ConfigEventType.TIME_CLICK)
        ),
        'pvp_button':
        MultipleIconButton(
            parent=config_container,
            relative_position=(-0.225, 0.5),
            relative_size=(0.45, 0.15),
            margin=15,
            anchor_x='center',
            icons_dict=pvp_icons,
            stretch=False,
            event=CustomEvent(ConfigEventType.PVP_CLICK)
        ),
        'pvc_button':
        MultipleIconButton(
            parent=config_container,
            relative_position=(0.225, 0.5),
            relative_size=(0.45, 0.15),
            anchor_x='center',
            margin=15,
            icons_dict=pvc_icons,
            stretch=False,
            event=CustomEvent(ConfigEventType.PVC_CLICK)
        ),
        'invalid_fen_string':
        Text(
            parent=board_thumbnail,
            relative_position=(0, 0),
            relative_size=(0.9, 0.1),
            fit_vertical=False,
            anchor_x='center',
            anchor_y='center',
            text='INVALID FEN STRING!',
            margin=10,
            fill_colour=theme['fillError'],
            text_colour=theme['textError'],
```

```
    ),
    'preset_1':
    BoardThumbnailButton(
        parent=preview_container,
        relative_width=0.25,
        relative_position=(0, 0),
        scale_mode='width',
        fen_string="sc3ncfcncpb2/2pc7/3Pd6/pa1Pc1rbra1pb1Pd/pb1Pd1RaRb1pa1Pc/6pb3/7Pa2/2PdNaFaNa3Sa b",
        event=CustomEvent(ConfigEventType.PRESET_CLICK)
    ),
    'preset_2':
    BoardThumbnailButton(
        parent=preview_container,
        relative_width=0.25,
        relative_position=(0, 0.35),
        scale_mode='width',
        fen_string="sc3ncfcncra2/10/3Pd2pa3/paPc2Pbra2pbPd/pbPd2Rapd2paPc/3Pc2pb3/10/2RaNaFaNa3Sa b",
        event=CustomEvent(ConfigEventType.PRESET_CLICK)
    ),
    'preset_3':
    BoardThumbnailButton(
        parent=preview_container,
        relative_width=0.25,
        relative_position=(0, 0.7),
        scale_mode='width',
        fen_string="sc3pcncpb3/5fc4/pa3pcncra3/pb1rd1Pd1Pb3/3pd1pb1Rd1Pd/3RaNaPa3Pc/4Fa5/3PdNaPa3Sa b",
        event=CustomEvent(ConfigEventType.PRESET_CLICK)
    ),
    'to_move_button':
    MultipleIconButton(
        parent=to_move_container,
        scale_mode='height',
        relative_position=(0, 0),
        relative_size=(1, 1),
        icons_dict=colour_icons,
        anchor_x='left',
        event=CustomEvent(ConfigEventType.COLOUR_CLICK)
    ),
    'to_move_text':
    Text(
        parent=to_move_container,
        relative_position=(0, 0),
        relative_size=(0.75, 1),
        fit_vertical=False,
        text='TO MOVE',
        anchor_x='right'
    ),
    'cpu_depth_carousel':
    Carousel(
        parent=config_container,
        relative_position=(0, 0.65),
        event=CustomEvent(ConfigEventType.CPU_DEPTH_CLICK),
        anchor_x='center',
        border_width=0,
        fill_colour=(0, 0, 0, 0),
        widgets_dict={
            2: Text(
                parent=config_container,
                relative_position=(0, 0),
```

```
                    relative_size=(0.8, 0.075),
                    text="EASY",
                    margin=0,
                    border_width=0,
                    fill_colour=(0, 0, 0, 0)
                ),
                3: Text(
                    parent=config_container,
                    relative_position=(0, 0),
                    relative_size=(0.8, 0.075),
                    text="MEDIUM",
                    margin=0,
                    border_width=0,
                    fill_colour=(0, 0, 0, 0)
                ),
                4: Text(
                    parent=config_container,
                    relative_position=(0, 0),
                    relative_size=(0.8, 0.075),
                    text="HARD",
                    margin=0,
                    border_width=0,
                    fill_colour=(0, 0, 0, 0)
                ),
            }
        )
}
```

## B.15 data\states\editor

### B.15.1 editor.py

```
import pygame
import pyperclip
from data.states.game.components.bitboard_collection import BitboardCollection
from data.utils.enums import Colour, RotationDirection, Piece, Rotation
from data.states.game.components.fen_parser import encode_fen_string
from data.states.game.components.overlay_draw import OverlayDraw
from data.states.game.components.piece_group import PieceGroup
from data.helpers.bitboard_helpers import coords_to_bitboard
from data.helpers.board_helpers import screen_pos_to_coords
from data.states.game.components.father import DragAndDrop
from data.states.editor.widget_dict import EDITOR_WIDGETS
from data.utils.event_types import EditorEventType
from data.managers.logs import initialise_logger
from data.managers.window import window
from data.control import _State

logger = initialise_logger(__name__)

class Editor(_State):
    def __init__(self):
        super().__init__()

        self._bitboards = None
        self._piece_group = None
        self._selected_coords = None
        self._selected_tool = None
        self._selected_tool_colour = None
        self._initial_fen_string = None
        self._starting_colour = None
```

```
        self._drag_and_drop = None
        self._overlay_draw = None

    def cleanup(self):
        super().cleanup()

        self.deselect_tool()

        return encode_fen_string(self._bitboards)

    def startup(self, persist):
        super().startup(EDITOR_WIDGETS)
        EDITOR_WIDGETS['help'].kill()

        self._drag_and_drop = DragAndDrop(EDITOR_WIDGETS['chessboard'].position, EDITOR_WIDGETS['chessboard'].size)
        self._overlay_draw = OverlayDraw(EDITOR_WIDGETS['chessboard'].position, EDITOR_WIDGETS['chessboard'].size)
        self._bitboards = BitboardCollection(persist['FEN_STRING'])
        self._piece_group = PieceGroup()

        self._selected_coords = None
        self._selected_tool = None
        self._selected_tool_colour = None
        self._initial_fen_string = persist['FEN_STRING']
        self._starting_colour = Colour.BLUE

        self.refresh_pieces()
        self.set_starting_colour(Colour.BLUE if persist['FEN_STRING'][-1].lower() == 'b' else Colour.RED)
        self.draw()

    @property
    def selected_coords(self):
        return self._selected_coords

    @selected_coords.setter
    def selected_coords(self, new_coords):
        self._overlay_draw.set_selected_coords(new_coords)
        self._selected_coords = new_coords

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

        if event.type in [pygame.MOUSEBUTTONUP, pygame.KEYDOWN]:
            EDITOR_WIDGETS['help'].kill()

        if event.type == pygame.MOUSEBUTTONDOWN:
            clicked_coords = screen_pos_to_coords(event.pos, EDITOR_WIDGETS['chessboard'].position, EDITOR_WIDGETS['chessboard'].size)

            if clicked_coords:
                self.selected_coords = clicked_coords

                if self._selected_tool is None:
                    return

                if self._selected_tool == 'MOVE':
                    self.set_dragged_piece(clicked_coords)

                elif self._selected_tool == 'ERASE':
```

```
                    self.remove_piece()
                else:
                    self.set_piece(self._selected_tool, self._selected_tool_colour, Rotation.UP)

                return

        if event.type == pygame.MOUSEBUTTONUP:
            clicked_coords = screen_pos_to_coords(event.pos, EDITOR_WIDGETS['chessboard'].position, EDITOR_WIDGETS['chessboard'].size)

            if self._drag_and_drop.dragged_sprite:
                self.remove_dragged_piece(clicked_coords)
                return

        if widget_event is None:
            if event.type == pygame.MOUSEBUTTONDOWN and self._widget_group.on_widget(event.pos) is False:
                self.selected_coords = None

            return

        match widget_event.type:
            case None:
                return

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

            case EditorEventType.PICK_PIECE_CLICK:
                if widget_event.piece == self._selected_tool and widget_event.active_colour == self._selected_tool_colour:
                    self.deselect_tool()
                else:
                    self.select_tool(widget_event.piece, widget_event.active_colour)

            case EditorEventType.ROTATE_PIECE_CLICK:
                self.rotate_piece(widget_event.rotation_direction)

            case EditorEventType.EMPTY_CLICK:
                self._bitboards = BitboardCollection(fen_string='sc9/10/10/10/10/10/10/9Sa b')
                self.refresh_pieces()

            case EditorEventType.RESET_CLICK:
                self.reset_board()

            case EditorEventType.COPY_CLICK:
                logger.info(f'COPYING TO CLIPBOARD: {encode_fen_string(self._bitboards)}')
                pyperclip.copy(encode_fen_string(self._bitboards))

            case EditorEventType.BLUE_START_CLICK:
                self.set_starting_colour(Colour.BLUE)

            case EditorEventType.RED_START_CLICK:
                self.set_starting_colour(Colour.RED)

            case EditorEventType.START_CLICK:
                self.next = 'config'
```

```
                self.done = True

            case EditorEventType.CONFIG_CLICK:
                self.reset_board()
                self.next = 'config'
                self.done = True

            case EditorEventType.ERASE_CLICK:
                if self._selected_tool == 'ERASE':
                    self.deselect_tool()
                else:
                    self.select_tool('ERASE', None)

            case EditorEventType.MOVE_CLICK:
                if self._selected_tool == 'MOVE':
                    self.deselect_tool()
                else:
                    self.select_tool('MOVE', None)

            case EditorEventType.HELP_CLICK:
                self._widget_group.add(EDITOR_WIDGETS['help'])
                self._widget_group.handle_resize(window.size)

    def reset_board(self):
        self._bitboards = BitboardCollection(self._initial_fen_string)
        self.refresh_pieces()

    def refresh_pieces(self):
        self._piece_group.initialise_pieces(self._bitboards.convert_to_piece_list
    (), EDITOR_WIDGETS['chessboard'].position, EDITOR_WIDGETS['chessboard'].size)

    def set_starting_colour(self, new_colour):
        if new_colour == Colour.BLUE:
            EDITOR_WIDGETS['blue_start_button'].set_locked(True)
            EDITOR_WIDGETS['red_start_button'].set_locked(False)
        elif new_colour == Colour.RED:
            EDITOR_WIDGETS['blue_start_button'].set_locked(False)
            EDITOR_WIDGETS['red_start_button'].set_locked(True)

        if new_colour != self._starting_colour:
            EDITOR_WIDGETS['blue_start_button'].set_next_icon()
            EDITOR_WIDGETS['red_start_button'].set_next_icon()

        self._starting_colour = new_colour
        self._bitboards.active_colour = new_colour

    def set_dragged_piece(self, coords):
        bitboard_under_mouse = coords_to_bitboard(coords)
        dragged_piece = self._bitboards.get_piece_on(bitboard_under_mouse, Colour.
    BLUE) or self._bitboards.get_piece_on(bitboard_under_mouse, Colour.RED)

        if dragged_piece is None:
            return

        dragged_colour = self._bitboards.get_colour_on(bitboard_under_mouse)
        dragged_rotation = self._bitboards.get_rotation_on(bitboard_under_mouse)

        self._drag_and_drop.set_dragged_piece(dragged_piece, dragged_colour,
    dragged_rotation)
        self._overlay_draw.set_hover_limit(False)

    def remove_dragged_piece(self, coords):
```

```
        piece, colour, rotation = self._drag_and_drop.get_dragged_info()

        if coords and coords != self._selected_coords and piece != Piece.SPHINX:
            self.remove_piece()
            self.selected_coords = coords
            self.set_piece(piece, colour, rotation)
            self.selected_coords = None

        self._drag_and_drop.remove_dragged_piece()
        self._overlay_draw.set_hover_limit(True)

    def set_piece(self, piece, colour, rotation):
        if self.selected_coords is None or self.selected_coords == (0, 7) or self.selected_coords == (9, 0):
            return

        self.remove_piece()

        selected_bitboard = coords_to_bitboard(self.selected_coords)
        self._bitboards.set_square(selected_bitboard, piece, colour)
        self._bitboards.set_rotation(selected_bitboard, rotation)

        self.refresh_pieces()

    def remove_piece(self):
        if self.selected_coords is None or self.selected_coords == (0, 7) or self.selected_coords == (9, 0):
            return

        selected_bitboard = coords_to_bitboard(self.selected_coords)
        self._bitboards.clear_square(selected_bitboard, Colour.BLUE)
        self._bitboards.clear_square(selected_bitboard, Colour.RED)
        self._bitboards.clear_rotation(selected_bitboard)

        self.refresh_pieces()

    def rotate_piece(self, rotation_direction):
        if self.selected_coords is None or self.selected_coords == (0, 7) or self.selected_coords == (9, 0):
            return

        selected_bitboard = coords_to_bitboard(self.selected_coords)

        if self._bitboards.get_piece_on(selected_bitboard, Colour.BLUE) is None and self._bitboards.get_piece_on(selected_bitboard, Colour.RED) is None:
            return

        current_rotation = self._bitboards.get_rotation_on(selected_bitboard)

        if rotation_direction == RotationDirection.CLOCKWISE:
            self._bitboards.update_rotation(selected_bitboard, selected_bitboard, current_rotation.get_clockwise())
        elif rotation_direction == RotationDirection.ANTICLOCKWISE:
            self._bitboards.update_rotation(selected_bitboard, selected_bitboard, current_rotation.get_anticlockwise())

        self.refresh_pieces()

    def select_tool(self, piece, colour):
        dict_name_map = { Colour.BLUE: 'blue_piece_buttons', Colour.RED: 'red_piece_buttons' }

```

```
        self.deselect_tool()

        if piece == 'ERASE':
            EDITOR_WIDGETS['erase_button'].set_locked(True)
            EDITOR_WIDGETS['erase_button'].set_next_icon()
        elif piece == 'MOVE':
            EDITOR_WIDGETS['move_button'].set_locked(True)
            EDITOR_WIDGETS['move_button'].set_next_icon()
        else:
            EDITOR_WIDGETS[dict_name_map[colour]][piece].set_locked(True)
            EDITOR_WIDGETS[dict_name_map[colour]][piece].set_next_icon()

        self._selected_tool = piece
        self._selected_tool_colour = colour

    def deselect_tool(self):
        dict_name_map = { Colour.BLUE: 'blue_piece_buttons', Colour.RED: '
    red_piece_buttons' }

        if self._selected_tool:
            if self._selected_tool == 'ERASE':
                EDITOR_WIDGETS['erase_button'].set_locked(False)
                EDITOR_WIDGETS['erase_button'].set_next_icon()
            elif self._selected_tool == 'MOVE':
                EDITOR_WIDGETS['move_button'].set_locked(False)
                EDITOR_WIDGETS['move_button'].set_next_icon()
            else:
                EDITOR_WIDGETS[dict_name_map[self._selected_tool_colour]][self.
    _selected_tool].set_locked(False)
                EDITOR_WIDGETS[dict_name_map[self._selected_tool_colour]][self.
    _selected_tool].set_next_icon()

        self._selected_tool = None
        self._selected_tool_colour = None

    def handle_resize(self):
        super().handle_resize()
        self._piece_group.handle_resize(EDITOR_WIDGETS['chessboard'].position,
    EDITOR_WIDGETS['chessboard'].size)
        self._drag_and_drop.handle_resize(EDITOR_WIDGETS['chessboard'].position,
    EDITOR_WIDGETS['chessboard'].size)
        self._overlay_draw.handle_resize(EDITOR_WIDGETS['chessboard'].position,
    EDITOR_WIDGETS['chessboard'].size)

    def draw(self):
        self._widget_group.draw()
        self._overlay_draw.draw(window.screen)
        self._piece_group.draw(window.screen)
        self._drag_and_drop.draw(window.screen)
```

### B.15.2 widget_dict.py

```
from data.utils.enums import Piece, Colour, RotationDirection
from data.helpers.asset_helpers import get_highlighted_icon
from data.components.custom_event import CustomEvent
from data.utils.constants import BLUE_BUTTON_COLOURS
from data.utils.event_types import EditorEventType
from data.utils.assets import GRAPHICS
from data.widgets import *

blue_pieces_container = Rectangle(
    relative_position=(0.25, 0),
```

```
    relative_size=(0.13, 0.65),
    scale_mode='height',
    anchor_y='center',
    anchor_x='center'
)

red_pieces_container = Rectangle(
    relative_position=(-0.25, 0),
    relative_size=(0.13, 0.65),
    scale_mode='height',
    anchor_y='center',
    anchor_x='center'
)

bottom_actions_container = Rectangle(
    relative_position=(0, 0.05),
    relative_size=(0.4, 0.1),
    anchor_x='center',
    anchor_y='bottom'
)

top_actions_container = Rectangle(
    relative_position=(0, 0.05),
    relative_size=(0.3, 0.1),
    anchor_x='center',
    scale_mode='height'
)

top_right_container = Rectangle(
    relative_position=(0, 0),
    relative_size=(0.15, 0.075),
    fixed_position=(5, 5),
    anchor_x='right',
    scale_mode='height'
)

EDITOR_WIDGETS = {
    'help':
    Icon(
        relative_position=(0, 0),
        relative_size=(1.02, 1.02),
        icon=GRAPHICS['editor_help'],
        anchor_x='center',
        anchor_y='center',
        border_width=0,
        fill_colour=(0, 0, 0, 0)
    ),
    'default': [
        red_pieces_container,
        blue_pieces_container,
        bottom_actions_container,
        top_actions_container,
        top_right_container,
        ReactiveIconButton(
            parent=top_right_container,
            relative_position=(0, 0),
            relative_size=(1, 1),
            anchor_x='right',
            scale_mode='height',
            base_icon=GRAPHICS['home_base'],
            hover_icon=GRAPHICS['home_hover'],
            press_icon=GRAPHICS['home_press'],
```

```
            event=CustomEvent(EditorEventType.MENU_CLICK)
        ),
        ReactiveIconButton(
            parent=top_right_container,
            relative_position=(0, 0),
            relative_size=(1, 1),
            scale_mode='height',
            base_icon=GRAPHICS['help_base'],
            hover_icon=GRAPHICS['help_hover'],
            press_icon=GRAPHICS['help_press'],
            event=CustomEvent(EditorEventType.HELP_CLICK)
        ),
        ReactiveIconButton(
            parent=bottom_actions_container,
            relative_position=(0.06, 0),
            relative_size=(1, 1),
            anchor_x='center',
            scale_mode='height',
            base_icon=GRAPHICS['clockwise_arrow_base'],
            hover_icon=GRAPHICS['clockwise_arrow_hover'],
            press_icon=GRAPHICS['clockwise_arrow_press'],
            event=CustomEvent(EditorEventType.ROTATE_PIECE_CLICK,
    rotation_direction=RotationDirection.CLOCKWISE)
        ),
        ReactiveIconButton(
            parent=bottom_actions_container,
            relative_position=(-0.06, 0),
            relative_size=(1, 1),
            anchor_x='center',
            scale_mode='height',
            base_icon=GRAPHICS['anticlockwise_arrow_base'],
            hover_icon=GRAPHICS['anticlockwise_arrow_hover'],
            press_icon=GRAPHICS['anticlockwise_arrow_press'],
            event=CustomEvent(EditorEventType.ROTATE_PIECE_CLICK,
    rotation_direction=RotationDirection.ANTICLOCKWISE)
        ),
        ReactiveIconButton(
            parent=top_actions_container,
            relative_position=(0, 0),
            relative_size=(1, 1),
            scale_mode='height',
            anchor_x='right',
            base_icon=GRAPHICS['copy_base'],
            hover_icon=GRAPHICS['copy_hover'],
            press_icon=GRAPHICS['copy_press'],
            event=CustomEvent(EditorEventType.COPY_CLICK),
        ),
        ReactiveIconButton(
            parent=top_actions_container,
            relative_position=(0, 0),
            relative_size=(1, 1),
            scale_mode='height',
            base_icon=GRAPHICS['delete_base'],
            hover_icon=GRAPHICS['delete_hover'],
            press_icon=GRAPHICS['delete_press'],
            event=CustomEvent(EditorEventType.EMPTY_CLICK),
        ),
        ReactiveIconButton(
            parent=top_actions_container,
            relative_position=(0, 0),
            relative_size=(1, 1),
            scale_mode='height',
```

```
            anchor_x='center',
            base_icon=GRAPHICS['discard_arrow_base'],
            hover_icon=GRAPHICS['discard_arrow_hover'],
            press_icon=GRAPHICS['discard_arrow_press'],
            event=CustomEvent(EditorEventType.RESET_CLICK),
        ),
        ReactiveIconButton(
            relative_position=(0, 0),
            fixed_position=(10, 0),
            relative_size=(0.1, 0.1),
            anchor_x='right',
            anchor_y='center',
            scale_mode='height',
            base_icon=GRAPHICS['play_arrow_base'],
            hover_icon=GRAPHICS['play_arrow_hover'],
            press_icon=GRAPHICS['play_arrow_press'],
            event=CustomEvent(EditorEventType.START_CLICK),
        ),
        ReactiveIconButton(
            relative_position=(0, 0),
            fixed_position=(10, 0),
            relative_size=(0.1, 0.1),
            anchor_y='center',
            scale_mode='height',
            base_icon=GRAPHICS['return_arrow_base'],
            hover_icon=GRAPHICS['return_arrow_hover'],
            press_icon=GRAPHICS['return_arrow_press'],
            event=CustomEvent(EditorEventType.CONFIG_CLICK),
        )
    ],
    'blue_piece_buttons': {},
    'red_piece_buttons': {},
    'erase_button':
    MultipleIconButton(
        parent=red_pieces_container,
        relative_position=(0, 0),
        relative_size=(0.2, 0.2),
        scale_mode='height',
        margin=10,
        icons_dict={True: GRAPHICS['eraser'], False: get_highlighted_icon(GRAPHICS
    ['eraser'])},
        event=CustomEvent(EditorEventType.ERASE_CLICK),
    ),
    'move_button':
    MultipleIconButton(
        parent=blue_pieces_container,
        relative_position=(0, 0),
        relative_size=(0.2, 0.2),
        scale_mode='height',
        box_colours=BLUE_BUTTON_COLOURS,
        icons_dict={True: GRAPHICS['finger'], False: get_highlighted_icon(GRAPHICS
    ['finger'])},
        event=CustomEvent(EditorEventType.MOVE_CLICK),
    ),
    'chessboard':
    Chessboard(
        relative_position=(0, 0),
        relative_width=0.4,
        scale_mode='width',
        anchor_x='center',
        anchor_y='center'
    ),
```

```
    'blue_start_button':
    MultipleIconButton(
        parent=bottom_actions_container,
        relative_position=(0, 0),
        relative_size=(1, 1),
        scale_mode='height',
        anchor_x='right',
        box_colours=BLUE_BUTTON_COLOURS,
        icons_dict={False: get_highlighted_icon(GRAPHICS['pharaoh_0_a']), True:
    GRAPHICS['pharaoh_0_a']},
        event=CustomEvent(EditorEventType.BLUE_START_CLICK)
    ),
    'red_start_button':
    MultipleIconButton(
        parent=bottom_actions_container,
        relative_position=(0, 0),
        relative_size=(1, 1),
        scale_mode='height',
        icons_dict={True: GRAPHICS['pharaoh_1_a'], False: get_highlighted_icon(
    GRAPHICS['pharaoh_1_a'])},
        event=CustomEvent(EditorEventType.RED_START_CLICK)
    )
}

for index, piece in enumerate([piece for piece in Piece if piece != Piece.SPHINX])
    :
    blue_icon = GRAPHICS[f'{piece.name.lower()}_0_a']
    dimmed_blue_icon = get_highlighted_icon(blue_icon)

    EDITOR_WIDGETS['blue_piece_buttons'][piece] = MultipleIconButton(
        parent=blue_pieces_container,
        relative_position=(0, (index + 1) / 5),
        relative_size=(0.2, 0.2),
        scale_mode='height',
        box_colours=BLUE_BUTTON_COLOURS,
        icons_dict={True: blue_icon, False: dimmed_blue_icon},
        event=CustomEvent(EditorEventType.PICK_PIECE_CLICK, piece=piece,
    active_colour=Colour.BLUE)
    )

    red_icon = GRAPHICS[f'{piece.name.lower()}_1_a']

    dimmed_red_icon = get_highlighted_icon(red_icon)

    EDITOR_WIDGETS['red_piece_buttons'][piece] = MultipleIconButton(
        parent=red_pieces_container,
        relative_position=(0, (index + 1) / 5),
        relative_size=(0.2, 0.2),
        scale_mode='height',
        icons_dict={True: red_icon, False: dimmed_red_icon},
        event=CustomEvent(EditorEventType.PICK_PIECE_CLICK, piece=piece,
    active_colour=Colour.RED)
    )
```

## B.16 data\states\game

### B.16.1 game.py

```
import pygame
from functools import partial
from data.states.game.mvc.game_controller import GameController
```

```python
from data.helpers.database_helpers import insert_into_games
from data.states.game.mvc.game_model import GameModel
from data.states.game.mvc.pause_view import PauseView
from data.states.game.mvc.game_view import GameView
from data.states.game.mvc.win_view import WinView
from data.components.game_entry import GameEntry
from data.managers.logs import initialise_logger
from data.managers.window import window
from data.managers.audio import audio
from data.utils.constants import ShaderType
from data.utils.assets import MUSIC, SFX
from data.control import _State

logger = initialise_logger(__name__)

class Game(_State):
    def __init__(self):
        super().__init__()

    def cleanup(self):
        super().cleanup()

        window.clear_apply_arguments(ShaderType.BLOOM)
        window.clear_effect(ShaderType.RAYS)

        game_entry = GameEntry(self.model.states, final_fen_string=self.model.
    get_fen_string())
        inserted_game = insert_into_games(game_entry.convert_to_row())

        return inserted_game

    def switch_to_menu(self):
        self.next = 'menu'
        self.done = True

    def switch_to_review(self):
        self.next = 'review'
        self.done = True

    def startup(self, persist):
        music = MUSIC[['cpu_easy', 'cpu_medium', 'cpu_hard'][persist['CPU_DEPTH']
    - 2]] if persist['CPU_ENABLED'] else MUSIC['pvp']
        super().startup(music=music)

        window.set_apply_arguments(ShaderType.BASE, background_type=ShaderType.
    BACKGROUND_LASERS)
        window.set_apply_arguments(ShaderType.BLOOM, highlight_colours=[(pygame.
    Color('0x95e0cc')).rgb, pygame.Color('0xf14e52').rgb], colour_intensity=0.8)
        binded_startup = partial(self.startup, persist)

        self.model = GameModel(persist)
        self.view = GameView(self.model)
        self.pause_view = PauseView(self.model)
        self.win_view = WinView(self.model)
        self.controller = GameController(self.model, self.view, self.win_view,
    self.pause_view, self.switch_to_menu, self.switch_to_review, binded_startup)

        self.view.draw()

        audio.play_sfx(SFX['game_start_1'])
        audio.play_sfx(SFX['game_start_2'])

```

```
    def get_event(self, event):
        self.controller.handle_event(event)

    def handle_resize(self):
        self.view.handle_resize()
        self.win_view.handle_resize()
        self.pause_view.handle_resize()

    def draw(self):
        self.view.draw()
        self.win_view.draw()
        self.pause_view.draw()

    def update(self):
        self.controller.check_cpu()
        super().update()
```

### B.16.2 widget_dict.py

```
from data.widgets import *
from data.utils.enums import RotationDirection, Colour
from data.components.custom_event import CustomEvent
from data.utils.event_types import GameEventType
from data.utils.assets import GRAPHICS

right_container = Rectangle(
    relative_position=(0.05, 0),
    relative_size=(0.2, 0.5),
    anchor_y='center',
    anchor_x='right',
)

rotate_container = Rectangle(
    relative_position=(0, 0.05),
    relative_size=(0.2, 0.1),
    anchor_x='center',
    anchor_y='bottom',
)

move_list = MoveList(
    parent=right_container,
    relative_position=(0, 0),
    relative_width=1,
    minimum_height=300,
    move_list=[]
)

resign_button = TextButton(
    parent=right_container,
    relative_position=(0, 0),
    relative_size=(0.5, 0.2),
    fit_vertical=False,
    anchor_y='bottom',
    text="   Resign",
    margin=5,
    event=CustomEvent(GameEventType.RESIGN_CLICK)
)

draw_button = TextButton(
    parent=right_container,
    relative_position=(0, 0),
    relative_size=(0.5, 0.2),
```

```
    fit_vertical=False,
    anchor_x='right',
    anchor_y='bottom',
    text="    Draw",
    margin=5,
    event=CustomEvent(GameEventType.DRAW_CLICK)
)

top_right_container = Rectangle(
    relative_position=(0, 0),
    relative_size=(0.225, 0.075),
    fixed_position=(5, 5),
    anchor_x='right',
    scale_mode='height'
)

GAME_WIDGETS = {
    'help':
    Icon(
        relative_position=(0, 0),
        relative_size=(1.02, 1.02),
        icon=GRAPHICS['game_help'],
        anchor_x='center',
        anchor_y='center',
        border_width=0,
        fill_colour=(0, 0, 0, 0)
    ),
    'tutorial':
    Icon(
        relative_position=(0, 0),
        relative_size=(0.9, 0.9),
        icon=GRAPHICS['game_tutorial'],
        anchor_x='center',
        anchor_y='center',
    ),
    'default': [
        right_container,
        rotate_container,
        top_right_container,
        ReactiveIconButton(
            parent=top_right_container,
            relative_position=(0, 0),
            relative_size=(1, 1),
            anchor_x='right',
            scale_mode='height',
            base_icon=GRAPHICS['home_base'],
            hover_icon=GRAPHICS['home_hover'],
            press_icon=GRAPHICS['home_press'],
            event=CustomEvent(GameEventType.MENU_CLICK)
        ),
        ReactiveIconButton(
            parent=top_right_container,
            relative_position=(0, 0),
            relative_size=(1, 1),
            scale_mode='height',
            base_icon=GRAPHICS['tutorial_base'],
            hover_icon=GRAPHICS['tutorial_hover'],
            press_icon=GRAPHICS['tutorial_press'],
            event=CustomEvent(GameEventType.TUTORIAL_CLICK)
        ),
        ReactiveIconButton(
            parent=top_right_container,
```

```
            relative_position=(0.33, 0),
            relative_size=(1, 1),
            scale_mode='height',
            base_icon=GRAPHICS['help_base'],
            hover_icon=GRAPHICS['help_hover'],
            press_icon=GRAPHICS['help_press'],
            event=CustomEvent(GameEventType.HELP_CLICK)
        ),
        ReactiveIconButton(
            parent=rotate_container,
            relative_position=(0, 0),
            relative_size=(1, 1),
            scale_mode='height',
            anchor_x='right',
            base_icon=GRAPHICS['clockwise_arrow_base'],
            hover_icon=GRAPHICS['clockwise_arrow_hover'],
            press_icon=GRAPHICS['clockwise_arrow_press'],
            event=CustomEvent(GameEventType.ROTATE_PIECE, rotation_direction=
    RotationDirection.CLOCKWISE)
        ),
        ReactiveIconButton(
            parent=rotate_container,
            relative_position=(0, 0),
            relative_size=(1, 1),
            scale_mode='height',
            base_icon=GRAPHICS['anticlockwise_arrow_base'],
            hover_icon=GRAPHICS['anticlockwise_arrow_hover'],
            press_icon=GRAPHICS['anticlockwise_arrow_press'],
            event=CustomEvent(GameEventType.ROTATE_PIECE, rotation_direction=
    RotationDirection.ANTICLOCKWISE)
        ),
        resign_button,
        draw_button,
        Icon(
            parent=resign_button,
            relative_position=(0, 0),
            relative_size=(0.75, 0.75),
            fill_colour=(0, 0, 0, 0),
            scale_mode='height',
            anchor_y='center',
            border_radius=0,
            border_width=0,
            margin=5,
            icon=GRAPHICS['resign']
        ),
        Icon(
            parent=draw_button,
            relative_position=(0, 0),
            relative_size=(0.75, 0.75),
            fill_colour=(0, 0, 0, 0),
            scale_mode='height',
            anchor_y='center',
            border_radius=0,
            border_width=0,
            margin=5,
            icon=GRAPHICS['draw']
        ),
    ],
    'scroll_area': # REMEMBER SCROLL AREA AFTER CONTAINER FOR RESIZING
    ScrollArea(
        parent=right_container,
        relative_position=(0, 0),
```

```
        relative_size=(1, 0.8),
        vertical=True,
        widget=move_list
    ),
    'move_list':
        move_list,
    'blue_timer':
    Timer(
        relative_position=(0.05, 0.05),
        anchor_y='center',
        relative_size=(0.1, 0.1),
        active_colour=Colour.BLUE,
        event=CustomEvent(GameEventType.TIMER_END),
    ),
    'red_timer':
    Timer(
        relative_position=(0.05, -0.05),
        anchor_y='center',
        relative_size=(0.1, 0.1),
        active_colour=Colour.RED,
        event=CustomEvent(GameEventType.TIMER_END),
    ),
    'status_text':
    Text(
        relative_position=(0, 0.05),
        relative_size=(0.4, 0.1),
        anchor_x='center',
        fit_vertical=False,
        margin=10,
        text="g",
        minimum_width=400
    ),
    'chessboard':
    Chessboard(
        relative_position=(0, 0),
        anchor_x='center',
        anchor_y='center',
        scale_mode='width',
        relative_width=0.4
    ),
    'blue_piece_display':
    PieceDisplay(
        relative_position=(0.05, 0.05),
        relative_size=(0.2, 0.1),
        anchor_y='bottom',
        active_colour=Colour.BLUE
    ),
    'red_piece_display':
    PieceDisplay(
        relative_position=(0.05, 0.05),
        relative_size=(0.2, 0.1),
        active_colour=Colour.RED
    )
}

PAUSE_WIDGETS = {
    'default': [
        TextButton(
            relative_position=(0, -0.125),
            relative_size=(0.3, 0.2),
            anchor_x='center',
            anchor_y='center',
```

```
            text='GO TO MENU',
            fit_vertical=False,
            event=CustomEvent(GameEventType.MENU_CLICK)
        ),
        TextButton(
            relative_position=(0, 0.125),
            relative_size=(0.3, 0.2),
            anchor_x='center',
            anchor_y='center',
            text='RESUME GAME',
            fit_vertical=False,
            event=CustomEvent(GameEventType.PAUSE_CLICK)
        )
    ]
}

win_container = Rectangle(
    relative_position=(0, 0),
    relative_size=(0.4, 0.8),
    scale_mode='height',
    anchor_x='center',
    anchor_y='center',
    fill_colour=(128, 128, 128, 200),
    visible=True
)

WIN_WIDGETS = {
    'default': [
        win_container,
        TextButton(
            parent=win_container,
            relative_position=(0, 0.5),
            relative_size=(0.8, 0.15),
            text='GO TO MENU',
            anchor_x='center',
            fit_vertical=False,
            event=CustomEvent(GameEventType.MENU_CLICK)
        ),
        TextButton(
            parent=win_container,
            relative_position=(0, 0.65),
            relative_size=(0.8, 0.15),
            text='REVIEW GAME',
            anchor_x='center',
            fit_vertical=False,
            event=CustomEvent(GameEventType.REVIEW_CLICK)
        ),
        TextButton(
            parent=win_container,
            relative_position=(0, 0.8),
            relative_size=(0.8, 0.15),
            text='NEW GAME',
            anchor_x='center',
            fit_vertical=False,
            event=CustomEvent(GameEventType.GAME_CLICK)
        ),
    ],
    'blue_won':
    Icon(
        parent=win_container,
        relative_position=(0, 0.05),
        relative_size=(0.8, 0.3),
```

```
            anchor_x='center',
            border_width=0,
            margin=0,
            icon=GRAPHICS['blue_won'],
            fill_colour=(0, 0, 0, 0),
        ),
        'red_won':
        Icon(
            parent=win_container,
            relative_position=(0, 0.05),
            relative_size=(0.8, 0.3),
            anchor_x='center',
            border_width=0,
            margin=0,
            icon=GRAPHICS['red_won'],
            fill_colour=(0, 0, 0, 0),
            fit_icon=True,
        ),
        'draw_won':
        Icon(
            parent=win_container,
            relative_position=(0, 0.05),
            relative_size=(0.8, 0.3),
            anchor_x='center',
            border_width=0,
            margin=0,
            icon=GRAPHICS['draw_won'],
            fill_colour=(0, 0, 0, 0),
        ),
        'by_checkmate':
        Icon(
            parent=win_container,
            relative_position=(0, 0.375),
            relative_size=(0.8, 0.1),
            anchor_x='center',
            border_width=0,
            margin=0,
            icon=GRAPHICS['by_checkmate'],
            fill_colour=(0, 0, 0, 0),
        ),
        'by_resignation':
        Icon(
            parent=win_container,
            relative_position=(0, 0.375),
            relative_size=(0.8, 0.1),
            anchor_x='center',
            border_width=0,
            margin=0,
            icon=GRAPHICS['by_resignation'],
            fill_colour=(0, 0, 0, 0),
        ),
        'by_draw':
        Icon(
            parent=win_container,
            relative_position=(0, 0.375),
            relative_size=(0.8, 0.1),
            anchor_x='center',
            border_width=0,
            margin=0,
            icon=GRAPHICS['by_draw'],
            fill_colour=(0, 0, 0, 0),
        ),
```

```
    'by_timeout':
    Icon(
        parent=win_container,
        relative_position=(0, 0.375),
        relative_size=(0.8, 0.1),
        anchor_x='center',
        border_width=0,
        margin=0,
        icon=GRAPHICS['by_timeout'],
        fill_colour=(0, 0, 0, 0),
    )
}
```

## 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

```
from data.states.game.components.particles_draw import ParticlesDraw
from data.helpers.board_helpers import coords_to_screen_pos
from data.managers.animation import animation
from data.utils.constants import ShaderType
from data.managers.window import window
from data.utils.enums import Colour

class CaptureDraw:
    def __init__(self, board_position, board_size):
        self._board_position = board_position
        self._square_size = board_size[0] / 10
        self._particles_draw = ParticlesDraw()

    def add_capture(self, piece, colour, rotation, piece_coords, sphinx_coords, active_colour, particles=True, shake=True):
        if particles:
            self._particles_draw.add_captured_piece(
                piece,
                colour,
                rotation,
                coords_to_screen_pos(piece_coords, self._board_position, self._square_size),
                self._square_size
            )
            self._particles_draw.add_sparks(
                3,
                (255, 0, 0) if active_colour == Colour.RED else (0, 0, 255),
                coords_to_screen_pos(sphinx_coords, self._board_position, self._square_size)
            )

        if shake:
            window.set_effect(ShaderType.SHAKE)
```

```python
            animation.set_timer(500, lambda: window.clear_effect(ShaderType.SHAKE))

    def draw(self, screen):
        self._particles_draw.draw(screen)

    def update(self):
        self._particles_draw.update()

    def handle_resize(self, board_position, board_size):
        self._board_position = board_position
        self._square_size = board_size[0] / 10
```

### B.17.4 father.py

```python
import pygame
from data.states.game.components.piece_sprite import PieceSprite
from data.utils.enums import CursorMode
from data.managers.cursor import cursor

DRAG_THRESHOLD = 500

class DragAndDrop:
    def __init__(self, board_position, board_size, change_cursor=True):
        self._board_position = board_position
        self._board_size = board_size
        self._change_cursor = change_cursor
        self._ticks_since_drag = 0

        self.dragged_sprite = None

    def set_dragged_piece(self, piece, colour, rotation):
        sprite = PieceSprite(piece=piece, colour=colour, rotation=rotation)
        sprite.set_geometry((0, 0), self._board_size[0] / 10)
        sprite.set_image()

        self.dragged_sprite = sprite
        self._ticks_since_drag = pygame.time.get_ticks()

        if self._change_cursor:
            cursor.set_mode(CursorMode.CLOSEDHAND)

    def remove_dragged_piece(self):
        self.dragged_sprite = None
        time_dragged = pygame.time.get_ticks() - self._ticks_since_drag
        self._ticks_since_drag = 0

        if self._change_cursor:
            cursor.set_mode(CursorMode.OPENHAND)

        return time_dragged > DRAG_THRESHOLD

    def get_dragged_info(self):
        return self.dragged_sprite.type, self.dragged_sprite.colour, self.dragged_sprite.rotation

    def draw(self, screen):
        if self.dragged_sprite is None:
            return

        self.dragged_sprite.rect.center = pygame.mouse.get_pos()
        screen.blit(self.dragged_sprite.image, self.dragged_sprite.rect.topleft)
```

```python

    def handle_resize(self, board_position, board_size):
        if self.dragged_sprite:
            self.dragged_sprite.set_geometry(board_position, board_size[0] / 10)

        self._board_position = board_position
        self._board_size = board_size
```

### B.17.5 fen_parser.py

```python
from data.helpers.bitboard_helpers import occupied_squares, bitboard_to_index
from data.utils.enums import Colour, RotationIndex, Rotation, Piece
from data.utils.constants import EMPTY_BB

def parse_fen_string(fen_string):
    #sc3ncfcncpb2/2pc7/3Pd6/pa1Pc1rbra1pb1Pd/pb1Pd1RaRb1pa1Pc/6pb3/7Pa2/2PdNaFaNa3Sa b
    piece_bitboards = [{char: EMPTY_BB for char in Piece}, {char: EMPTY_BB for char in Piece}]
    rotation_bitboards = [EMPTY_BB, EMPTY_BB]
    combined_colour_bitboards = [EMPTY_BB, EMPTY_BB]
    combined_all_bitboard = 0
    part_1, part_2 = fen_string.split(' ')

    rank = 7
    file = 0

    piece_count = {char.lower(): 0 for char in Piece} | {char.upper(): 0 for char in Piece}

    for index, character in enumerate(part_1):
        square = rank * 10 + file

        if character.lower() in Piece:
            piece_count[character] += 1
            if character.isupper():
                piece_bitboards[Colour.BLUE][character.lower()] |= 1 << square

            else:
                piece_bitboards[Colour.RED][character.lower()] |= 1 << square

            rotation = part_1[index + 1]
            match rotation:
                case Rotation.UP:
                    pass
                case Rotation.RIGHT:
                    rotation_bitboards[RotationIndex.FIRSTBIT] |= 1 << square
                case Rotation.DOWN:
                    rotation_bitboards[RotationIndex.SECONDBIT] |= 1 << square
                case Rotation.LEFT:
                    rotation_bitboards[RotationIndex.SECONDBIT] |= 1 << square
                    rotation_bitboards[RotationIndex.FIRSTBIT] |= 1 << square
                case _:
                    raise ValueError('Invalid FEN String - piece character not followed by rotational character')

            file += 1
        elif character in '0123456789':
            if character == '1' and fen_string[index + 1] == '0':
                file += 10
                continue

```

```python
            file += int(character)
        elif character == '/':
            rank = rank - 1
            file = 0
        elif character in Rotation:
            continue
        else:
            raise ValueError('Invalid FEN String - invalid character found:', character)

    if piece_count['s'] != 1 or piece_count['S'] != 1:
        raise ValueError('Invalid FEN string - invalid number of Sphinx pieces')
    # COMMENTED OUT AS NO PHARAOH PIECES IS OKAY IF PARSING FEN STRING FOR FINISHED GAME BOARD THUMBNAIL
    elif piece_count['f'] > 1 or piece_count['F'] > 1:
        raise ValueError('Invalid FEN string - invalid number of Pharaoh pieces')

    if part_2 == 'b':
        colour = Colour.BLUE
    elif part_2 == 'r':
        colour = Colour.RED
    else:
        raise ValueError('Invalid FEN string - invalid active colour')

    for piece in Piece:
        combined_colour_bitboards[Colour.BLUE] |= piece_bitboards[Colour.BLUE][piece]
        combined_colour_bitboards[Colour.RED] |= piece_bitboards[Colour.RED][piece]

    combined_all_bitboard = combined_colour_bitboards[Colour.BLUE] | combined_colour_bitboards[Colour.RED]
    return (piece_bitboards, combined_colour_bitboards, combined_all_bitboard, rotation_bitboards, colour)

def encode_fen_string(bitboard_collection):
    blue_bitboards = bitboard_collection.piece_bitboards[Colour.BLUE]
    red_bitboards = bitboard_collection.piece_bitboards[Colour.RED]

    fen_string_list = [''] * 80

    for piece, bitboard in blue_bitboards.items():
        for individual_bitboard in occupied_squares(bitboard):
            index = bitboard_to_index(individual_bitboard)
            rotation = bitboard_collection.get_rotation_on(individual_bitboard)
            fen_string_list[index] = piece.upper() + rotation

    for piece, bitboard in red_bitboards.items():
        for individual_bitboard in occupied_squares(bitboard):
            index = bitboard_to_index(individual_bitboard)
            rotation = bitboard_collection.get_rotation_on(individual_bitboard)
            fen_string_list[index] = piece.lower() + rotation

    fen_string = ''
    row_string = ''
    empty_count = 0
    for index, square in enumerate(fen_string_list):
        if square == '':
            empty_count += 1
        else:
            if empty_count > 0:
                row_string += str(empty_count)
```

```
                empty_count = 0

            row_string += square

        if index % 10 == 9:
            if empty_count > 0:
                fen_string = '/' + row_string + str(empty_count) + fen_string
            else:
                fen_string = '/' + row_string + fen_string

            row_string = ''
            empty_count = 0

    fen_string = fen_string[1:]

    if bitboard_collection.active_colour == Colour.BLUE:
        colour = 'b'
    else:
        colour = 'r'

    return fen_string + ' ' + colour
```

### B.17.6 laser.py

```
from data.utils.constants import A_FILE_MASK, J_FILE_MASK, ONE_RANK_MASK, EIGHT_RANK_MASK, EMPTY_BB
from data.helpers import bitboard_helpers as bb_helpers
from data.utils.enums import Piece, Colour, Rotation

class Laser:
    def __init__(self, bitboards):
        self._bitboards = bitboards
        self.hit_square_bitboard, self.piece_hit, self.laser_path, self.path_bitboard, self.pieces_on_trajectory, self.end_cap = self.calculate_trajectory()

        if (self.hit_square_bitboard != EMPTY_BB):
            self.piece_rotation = self._bitboards.get_rotation_on(self.hit_square_bitboard)
            self.piece_colour = self._bitboards.get_colour_on(self.hit_square_bitboard)

    def calculate_trajectory(self):
        current_square = self._bitboards.get_piece_bitboard(Piece.SPHINX, self._bitboards.active_colour)
        previous_direction = self._bitboards.get_rotation_on(current_square)
        trajectory_bitboard = 0b0
        trajectory_list = []
        square_animation_states = []
        pieces_on_trajectory = []

        while current_square:
            current_piece = self._bitboards.get_piece_on(current_square, Colour.BLUE) or self._bitboards.get_piece_on(current_square, Colour.RED)
            current_rotation = self._bitboards.get_rotation_on(current_square)

            next_square, direction, piece_hit = self.calculate_next_square(current_square, current_piece, current_rotation, previous_direction)

            trajectory_bitboard |= current_square
            trajectory_list.append(bb_helpers.bitboard_to_coords(current_square))
            square_animation_states.append(direction)
```

```python

            if previous_direction != direction or (current_piece == Piece.ANUBIS and not piece_hit):
                pieces_on_trajectory.append(current_square)

            if next_square == EMPTY_BB:
                hit_square_bitboard = 0b0

                if piece_hit:
                    hit_square_bitboard = current_square

                if piece_hit or current_piece == Piece.ANUBIS:
                    end_cap = True
                else:
                    end_cap = False

                return hit_square_bitboard, piece_hit, list(zip(trajectory_list, square_animation_states)), trajectory_bitboard, pieces_on_trajectory, end_cap

            current_square = next_square
            previous_direction = direction

    def calculate_next_square(self, square, piece, rotation, previous_direction):
        match piece:
            case Piece.SPHINX:
                if previous_direction != rotation:
                    return EMPTY_BB, previous_direction, None

                next_square = self.next_square_bitboard(square, rotation)
                return next_square, previous_direction, Piece.SPHINX

            case Piece.PYRAMID:
                if previous_direction in [rotation, rotation.get_clockwise()]:
                    return EMPTY_BB, previous_direction, Piece.PYRAMID

                if previous_direction == rotation.get_anticlockwise():
                    new_direction = previous_direction.get_clockwise()
                else:
                    new_direction = previous_direction.get_anticlockwise()

                next_square = self.next_square_bitboard(square, new_direction)

                return next_square, new_direction, None

            case Piece.ANUBIS:
                if previous_direction == rotation.get_clockwise().get_clockwise():
                    return EMPTY_BB, previous_direction, None

                return EMPTY_BB, previous_direction, Piece.ANUBIS

            case Piece.SCARAB:
                if previous_direction in [rotation.get_clockwise(), rotation.get_anticlockwise()]:
                    new_direction = previous_direction.get_anticlockwise()
                else:
                    new_direction = previous_direction.get_clockwise()

                next_square = self.next_square_bitboard(square, new_direction)

                return next_square, new_direction, None

            case Piece.PHARAOH:
```

```
                    return EMPTY_BB, previous_direction, Piece.PHARAOH

            case None:
                next_square = self.next_square_bitboard(square, previous_direction)

                return next_square, previous_direction, None

    def next_square_bitboard(self, src_bitboard, previous_direction):
        match previous_direction:
            case Rotation.UP:
                masked_src_bitboard = src_bitboard & EIGHT_RANK_MASK
                return masked_src_bitboard << 10
            case Rotation.RIGHT:
                masked_src_bitboard = src_bitboard & J_FILE_MASK
                return masked_src_bitboard << 1
            case Rotation.DOWN:
                masked_src_bitboard = src_bitboard & ONE_RANK_MASK
                return masked_src_bitboard >> 10
            case Rotation.LEFT:
                masked_src_bitboard = src_bitboard & A_FILE_MASK
                return masked_src_bitboard >> 1
```

### B.17.7 laser_draw.py

See Section 3.4.1.

### B.17.8 move.py

```
import re
from data.helpers.bitboard_helpers import notation_to_bitboard, coords_to_bitboard, bitboard_to_coords, bitboard_to_notation
from data.utils.enums import MoveType, Colour, RotationDirection
from data.managers.logs import initialise_logger

logger = initialise_logger(__name__)

class Move():
    def __init__(self, move_type, src, dest=None, rotation_direction=None):
        self.move_type = move_type
        self.src = src
        self.dest = dest
        self.rotation_direction = rotation_direction

    def to_notation(self, colour, piece, hit_square_bitboard):
        hit_square = ''
        if colour == Colour.BLUE:
            piece = piece.upper()

        if hit_square_bitboard:
            hit_square = 'x' + bitboard_to_notation(hit_square_bitboard)

        if self.move_type == MoveType.MOVE:
            return 'M' + piece + bitboard_to_notation(self.src) + bitboard_to_notation(self.dest) + hit_square
        else:
            return 'R' + piece + bitboard_to_notation(self.src) + self.rotation_direction + hit_square

    def __str__(self):
        rotate_text = ''
```

```python
        coords_1 = '(' + chr(bitboard_to_coords(self.src)[0] + 65) + ',' + str(bitboard_to_coords(self.src)[1] + 1) + ')'

        if self.move_type == MoveType.ROTATE:
            rotate_text = ' ' + self.rotation_direction.name
            return f'{self.move_type.name}{rotate_text}: ON {coords_1}'

        elif self.move_type == MoveType.MOVE:
            coords_2 = '(' + chr(bitboard_to_coords(self.dest)[0] + 65) + ', ' + str(bitboard_to_coords(self.dest)[1] + 1) + ')'
            return f'{self.move_type.name}{rotate_text}: FROM {coords_1} TO {coords_2}'

        # (Rotation: {self.rotation_direction})

    @classmethod
    def instance_from_notation(move_cls, notation):
        try:
            notation = notation.split('x')[0]
            move_type = notation[0].lower()

            moves = notation[2:]
            letters = re.findall(r'[A-Za-z]+', moves)
            numbers = re.findall(r'\d+', moves)

            if move_type == MoveType.MOVE:
                src_bitboard = notation_to_bitboard(letters[0] + numbers[0])
                dest_bitboard = notation_to_bitboard(letters[1] + numbers[1])

                return move_cls(move_type, src_bitboard, dest_bitboard)

            elif move_type == MoveType.ROTATE:
                src_bitboard = notation_to_bitboard(letters[0] + numbers[0])
                rotation_direction = RotationDirection(letters[1])

                return move_cls(move_type, src_bitboard, src_bitboard, rotation_direction)
            else:
                raise ValueError('(Move.instance_from_notation) Invalid move type: ', move_type)

        except Exception as error:
            logger.info('(Move.instance_from_notation) Error occured while parsing:', error)
            raise error

    @classmethod
    def instance_from_input(move_cls, move_type, src, dest=None, rotation=None):
        try:
            if move_type == MoveType.MOVE:
                src_bitboard = notation_to_bitboard(src)
                dest_bitboard = notation_to_bitboard(dest)

            elif move_type == MoveType.ROTATE:
                src_bitboard = notation_to_bitboard(src)
                dest_bitboard = src_bitboard

            return move_cls(move_type, src_bitboard, dest_bitboard, rotation)
        except Exception as error:
            logger.info('Error (Move.instance_from):', error)
            raise error
```

```
    @classmethod
    def instance_from_coords(move_cls, move_type, src_coords, dest_coords=None, rotation_direction=None):
        try:
            src_bitboard = coords_to_bitboard(src_coords)
            dest_bitboard = coords_to_bitboard(dest_coords)

            return move_cls(move_type, src_bitboard, dest_bitboard, rotation_direction)
        except Exception as error:
            logger.info('Error (Move.instance_from_coords):', error)
            raise error

    @classmethod
    def instance_from_bitboards(move_cls, move_type, src_bitboard, dest_bitboard=None, rotation_direction=None):
        try:
            return move_cls(move_type, src_bitboard, dest_bitboard, rotation_direction)
        except Exception as error:
            logger.info('Error (Move.instance_from_bitboards):', error)
            raise error
```

### B.17.9 overlay_draw.py

```
import pygame
from data.utils.constants import OVERLAY_COLOUR_LIGHT, OVERLAY_COLOUR_DARK
from data.helpers.board_helpers import coords_to_screen_pos, screen_pos_to_coords, create_square_overlay, create_circle_overlay

class OverlayDraw:
    def __init__(self, board_position, board_size, limit_hover=True):
        self._board_position = board_position
        self._board_size = board_size

        self._hovered_coords = None
        self._selected_coords = None
        self._available_coords = None

        self._limit_hover = limit_hover

        self._selected_overlay = None
        self._hovered_overlay = None
        self._available_overlay = None

        self.initialise_overlay_surfaces()

    @property
    def square_size(self):
        return self._board_size[0] / 10

    def initialise_overlay_surfaces(self):
        self._selected_overlay = create_square_overlay(self.square_size, OVERLAY_COLOUR_DARK)
        self._hovered_overlay = create_square_overlay(self.square_size, OVERLAY_COLOUR_LIGHT)
        self._available_overlay = create_circle_overlay(self.square_size, OVERLAY_COLOUR_LIGHT)

    def set_hovered_coords(self, mouse_pos):
        self._hovered_coords = screen_pos_to_coords(mouse_pos, self._board_position, self._board_size)
```

```

    def set_selected_coords(self, coords):
        self._selected_coords = coords

    def set_available_coords(self, coords_list):
        self._available_coords = coords_list

    def set_hover_limit(self, new_limit):
        self._limit_hover = new_limit

    def draw(self, screen):
        self.set_hovered_coords(pygame.mouse.get_pos())

        if self._selected_coords:
            screen.blit(self._selected_overlay, coords_to_screen_pos(self._selected_coords, self._board_position, self.square_size))

        if self._available_coords:
            for coords in self._available_coords:
                screen.blit(self._available_overlay, coords_to_screen_pos(coords, self._board_position, self.square_size))

        if self._hovered_coords:
            if self._hovered_coords is None:
                return

            if self._limit_hover and ((self._available_coords is None) or (self._hovered_coords not in self._available_coords)):
                return

            screen.blit(self._hovered_overlay, coords_to_screen_pos(self._hovered_coords, self._board_position, self.square_size))

    def handle_resize(self, board_position, board_size):
        self._board_position = board_position
        self._board_size = board_size

        self.initialise_overlay_surfaces()
```

### B.17.10 particles_draw.py

See Section 3.4.2.

### B.17.11 piece_group.py

```
import pygame
from data.states.game.components.piece_sprite import PieceSprite
from data.utils.enums import Colour, Piece

class PieceGroup(pygame.sprite.Group):
    def __init__(self):
        super().__init__()

    def initialise_pieces(self, piece_list, board_position, board_size):
        self.empty()

        for index, piece_and_rotation in enumerate(piece_list):
            x = index % 10
            y = index // 10

```

```
            if piece_and_rotation:
                if piece_and_rotation[0].isupper():
                    colour = Colour.BLUE
                else:
                    colour = Colour.RED

                piece = PieceSprite(piece=Piece(piece_and_rotation[0].lower()), colour=colour, rotation=piece_and_rotation[1])
                piece.set_coords((x, y))
                piece.set_geometry(board_position, board_size[0] / 10)
                piece.set_image()
                self.add(piece)

    def set_geometry(self, board_position, board_size):
        for sprite in self.sprites():
            sprite.set_geometry(board_position, board_size[0] / 10)

    def handle_resize(self, board_position, board_size):
        self.set_geometry(board_position, board_size)

        for sprite in self.sprites():
            sprite.set_image()

    def remove_piece(self, coords):
        for sprite in self.sprites():
            if sprite.coords == coords:
                sprite.kill()
```

### B.17.12 piece_sprite.py

```
import pygame
from data.helpers.board_helpers import coords_to_screen_pos
from data.helpers.asset_helpers import scale_and_cache
from data.utils.assets import GRAPHICS
from data.utils.enums import Piece

class PieceSprite(pygame.sprite.Sprite):
    def __init__(self, piece, colour, rotation):
        super().__init__()
        self.colour = colour
        self.rotation = rotation

        self.type = piece
        self.coords = None
        self.size = None

    @property
    def image_name(self):
        return Piece(self.type).name.lower() + '_' + str(self.colour) + '_' + self.rotation

    def set_image(self):
        self.image = scale_and_cache(GRAPHICS[self.image_name], (self.size, self.size))

    def set_geometry(self, new_position, square_size):
        self.size = square_size
        self.rect = pygame.FRect((0, 0, square_size, square_size))

        if self.coords:
            self.rect.topleft = coords_to_screen_pos(self.coords, new_position, square_size)
```

```
        else:
            self.rect.topleft = new_position

    def set_coords(self, new_coords):
        self.coords = new_coords
```

### B.17.13 psqt.py

```
from data.utils.enums import Piece

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

PSQT = {
    Piece.PYRAMID: [
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
    ],
    Piece.ANUBIS: [
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        6, 6, 6, 6, 6, 6, 6, 6, 6, 6,
        4, 4, 4, 4, 4, 4, 4, 4, 4, 4,
        2, 2, 2, 2, 2, 2, 2, 2, 2, 2,
    ],
    Piece.SCARAB: [
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 1, 1, 1, 1, 1, 1, 0, 0,
        0, 0, 1, 2, 2, 2, 2, 1, 0, 0,
        0, 0, 1, 2, 3, 3, 2, 1, 0, 0,
        0, 0, 1, 2, 3, 3, 2, 1, 0, 0,
        0, 0, 1, 2, 2, 2, 2, 1, 0, 0,
        0, 0, 1, 1, 1, 1, 1, 1, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
    ],
    Piece.PHARAOH: [
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 2, 2, 2, 2, 0, 0, 0,
        0, 0, 0, 2, 4, 4, 2, 0, 0, 0,
    ],
```

```
}
```

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

### B.18.1 base.py

```
import time
from pprint import PrettyPrinter
from data.utils.enums import Colour, Score, Miscellaneous
from data.states.game.cpu.evaluator import Evaluator
from data.managers.logs import initialise_logger

logger = initialise_logger(__name__)
printer = PrettyPrinter(indent=2, sort_dicts=False)

class BaseCPU:
    def __init__(self, callback, verbose=True):
        self._evaluator = Evaluator(verbose=False)
        self._verbose = verbose
        self._callback = callback
        self._stats = {}

    def initialise_stats(self):
        self._stats = {
            'nodes': 0,
            'leaf_nodes' : 0,
            'draws': 0,
            'mates': 0,
            'ms_per_node': 0,
            'time_taken': time.time()
        }

    def print_stats(self, score, move):
        """
        Prints statistics after traversing tree.

        Args:
            score (int): Final score obtained after traversal.
            move (Move): Best move obtained after traversal.
        """
        if self._verbose is False:
            return

        self._stats['time_taken'] = round(1000 * (time.time() - self._stats['time_taken']), 3)
        self._stats['ms_per_node'] = round(self._stats['time_taken'] / self._stats['nodes'], 3)

        # Prints stats across multiple lines
        if self._verbose is True:
            logger.info(f'\n\n'
                        f'{self.__str__()} Search Results:\n'
                        f'{printer.pformat(self._stats)}\n'
                        f'Best score: {score}   Best move: {move}\n'
                        )

        # Prints stats in a compacted format
        elif self._verbose.lower() == 'compact':
            logger.info(self._stats)
            logger.info(f'Best score: {score}   Best move: {move}')

```

```python
    def find_move(self, board, stop_event=None):
        raise NotImplementedError

    def search(self, board, depth, stop_event, absolute=False, **kwargs):
        if stop_event and stop_event.is_set():
            raise TimeoutError(f'Thread killed - stopping minimax function ({self.__str__}.search)')

        self._stats['nodes'] += 1

        if (winner := board.check_win()) is not None:
            self._stats['leaf_nodes'] += 1
            return self.process_win(winner, depth, absolute)

        if depth == 0:
            self._stats['leaf_nodes'] += 1
            return self._evaluator.evaluate(board, absolute), None

    def process_win(self, winner, depth, absolute):
        self._stats['leaf_nodes'] += 1

        if winner == Miscellaneous.DRAW:
            self._stats['draws'] += 1
            return 0, None
        elif winner == Colour.BLUE or absolute:
            self._stats['mates'] += 1
            return Score.CHECKMATE + depth, None
        elif winner == Colour.RED:
            self._stats['mates'] += 1
            return -Score.CHECKMATE - depth, None

    def __str__(self):
        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

```python
from data.states.game.cpu.evaluator import Evaluator

class SimpleEvaluator:
    def __init__(self):
        self._evaluator = Evaluator(verbose=False)
        self._cache = {}

    def evaluate(self, board):
        if (hashed := board.to_hash()) in self._cache:
            return self._cache[hashed]

        score = self._evaluator.evaluate_material(board, board.get_active_colour())
        self._cache[hashed] = score

        return score
```

```python

class MoveOrderer:
    def __init__(self):
        self._evaluator = SimpleEvaluator()

    # def get_eval(self, board, move):
    #     laser_result = board.apply_move(move)
    #     score = self._evaluator.evaluate(board)
    #     board.undo_move(move, laser_result)
    #     return score

    # def score_moves(self, board, moves):
    #     for i in range(len(moves)):
    #         score = self.get_eval(board, moves[i])
    #         moves[i] = (moves[i], score)

    #     return moves

    def best_move_to_front(self, moves, start_idx, laser_coords):
        for i in range(start_idx + 1, len(moves)):
            if moves[i].src in laser_coords:
                moves[i], moves[start_idx] = moves[start_idx], moves[i]
                return

    def get_moves(self, board, hint=None, laser_coords=None):
        if hint:
            yield hint

        colour = board.get_active_colour()
        moves = list(board.generate_all_moves(colour))

        for i in range(len(moves)):
            if laser_coords:
                self.best_move_to_front(moves, i, laser_coords)

            yield moves[i]
```

### B.18.5 temp.py

```python
from data.utils.constants import Score, Colour
from data.states.game.cpu.base import BaseCPU
from pprint import pprint

class MinimaxCPU(BaseCPU):
    def __init__(self, max_depth, callback, verbose):
        super().__init__(callback, verbose)
        self._max_depth = max_depth

    def find_move(self, board, stop_event):
        # No bit_length bug as None type returned, so Move __str__ called on
    NoneType I think (just deal with None being returned)
        try:
            best_move = self.search(board, self._max_depth, -Score.INFINITE, Score
    .INFINITE, stop_event)

            if self._verbose:
                print('\nCPU Search Results:')
                pprint(self._stats)
                print('Best move:', best_move, '\n')

                self._callback(self._best_move)
        except Exception as error:
```

```
            print('(MinimaxBase.find_move) Error has occured:')
            raise error

    def search(self, board, depth, alpha, beta, stop_event):
        if stop_event.is_set():
            raise Exception('Thread killed - stopping minimax function (CPU.minimax)')

        # cached_move, cached_score = self._transposition_table.get_entry(hash_key=board.bitboards.get_hash(), depth=depth, alpha=alpha, beta=beta)
        # if cached_move or cached_score:
        #     if depth == self._max_depth:
        #         self._best_move = cached_move
        #     return cached_score


        if depth == 0:
            return self.evaluate(board)

        is_maximiser = board.get_active_colour() == Colour.BLUE

        if is_maximiser:
            score = -Score.INFINITE

            for move in board.generate_all_moves(board.get_active_colour()):
                before, before_score = board.bitboards.get_rotation_string(), self.evaluate(board)

                laser_result = board.apply_move(move)
                new_score = self.minimax(board, depth - 1, alpha, beta, False, stop_event)

                if new_score >= score:
                    score = new_score

                    if depth == self._max_depth:
                        self._best_move = move

                board.undo_move(move, laser_result)

                alpha = max(alpha, score)
                if depth == self._max_depth: # https://stackoverflow.com/questions/31429974/alphabeta-pruning-alpha-equals-or-greater-than-beta-why-equals
                    if beta < alpha:
                        break
                else:
                    if beta <= alpha:
                        break

                after, after_score = board.bitboards.get_rotation_string(), self.evaluate(board)
                if (before != after or before_score != after_score):
                    print('shit\n\n')

            return score

        else:
            score = Score.INFINITE

            for move in board.generate_all_moves(board.get_active_colour()):
                bef, before_score = board.bitboards.get_rotation_string(), self.evaluate(board)
```

```python

                laser_result = board.apply_move(move)
                new_score = self.minimax(board, depth - 1, alpha, beta, False, stop_event)

                if new_score <= score:
                    score = new_score
                    if depth == self._max_depth:
                        self._best_move = move

                board.undo_move(move, laser_result)

                beta = min(beta, score)
                if depth == self._max_depth:
                    if beta < alpha:
                        break
                else:
                    if beta <= alpha:
                        break

                after, after_score = board.bitboards.get_rotation_string(), self.evaluate(board)
                if (bef != after or before_score != after_score):
                    print('shit\n\n')
                    raise ValueError

            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

```python
from random import choice
from data.states.game.cpu.engines.transposition_table import TranspositionTableMixin
```

```python
from data.states.game.cpu.engines.iterative_deepening import IterativeDeepeningMixin
from data.states.game.cpu.base import BaseCPU
from data.utils.enums import Score

class NegamaxCPU(BaseCPU):
    def __init__(self, max_depth, callback, verbose=False):
        super().__init__(callback, verbose)
        self._max_depth = max_depth

    def find_move(self, board, stop_event):
        self.initialise_stats()
        best_score, best_move = self.search(board, self._max_depth, stop_event)

        if self._verbose:
            self.print_stats(best_score, best_move)

        self._callback(best_move)

    def search(self, board, depth, stop_event, moves=None):
        if (base_case := super().search(board, depth, stop_event, absolute=True)):
            return base_case

        best_move = None
        best_score = -Score.INFINITE

        for move in board.generate_all_moves(board.get_active_colour()):
            laser_result = board.apply_move(move)

            new_score = self.search(board, depth - 1, stop_event)[0]
            new_score = -new_score

            if new_score > best_score:
                best_score = new_score
                best_move = move
            elif new_score == best_score:
                best_move = choice([best_move, move])

            board.undo_move(move, laser_result)

        return best_score, best_move

class ABNegamaxCPU(BaseCPU):
    def __init__(self, max_depth, callback, verbose=True):
        super().__init__(callback, verbose)
        self._max_depth = max_depth

    def initialise_stats(self):
        """Initialises the statistics for the search."""
        super().initialise_stats()
        self._stats['beta_prunes'] = 0

    def find_move(self, board, stop_event):
        """Finds the best move for the current board state.

        Args:
            board (Board): The current board state.
            stop_event (threading.Event): The event to signal stopping the search.
        """
        self.initialise_stats()
        best_score, best_move = self.search(board, self._max_depth, -Score.INFINITE, Score.INFINITE, stop_event)
```

```

        if self._verbose:
            self.print_stats(best_score, best_move)

        self._callback(best_move)

    def search(self, board, depth, alpha, beta, stop_event):
        """Searches for the best move using the Alpha-Beta Negamax algorithm.

        Args:
            board (Board): The current board state.
            depth (int): The current depth in the game tree.
            alpha (int): The alpha value for pruning.
            beta (int): The beta value for pruning.
            stop_event (threading.Event): The event to signal stopping the search.

        Returns:
            tuple: The best score and the best move found.
        """
        if (base_case := super().search(board, depth, stop_event, absolute=True)):
            return base_case

        best_move = None
        best_score = alpha

        for move in board.generate_all_moves(board.get_active_colour()):
            laser_result = board.apply_move(move)

            new_score = self.search(board, depth - 1, -beta, -best_score, stop_event)[0]
            new_score = -new_score

            if new_score > best_score:
                best_score = new_score
                best_move = move
            elif new_score == best_score:
                best_move = choice([best_move, move])

            board.undo_move(move, laser_result)

            if best_score >= beta:
                self._stats['beta_prunes'] += 1
                break

        return best_score, best_move

class TTNegamaxCPU(TranspositionTableMixin, ABNegamaxCPU):
    def initialise_stats(self):
        """Initialises the statistics for the search."""
        super().initialise_stats()
        self._stats['cache_hits'] = 0

    def print_stats(self, score, move):
        """Prints the statistics for the search.

        Args:
            score (int): The best score found.
            move (Move): The best move found.
        """
        self._stats['cache_hits_percentage'] = round(self._stats['cache_hits'] / self._stats['nodes'], 3)
        self._stats['cache_entries'] = len(self._table._table)
```

```
        super().print_stats(score, move)

class IDNegamaxCPU(TranspositionTableMixin, IterativeDeepeningMixin, ABNegamaxCPU):
    def initialise_stats(self):
        """Initialises the statistics for the search."""
        super().initialise_stats()
        self._stats['cache_hits'] = 0

    def print_stats(self, score, move):
        """Prints the statistics for the search.

        Args:
            score (int): The best score found.
            move (Move): The best move found.
        """
        self._stats['cache_hits_percentage'] = self._stats['cache_hits'] / self._stats['nodes']
        self._stats['cache_entries'] = len(self._table._table)
        super().print_stats(score, move)
```

### B.19.5 simple.py

```
from data.states.game.cpu.base import BaseCPU
from data.utils.enums import Colour, Score

class SimpleCPU(BaseCPU):
    def __init__(self, callback, verbose=True):
        super().__init__(callback, verbose)

    def find_move(self, board, stop_event=None):
        self.initialise_stats()
        best_score, best_move = self.search(board, stop_event)

        if self._verbose:
            self.print_stats(best_score, best_move)

        self._callback(best_move)

    def search(self, board, stop_event):
        if stop_event and stop_event.is_set():
            raise Exception('Thread killed - stopping simple function (SimpleCPU.search)')

        active_colour = board.bitboards.active_colour
        best_score = -Score.INFINITE if active_colour == Colour.BLUE else Score.INFINITE
        best_move = None

        for move in board.generate_all_moves(active_colour):
            laser_result = board.apply_move(move)

            self._stats['nodes'] += 1

            if winner := board.check_win() is not None:
                self.process_win(winner)
            else:
                self._stats['leaf_nodes'] += 1

            score = self._evaluator.evaluate(board)

```

```python
            if (active_colour == Colour.BLUE and score > best_score) or (
    active_colour == Colour.RED and score < best_score):
                best_move = move
                best_score = score

            board.undo_move(move, laser_result)

        return best_score, best_move
```

### B.19.6 transposition_table.py

See Section 3.6.3.

### B.19.7 __init__.py

```python
from data.states.game.cpu.engines.simple import SimpleCPU
from data.states.game.cpu.engines.negamax import NegamaxCPU
from data.states.game.cpu.engines.minimax import MinimaxCPU
from data.states.game.cpu.engines.alpha_beta import ABMinimaxCPU
from data.states.game.cpu.engines.iterative_deepening import IDMinimaxCPU
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

```python
import pygame
from data.states.game.widget_dict import PAUSE_WIDGETS
from data.components.widget_group import WidgetGroup
from data.utils.event_types import GameEventType
from data.utils.constants import PAUSE_COLOUR
from data.managers.window import window
from data.managers.audio import audio

class PauseView:
    def __init__(self, model):
        self._model = model

        self._screen_overlay = pygame.Surface(window.size, pygame.SRCALPHA)
        self._screen_overlay.fill(PAUSE_COLOUR)

        self._widget_group = WidgetGroup(PAUSE_WIDGETS)
        self._widget_group.handle_resize(window.size)

```

```
        self._model.register_listener(self.process_model_event, 'pause')

        self._event_to_func_map = {
            GameEventType.PAUSE_CLICK: self.handle_pause_click
        }

        self.states = {
            'PAUSED': False
        }

    def handle_pause_click(self, event):
        self.states['PAUSED'] = not self.states['PAUSED']

        if self.states['PAUSED']:
            audio.pause_sfx()
        else:
            audio.unpause_sfx()

    def handle_resize(self):
        self._screen_overlay = pygame.Surface(window.size, pygame.SRCALPHA)
        self._screen_overlay.fill(PAUSE_COLOUR)
        self._widget_group.handle_resize(window.size)

    def draw(self):
        if self.states['PAUSED']:
            window.screen.blit(self._screen_overlay, (0, 0))
            self._widget_group.draw()

    def process_model_event(self, event):
        try:
            self._event_to_func_map.get(event.type)(event)
        except:
            raise KeyError('Event type not recognized in Paused View (PauseView.
    process_model_event)', event)

    def convert_mouse_pos(self, event):
        return self._widget_group.process_event(event)
```

### B.20.5 win_view.py

```
from data.utils.enums import Colour, Miscellaneous, CursorMode
from data.components.widget_group import WidgetGroup
from data.states.game.widget_dict import WIN_WIDGETS
from data.managers.window import window
from data.managers.cursor import cursor

class WinView:
    def __init__(self, model):
        self._model = model

        self._widget_group = WidgetGroup(WIN_WIDGETS)
        self._widget_group.handle_resize(window.size)

    def handle_resize(self):
        self._widget_group.handle_resize(window.size)

    def draw(self):
        if self._model.states['WINNER'] is not None:
            if cursor.get_mode() != CursorMode.ARROW:
                cursor.set_mode(CursorMode.ARROW)

            if self._model.states['WINNER'] == Colour.BLUE:
```

```
                WIN_WIDGETS['red_won'].kill()
                WIN_WIDGETS['draw_won'].kill()
            elif self._model.states['WINNER'] == Colour.RED:
                WIN_WIDGETS['blue_won'].kill()
                WIN_WIDGETS['draw_won'].kill()
            elif self._model.states['WINNER'] == Miscellaneous.DRAW:
                WIN_WIDGETS['red_won'].kill()
                WIN_WIDGETS['blue_won'].kill()

            self._widget_group.draw()

    def set_win_type(self, win_type):
        WIN_WIDGETS['by_draw'].kill()
        WIN_WIDGETS['by_timeout'].kill()
        WIN_WIDGETS['by_resignation'].kill()
        WIN_WIDGETS['by_checkmate'].kill()

        match win_type:
            case 'CAPTURE':
                self._widget_group.add(WIN_WIDGETS['by_checkmate'])
            case 'DRAW':
                self._widget_group.add(WIN_WIDGETS['by_draw'])
            case 'RESIGN':
                self._widget_group.add(WIN_WIDGETS['by_resignation'])
            case 'TIME':
                self._widget_group.add(WIN_WIDGETS['by_timeout'])

    def convert_mouse_pos(self, event):
        return self._widget_group.process_event(event)
```

## B.21 data\states\menu

### B.21.1 menu.py

```
import pygame
import sys
from random import randint
from data.helpers.asset_helpers import get_rotational_angle
from data.helpers.asset_helpers import scale_and_cache
from data.states.menu.widget_dict import MENU_WIDGETS
from data.utils.assets import GRAPHICS, MUSIC, SFX
from data.managers.logs import initialise_logger
from data.utils.event_types import MenuEventType
from data.managers.animation import animation
from data.utils.constants import ShaderType
from data.managers.window import window
from data.managers.audio import audio
from data.control import _State

logger = initialise_logger(__file__)

class Menu(_State):
    def __init__(self):
        super().__init__()
        self._fire_laser = False
        self._bloom_mask = None
        self._laser_mask = None

    def cleanup(self):
        super().cleanup()

```

```
        window.clear_apply_arguments(ShaderType.BLOOM)
        window.clear_apply_arguments(ShaderType.SHAKE)
        window.clear_effect(ShaderType.CHROMATIC_ABBREVIATION)

        return None

    def startup(self, persist=None):
        super().startup(MENU_WIDGETS, music=MUSIC[f'menu_{randint(1, 3)}'])
        window.set_apply_arguments(ShaderType.BASE, background_type=ShaderType.BACKGROUND_BALATRO)
        window.set_effect(ShaderType.CHROMATIC_ABBREVIATION)

        MENU_WIDGETS['credits'].kill()

        self._fire_laser = False
        self._bloom_mask = None
        self._laser_mask = None

        self.draw()
        self.update_masks()

    @property
    def sphinx_center(self):
        return (window.size[0] - self.sphinx_size[0] / 2, window.size[1] - self.sphinx_size[1] / 2)

    @property
    def sphinx_size(self):
        return (min(window.size) * 0.1, min(window.size) * 0.1)

    @property
    def sphinx_rotation(self):
        mouse_pos = (pygame.mouse.get_pos()[0], pygame.mouse.get_pos()[1] + 0.01)
        return -get_rotational_angle(mouse_pos, self.sphinx_center)

    def get_event(self, event):
        if event.type in [pygame.MOUSEBUTTONUP, pygame.KEYDOWN]:
            MENU_WIDGETS['credits'].kill()

        if event.type == pygame.MOUSEBUTTONDOWN:
            self._fire_laser = True
            audio.play_sfx(SFX['menu_laser_windup'])
            audio.play_sfx(SFX['menu_laser_loop'], loop=True)
            animation.set_timer(SFX['menu_laser_loop'].get_length() * 1000 / 2, lambda: audio.play_sfx(SFX['menu_laser_loop'], loop=True) if self._fire_laser else ...) # Overlap two loops of sfx to hide transition

        elif event.type == pygame.MOUSEBUTTONUP:
            self._fire_laser = False

            window.clear_effect(ShaderType.RAYS)
            animation.set_timer(300, lambda: window.clear_effect(ShaderType.SHAKE))
            audio.stop_sfx(1000)

        widget_event = self._widget_group.process_event(event)

        if widget_event is None:
            return

        match widget_event.type:
            case None:
```

```
                return

            case MenuEventType.CONFIG_CLICK:
                self.next = 'config'
                self.done = True
            case MenuEventType.SETTINGS_CLICK:
                self.next = 'settings'
                self.done = True
            case MenuEventType.BROWSER_CLICK:
                self.next = 'browser'
                self.done = True
            case MenuEventType.QUIT_CLICK:
                pygame.quit()
                sys.exit()
                logger.info('quitting...')
            case MenuEventType.CREDITS_CLICK:
                self._widget_group.add(MENU_WIDGETS['credits'])

    def draw_sphinx(self):
        sphinx_surface = scale_and_cache(GRAPHICS['sphinx_0_b'], self.sphinx_size)
        sphinx_surface = pygame.transform.rotate(sphinx_surface, self.
    sphinx_rotation)
        sphinx_rect = pygame.FRect(0, 0, *self.sphinx_size)
        sphinx_rect.center = self.sphinx_center

        window.screen.blit(sphinx_surface, sphinx_rect)

    def update_masks(self):
        self.draw()

        widget_mask = window.screen.copy()
        laser_mask = pygame.mask.from_surface(widget_mask)
        laser_mask = laser_mask.to_surface(setcolor=(255, 0, 0, 255), unsetcolor
    =(0, 0, 0, 255))
        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)
    )
        pygame.draw.rect(widget_mask, (0, 0, 0, 255), (window.screen.width - 50,
    0, 50, 50))

        self._bloom_mask = widget_mask
        self._laser_mask = laser_mask

    def draw(self):
        self._widget_group.draw()
        self.draw_sphinx()

        if self._fire_laser:
            window.set_apply_arguments(ShaderType.RAYS, occlusion=self._laser_mask
    , softShadow=0.1)

        window.set_apply_arguments(ShaderType.BLOOM, highlight_surface=self.
    _bloom_mask, surface_intensity=0.3, brightness_intensity=0.6)

    def update(self, **kwargs):
        random_offset = lambda: randint(-5, 5) / 40
        if self._fire_laser:
            window.clear_effect(ShaderType.RAYS)
            window.set_effect(ShaderType.RAYS, lights=[[
                (self.sphinx_center[0] / window.size[0], self.sphinx_center[1] /
    window.size[1]),
                2.2,
```

```
                    (190, 190, 255),
                    0.99,
                    (self.sphinx_rotation - 2 + random_offset(), self.sphinx_rotation + 2 + random_offset())
                ]])

                window.set_effect(ShaderType.SHAKE)
                window.set_apply_arguments(ShaderType.SHAKE, intensity=1)
                pygame.mouse.set_pos(pygame.mouse.get_pos()[0] + random_offset(), pygame.mouse.get_pos()[1] + random_offset())

        super().update(**kwargs)

    def handle_resize(self):
        super().handle_resize()
        self.update_masks()
```

### B.21.2 widget_dict.py

```
from data.components.custom_event import CustomEvent
from data.utils.event_types import MenuEventType
from data.utils.assets import GRAPHICS
from data.managers.theme import theme
from data.widgets import *

top_right_container = Rectangle(
    relative_position=(0, 0),
    relative_size=(0.15, 0.075),
    fixed_position=(5, 5),
    anchor_x='right',
    scale_mode='height'
)

MENU_WIDGETS = {
    'credits':
    Icon(
        relative_position=(0, 0),
        relative_size=(0.7, 0.7),
        icon=GRAPHICS['credits'],
        anchor_x='center',
        anchor_y='center',
        margin=50
    ),
    'default': [
        top_right_container,
        Rectangle(
            relative_position=(0.65, 0.15),
            relative_size=(0.15, 0.15),
            scale_mode='height',
            border_width=0,
            border_radius=50,
            fill_colour=theme['fillSecondary'],
            visible=True
        ),
        Rectangle(
            relative_position=(0.8, 0.1),
            relative_size=(0.10, 0.10),
            scale_mode='height',
            border_width=0,
            border_radius=100,
            fill_colour=theme['fillSecondary'],
            visible=True
```

```
        ),
        Rectangle(
            relative_position=(0.5, 0.1),
            relative_size=(0.20, 0.20),
            scale_mode='height',
            border_width=0,
            border_radius=10,
            fill_colour=theme['fillSecondary'],
            visible=True
        ),
        Rectangle(
            relative_position=(0.9, 0.2),
            relative_size=(0.15, 0.15),
            scale_mode='height',
            border_width=0,
            border_radius=20,
            fill_colour=theme['fillSecondary'],
            visible=True
        ),
        Rectangle(
            relative_position=(0.85, 0.4),
            relative_size=(0.20, 0.20),
            scale_mode='height',
            border_width=0,
            border_radius=30,
            fill_colour=theme['fillSecondary'],
            visible=True
        ),
        Rectangle(
            relative_position=(0.7, 0.4),
            relative_size=(0.10, 0.10),
            scale_mode='height',
            border_width=0,
            border_radius=50,
            fill_colour=theme['fillSecondary'],
            visible=True
        ),
        ReactiveIconButton(
            parent=top_right_container,
            relative_position=(0, 0),
            relative_size=(1, 1),
            anchor_x='right',
            scale_mode='height',
            base_icon=GRAPHICS['quit_base'],
            hover_icon=GRAPHICS['quit_hover'],
            press_icon=GRAPHICS['quit_press'],
            event=CustomEvent(MenuEventType.QUIT_CLICK)
        ),
        ReactiveIconButton(
            parent=top_right_container,
            relative_position=(0, 0),
            relative_size=(1, 1),
            scale_mode='height',
            base_icon=GRAPHICS['credits_base'],
            hover_icon=GRAPHICS['credits_hover'],
            press_icon=GRAPHICS['credits_press'],
            event=CustomEvent(MenuEventType.CREDITS_CLICK)
        ),
        ReactiveIconButton(
            relative_position=(0.05, -0.2),
            relative_size=(0, 0.15),
            anchor_y='center',
```

```
            base_icon=GRAPHICS['play_text_base'],
            hover_icon=GRAPHICS['play_text_hover'],
            press_icon=GRAPHICS['play_text_press'],
            event=CustomEvent(MenuEventType.CONFIG_CLICK)
        ),
        ReactiveIconButton(
            relative_position=(0.05, 0),
            relative_size=(0, 0.15),
            anchor_y='center',
            base_icon=GRAPHICS['review_text_base'],
            hover_icon=GRAPHICS['review_text_hover'],
            press_icon=GRAPHICS['review_text_press'],
            event=CustomEvent(MenuEventType.BROWSER_CLICK)
        ),
        ReactiveIconButton(
            relative_position=(0.05, 0.2),
            relative_size=(0, 0.15),
            anchor_y='center',
            base_icon=GRAPHICS['settings_text_base'],
            hover_icon=GRAPHICS['settings_text_hover'],
            press_icon=GRAPHICS['settings_text_press'],
            event=CustomEvent(MenuEventType.SETTINGS_CLICK)
        ),
        # Icon(
        #     relative_position=(0.0, 0.1),
        #     relative_size=(0.3, 0.2),
        #     anchor_x='center',
        #     fill_colour=theme['fillSecondary'],
        #     icon=GRAPHICS['title_screen_art'],
        #     stretch=False
        # ),
    ]
}

# Widgets used for testing light rays effect
TEST_WIDGETS = {
    'default': [
        Rectangle(
            relative_position=(0.4, 0.2),
            relative_size=(0.1, 0.1),
            scale_mode='height',
            visible=True,
            border_width=0,
            fill_colour=(255, 0, 0),
            border_radius=1000
        ),
        Rectangle(
            relative_position=(0.5, 0.7),
            relative_size=(0.1, 0.1),
            scale_mode='height',
            visible=True,
            border_width=0,
            fill_colour=(255, 0, 0),
            border_radius=1000
        ),
        Rectangle(
            relative_position=(0.6, 0.6),
            relative_size=(0.2, 0.2),
            scale_mode='height',
            visible=True,
            border_width=0,
            fill_colour=(255, 0, 0),
```

```
            border_radius=1000
        ),
        Rectangle(
            relative_position=(0.4, 0.6),
            relative_size=(0.1, 0.1),
            scale_mode='height',
            visible=True,
            border_width=0,
            fill_colour=(255, 0, 0),
            border_radius=1000
        ),
        Rectangle(
            relative_position=(0.6, 0.4),
            relative_size=(0.1, 0.1),
            scale_mode='height',
            visible=True,
            border_width=0,
            fill_colour=(255, 0, 0),
            border_radius=1000
        ),
        Rectangle(
            relative_position=(0.3, 0.4),
            relative_size=(0.1, 0.1),
            scale_mode='height',
            visible=True,
            border_width=0,
            fill_colour=(255, 0, 0),
            border_radius=1000
        ),
        Rectangle(
            relative_position=(0.475, 0.15),
            relative_size=(0.2, 0.2),
            scale_mode='height',
            visible=True,
            border_width=0,
            fill_colour=(255, 0, 0),
            border_radius=1000
        ),
        Rectangle(
            relative_position=(0.6, 0.2),
            relative_size=(0.1, 0.1),
            scale_mode='height',
            visible=True,
            border_width=0,
            fill_colour=(255, 0, 0),
            border_radius=1000
        )
    ]
}
```

## B.22 data\states\review

### B.22.1 review.py

See Section 3.7.1.

### B.22.2 widget_dict.py

```
from data.widgets import *
from data.components.custom_event import CustomEvent
```

```
from data.utils.event_types import ReviewEventType
from data.utils.assets import GRAPHICS
from data.utils.enums import Colour

MOVE_LIST_WIDTH = 0.2

right_container = Rectangle(
    relative_position=(0.05, 0),
    relative_size=(0.2, 0.7),
    anchor_y='center',
    anchor_x='right'
)

info_container = Rectangle(
    parent=right_container,
    relative_position=(0, 0.5),
    relative_size=(1, 0.5),
    visible=True
)

arrow_container = Rectangle(
    relative_position=(0, 0.05),
    relative_size=(0.4, 0.1),
    anchor_x='center',
    anchor_y='bottom'
)

move_list = MoveList(
    parent=right_container,
    relative_position=(0, 0),
    relative_width=1,
    minimum_height=300,
    move_list=[]
)

top_right_container = Rectangle(
    relative_position=(0, 0),
    relative_size=(0.15, 0.075),
    fixed_position=(5, 5),
    anchor_x='right',
    scale_mode='height'
)

REVIEW_WIDGETS = {
    'help':
    Icon(
        relative_position=(0, 0),
        relative_size=(1.02, 1.02),
        icon=GRAPHICS['review_help'],
        anchor_x='center',
        anchor_y='center',
        border_width=0,
        fill_colour=(0, 0, 0, 0)
    ),
    'default': [
        arrow_container,
        right_container,
        info_container,
        top_right_container,
        ReactiveIconButton(
            parent=top_right_container,
            relative_position=(0, 0),
```

```
            relative_size=(1, 1),
            anchor_x='right',
            scale_mode='height',
            base_icon=GRAPHICS['home_base'],
            hover_icon=GRAPHICS['home_hover'],
            press_icon=GRAPHICS['home_press'],
            event=CustomEvent(ReviewEventType.MENU_CLICK)
        ),
        ReactiveIconButton(
            parent=top_right_container,
            relative_position=(0, 0),
            relative_size=(1, 1),
            scale_mode='height',
            base_icon=GRAPHICS['help_base'],
            hover_icon=GRAPHICS['help_hover'],
            press_icon=GRAPHICS['help_press'],
            event=CustomEvent(ReviewEventType.HELP_CLICK)
        ),
        ReactiveIconButton(
            parent=arrow_container,
            relative_position=(0, 0),
            relative_size=(1, 1),
            scale_mode='height',
            base_icon=GRAPHICS['left_arrow_filled_base'],
            hover_icon=GRAPHICS['left_arrow_filled_hover'],
            press_icon=GRAPHICS['left_arrow_filled_press'],
            event=CustomEvent(ReviewEventType.PREVIOUS_CLICK)
        ),
        ReactiveIconButton(
            parent=arrow_container,
            relative_position=(0, 0),
            relative_size=(1, 1),
            scale_mode='height',
            anchor_x='right',
            base_icon=GRAPHICS['right_arrow_filled_base'],
            hover_icon=GRAPHICS['right_arrow_filled_hover'],
            press_icon=GRAPHICS['right_arrow_filled_press'],
            event=CustomEvent(ReviewEventType.NEXT_CLICK)
        ),
    ],
    'move_list':
        move_list,
    'scroll_area':
    ScrollArea(
        parent=right_container,
        relative_position=(0, 0),
        relative_size=(1, 0.5),
        vertical=True,
        widget=move_list
    ),
    'chessboard':
    Chessboard(
        relative_position=(0, 0),
        relative_width=0.4,
        scale_mode='width',
        anchor_x='center',
        anchor_y='center'
    ),
    'move_number_text':
    Text(
        parent=info_container,
        relative_position=(0, 0),
```

```
            relative_size=(1, 0.3),
            anchor_y='bottom',
            text='MOVE NO:',
            fit_vertical=False,
            margin=10,
            border_width=0,
            fill_colour=(0, 0, 0, 0),
        ),
        'move_colour_text':
        Text(
            parent=info_container,
            relative_size=(1, 0.3),
            relative_position=(0, 0),
            anchor_y='center',
            text='TO MOVE',
            fit_vertical=False,
            margin=10,
            border_width=0,
            fill_colour=(0, 0, 0, 0),
        ),
        'winner_text':
        Text(
            parent=info_container,
            relative_size=(1, 0.3),
            relative_position=(0, 0),
            text='WINNER:',
            fit_vertical=False,
            margin=10,
            border_width=0,
            fill_colour=(0, 0, 0, 0),
        ),
        'blue_timer':
        Timer(
            relative_position=(0.05, 0.05),
            anchor_y='center',
            relative_size=(0.1, 0.1),
            active_colour=Colour.BLUE,
        ),
        'red_timer':
        Timer(
            relative_position=(0.05, -0.05),
            anchor_y='center',
            relative_size=(0.1, 0.1),
            active_colour=Colour.RED
        ),
        'timer_disabled_text':
        Text(
            relative_size=(0.2, 0.1),
            relative_position=(0.05, 0),
            anchor_y='center',
            fit_vertical=False,
            text='TIMER DISABLED',
        ),
        'blue_piece_display':
        PieceDisplay(
            relative_position=(0.05, 0.05),
            relative_size=(0.2, 0.1),
            anchor_y='bottom',
            active_colour=Colour.BLUE
        ),
        'red_piece_display':
        PieceDisplay(
```

```
        relative_position=(0.05, 0.05),
        relative_size=(0.2, 0.1),
        active_colour=Colour.RED
    ),
}
```

## B.23 data\states\settings

### B.23.1 settings.py

```
import pygame
from random import randint
from data.helpers.data_helpers import get_default_settings, get_user_settings,
    update_user_settings
from data.utils.constants import WidgetState, ShaderType, SHADER_MAP
from data.states.settings.widget_dict import SETTINGS_WIDGETS
from data.utils.event_types import SettingsEventType
from data.managers.logs import initialise_logger
from data.managers.window import window
from data.managers.audio import audio
from data.widgets import ColourPicker
from data.utils.assets import MUSIC
from data.control import _State

logger = initialise_logger(__name__)

class Settings(_State):
    def __init__(self):
        super().__init__()

        self._colour_picker = None
        self._settings = None

    def cleanup(self):
        super().cleanup()

        update_user_settings(self._settings)

        return None

    def startup(self, persist=None):
        super().startup(SETTINGS_WIDGETS, music=MUSIC[f'menu_{randint(1, 3)}'])

        window.set_apply_arguments(ShaderType.BASE, background_type=ShaderType.
    BACKGROUND_BALATRO)
        self._settings = get_user_settings()
        self.reload_settings()

        self.draw()

    def create_colour_picker(self, mouse_pos, button_type):
        if button_type == SettingsEventType.PRIMARY_COLOUR_BUTTON_CLICK:
            selected_colour = self._settings['primaryBoardColour']
            event_type = SettingsEventType.PRIMARY_COLOUR_PICKER_CLICK
        else:
            selected_colour = self._settings['secondaryBoardColour']
            event_type = SettingsEventType.SECONDARY_COLOUR_PICKER_CLICK

        self._colour_picker = ColourPicker(
            relative_position=(mouse_pos[0] / window.size[0], mouse_pos[1] /
    window.size[1]),
```

```
            relative_width=0.15,
            selected_colour=selected_colour,
            event_type=event_type
        )
        self._widget_group.add(self._colour_picker)

    def remove_colour_picker(self):
        self._colour_picker.kill()

    def reload_display_mode(self):
        relative_mouse_pos = (pygame.mouse.get_pos()[0] / window.size[0], pygame.
    mouse.get_pos()[1] / window.size[1])

        if self._settings['displayMode'] == 'fullscreen':
            window.set_fullscreen(desktop=True)
            window.handle_resize()

        elif self._settings['displayMode'] == 'windowed':
            window.set_windowed()
            window.handle_resize()
            window.restore()

        self._widget_group.handle_resize(window.size)

        new_mouse_pos = (relative_mouse_pos[0] * window.size[0],
    relative_mouse_pos[1] * window.size[1])
        pygame.mouse.set_pos(new_mouse_pos)

    def reload_shaders(self):
        window.clear_all_effects()

        for shader_type in SHADER_MAP[self._settings['shader']]:
            window.set_effect(shader_type)

    def reload_settings(self):
        SETTINGS_WIDGETS['primary_colour_button'].initialise_new_colours(self.
    _settings['primaryBoardColour'])
        SETTINGS_WIDGETS['secondary_colour_button'].initialise_new_colours(self.
    _settings['secondaryBoardColour'])
        SETTINGS_WIDGETS['primary_colour_button'].set_state_colour(WidgetState.
    BASE)
        SETTINGS_WIDGETS['secondary_colour_button'].set_state_colour(WidgetState.
    BASE)
        SETTINGS_WIDGETS['music_volume_slider'].set_volume(self._settings['
    musicVolume'])
        SETTINGS_WIDGETS['sfx_volume_slider'].set_volume(self._settings['sfxVolume
    '])
        SETTINGS_WIDGETS['display_mode_dropdown'].set_selected_word(self._settings
    ['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 widget_event.colour:
                    r, g, b = widget_event.colour.rgb
                    hex_colour = f'0x{hex(r)[2:].zfill(2)}{hex(g)[2:].zfill(2)}{hex(b)[2:].zfill(2)}'

                    if widget_event.type == SettingsEventType.PRIMARY_COLOUR_PICKER_CLICK:
                        SETTINGS_WIDGETS['primary_colour_button'].initialise_new_colours(widget_event.colour)
                        SETTINGS_WIDGETS['primary_colour_button'].set_state_colour(WidgetState.BASE)
                        self._settings['primaryBoardColour'] = hex_colour
                    elif widget_event.type == SettingsEventType.
```

```
SECONDARY_COLOUR_PICKER_CLICK:
                            SETTINGS_WIDGETS['secondary_colour_button'].
initialise_new_colours(widget_event.colour)
                            SETTINGS_WIDGETS['secondary_colour_button'].
set_state_colour(WidgetState.BASE)
                            self._settings['secondaryBoardColour'] = hex_colour

                case SettingsEventType.SHADER_PICKER_CLICK:
                    self._settings['shader'] = widget_event.data
                    self.reload_shaders()

                case SettingsEventType.OPENGL_CLICK:
                    self._settings['opengl'] = widget_event.toggled
                    self.reload_shaders()

                case SettingsEventType.PARTICLES_CLICK:
                    self._settings['particles'] = widget_event.toggled

    def draw(self):
        self._widget_group.draw()
```

### B.23.2 widget_dict.py

```
from data.widgets import *
from data.helpers.data_helpers import get_user_settings
from data.components.custom_event import CustomEvent
from data.utils.event_types import SettingsEventType
from data.utils.constants import SHADER_MAP
from data.utils.assets import GRAPHICS
from data.managers.theme import theme

user_settings = get_user_settings()
# font_size = text_width_to_font_size('Shaders (OPENGL GPU REQUIRED)',
    DEFAULT_FONT, 0.4 * window.screen.width)
FONT_SIZE = 21

carousel_widgets = {
    key: Text(
        relative_position=(0, 0),
        relative_size=(0.25, 0.04),
        margin=0,
        text=key.replace('_', ' ').upper(),
        fit_vertical=True,
        border_width=0,
        fill_colour=(0, 0, 0, 0),
    ) for key in SHADER_MAP.keys()
}

reset_container = Rectangle(
    relative_size=(0.2, 0.2),
    relative_position=(0, 0),
    fixed_position=(5, 5),
    anchor_x='right',
    anchor_y='bottom',
)

SETTINGS_WIDGETS = {
    'default': [
        reset_container,
        ReactiveIconButton(
            relative_position=(0, 0),
            relative_size=(0.075, 0.075),
```

```
            anchor_x='right',
            scale_mode='height',
            base_icon=GRAPHICS['home_base'],
            hover_icon=GRAPHICS['home_hover'],
            press_icon=GRAPHICS['home_press'],
            fixed_position=(5, 5),
            event=CustomEvent(SettingsEventType.MENU_CLICK)
        ),
        Text(
            relative_position=(0.01, 0.1),
            text='Display mode',
            relative_size=(0.4, 0.04),
            center=False,
            border_width=0,
            margin=0,
            font_size=21,
            fill_colour=(0, 0, 0, 0)
        ),
        Text(
            relative_position=(0.01, 0.2),
            text='Music',
            relative_size=(0.4, 0.04),
            center=False,
            border_width=0,
            margin=0,
            font_size=21,
            fill_colour=(0, 0, 0, 0)
        ),
        Text(
            relative_position=(0.01, 0.3),
            text='SFX',
            relative_size=(0.4, 0.04),
            center=False,
            border_width=0,
            margin=0,
            font_size=21,
            fill_colour=(0, 0, 0, 0)
        ),
        Text(
            relative_position=(0.01, 0.4),
            text='Primary board colour',
            relative_size=(0.4, 0.04),
            center=False,
            border_width=0,
            margin=0,
            font_size=21,
            fill_colour=(0, 0, 0, 0)
        ),
        Text(
            relative_position=(0.01, 0.5),
            text='Secondary board colour',
            relative_size=(0.4, 0.04),
            center=False,
            border_width=0,
            margin=0,
            font_size=21,
            fill_colour=(0, 0, 0, 0)
        ),
        Text(
            relative_position=(0.01, 0.6),
            text='Particles',
            relative_size=(0.4, 0.04),
```

```
                center=False,
                border_width=0,
                margin=0,
                font_size=21,
                fill_colour=(0, 0, 0, 0)
            ),
            Text(
                relative_position=(0.01, 0.7),
                text='Shaders (OPENGL GPU REQUIRED)',
                relative_size=(0.4, 0.04),
                center=False,
                border_width=0,
                margin=0,
                font_size=21,
                fill_colour=(0, 0, 0, 0)
            ),
            Text(
                relative_position=(0.01, 0.8),
                text='Super Secret Settings',
                relative_size=(0.4, 0.04),
                center=False,
                border_width=0,
                margin=0,
                font_size=21,
                fill_colour=(0, 0, 0, 0)
            ),
            TextButton(
                parent=reset_container,
                relative_position=(0, 0),
                relative_size=(1, 0.5),
                fit_vertical=False,
                margin=10,
                text='DISCARD CHANGES',
                text_colour=theme['textSecondary'],
                event=CustomEvent(SettingsEventType.RESET_USER)
            ),
            TextButton(
                parent=reset_container,
                relative_position=(0, 0.5),
                relative_size=(1, 0.5),
                fit_vertical=False,
                margin=10,
                text='RESET TO DEFAULT',
                text_colour=theme['textSecondary'],
                event=CustomEvent(SettingsEventType.RESET_DEFAULT)
            )
        ],
        'display_mode_dropdown':
        Dropdown(
            relative_position=(0.4, 0.1),
            relative_width=0.2,
            word_list=['fullscreen', 'windowed'],
            fill_colour=(255, 100, 100),
            event=CustomEvent(SettingsEventType.DROPDOWN_CLICK)
        ),
        'primary_colour_button':
        ColourButton(
            relative_position=(0.4, 0.4),
            relative_size=(0.08, 0.05),
            fill_colour=user_settings['primaryBoardColour'],
            border_width=5,
            event=CustomEvent(SettingsEventType.PRIMARY_COLOUR_BUTTON_CLICK)
```

```
    ),
    'secondary_colour_button':
    ColourButton(
        relative_position=(0.4, 0.5),
        relative_size=(0.08, 0.05),
        fill_colour=user_settings['secondaryBoardColour'],
        border_width=5,
        event=CustomEvent(SettingsEventType.SECONDARY_COLOUR_BUTTON_CLICK)
    ),
    'music_volume_slider':
    VolumeSlider(
        relative_position=(0.4, 0.2),
        relative_length=(0.5),
        default_volume=user_settings['musicVolume'],
        border_width=5,
        volume_type='music'
    ),
    'sfx_volume_slider':
    VolumeSlider(
        relative_position=(0.4, 0.3),
        relative_length=(0.5),
        default_volume=user_settings['sfxVolume'],
        border_width=5,
        volume_type='sfx'
    ),
    'shader_carousel':
    Carousel(
        relative_position = (0.4, 0.8),
        margin=5,
        border_width=0,
        fill_colour=(0, 0, 0, 0),
        widgets_dict=carousel_widgets,
        event=CustomEvent(SettingsEventType.SHADER_PICKER_CLICK),
    ),
    'particles_switch':
    Switch(
        relative_position=(0.4, 0.6),
        relative_height=0.04,
        event=CustomEvent(SettingsEventType.PARTICLES_CLICK)
    ),
    'opengl_switch':
    Switch(
        relative_position=(0.4, 0.7),
        relative_height=0.04,
        event=CustomEvent(SettingsEventType.OPENGL_CLICK)
    ),
}
```

## B.24 data\utils

### B.24.1 assets.py

```
from pathlib import Path
from data.helpers.load_helpers import *

module_path = Path(__file__).parent
GRAPHICS = load_all_gfx((module_path / '../../resources/graphics').resolve())
FONTS = load_all_fonts((module_path / '../../resources/fonts').resolve())
SFX = load_all_sfx((module_path / '../../resources/sfx').resolve())
MUSIC = load_all_music((module_path / '../../resources/music').resolve())

```

```
DEFAULT_FONT = FONTS['vhs-gothic']
DEFAULT_FONT.strong = True
DEFAULT_FONT.strength = 0.05
```

### B.24.2 constants.py

```
import pygame
from data.utils.enums import ShaderType, WidgetState

SCREEN_SIZE = (1600, 800)

PAUSE_COLOUR = (50, 50, 50, 128)
OVERLAY_COLOUR_LIGHT = (*pygame.Color('0xf14e52').rgb, 128)
OVERLAY_COLOUR_DARK = (*pygame.Color('0x9b222b').rgb, 192)

EMPTY_BB = 0
A_FILE_MASK = 0
    b11111111101111111110111111111011111111101111111110111111111011111111101111111110
J_FILE_MASK = 0
    b01111111110111111111011111111101111111110111111111011111111101111111110111111111
ONE_RANK_MASK = 0
    b11111111111111111111111111111111111111111111111111111111111111111111110000000000
EIGHT_RANK_MASK = 0
    b00000000001111111111111111111111111111111111111111111111111111111111111111111111
TEST_MASK = 0
    b00000000100000000010000000000000000000000000000000000000000000000000000000000000


GAMES_PER_PAGE = 10

SHADER_MAP = {
    'default': [
        ShaderType.BLOOM
    ],
    'retro': [
        ShaderType.CRT
    ],
    'really_retro': [
        ShaderType.CRT,
        ShaderType.GRAYSCALE
    ],
}

BLUE_BUTTON_COLOURS = {
    WidgetState.BASE: ['0x1c2638', '0x23495d', '0x39707a', '0x95e0cc'],
    WidgetState.HOVER: ['0xdaf2e9', '0x23495d', '0x39707a', '0x95e0cc'],
    WidgetState.PRESS: ['0xdaf2e9', '0x1c2638', '0x23495d', '0x39707a']
}

INPUT_COLOURS = {
    WidgetState.BASE: ['0x1c2638', '0x39707a', '0x23495d', '0x95e0cc'],
    WidgetState.HOVER: ['0xdaf2e9', '0x39707a', '0x23495d', '0x95e0cc'],
    WidgetState.PRESS: ['0xdaf2e9', '0x23495d', '0x1c2638', '0x39707a']
}

RED_BUTTON_COLOURS = {
    WidgetState.BASE: ['0x000000', '0x1c2638', '0x9b222b', '0xf14e52'],
    WidgetState.HOVER: ['0xdaf2e9', '0x1c2638', '0x9b222b', '0xf14e52'],
```

```
    WidgetState.PRESS: ['0xdaf2e9', '0x23495d', '0xf14e52', '0x95e0cc']
}

LOCKED_RED_BUTTON_COLOURS = {
    WidgetState.BASE: ['0x000000', '0x000000', '0x1c2638', '0x23495d'],
    WidgetState.HOVER: ['0xdaf2e9', '0x000000', '0x1c2638', '0x23495d'],
    WidgetState.PRESS: ['0xdaf2e9', '0x1c2638', '0x23495d', '0xf14e52']
}

LOCKED_BLUE_BUTTON_COLOURS = {
    WidgetState.BASE: ['0x000000', '0x000000', '0x1c2638', '0x23495d'],
    WidgetState.HOVER: ['0xdaf2e9', '0x000000', '0x1c2638', '0x23495d'],
    WidgetState.PRESS: ['0xdaf2e9', '0x1c2638', '0x23495d', '0x39707a']
}
```

### B.24.3 enums.py

```
from enum import IntEnum, StrEnum, auto

class CursorMode(IntEnum):
    ARROW = auto()
    IBEAM = auto()
    OPENHAND = auto()
    CLOSEDHAND = auto()
    NO = auto()

class ShaderType(StrEnum):
    BASE = auto()
    SHAKE = auto()
    BLOOM = auto()
    GRAYSCALE = auto()
    CRT = auto()
    RAYS = auto()
    CHROMATIC_ABBREVIATION = auto()
    BACKGROUND_WAVES = auto()
    BACKGROUND_BALATRO = auto()
    BACKGROUND_LASERS = auto()
    BACKGROUND_GRADIENT = auto()
    BACKGROUND_NONE = auto()

    _BLUR = auto()
    _HIGHLIGHT_BRIGHTNESS = auto()
    _HIGHLIGHT_COLOUR = auto()
    _CALIBRATE = auto()
    _LIGHTMAP = auto()
    _SHADOWMAP = auto()
    _OCCLUSION = auto()
    _BLEND = auto()
    _CROP = auto()

class TranspositionFlag(StrEnum):
    LOWER = auto()
    EXACT = auto()
    UPPER = auto()

class Miscellaneous(StrEnum):
    PLACEHOLDER = auto()
    DRAW = auto()

class WidgetState(StrEnum):
    BASE = auto()
    HOVER = auto()
```

```
    PRESS = auto()

class StatusText(StrEnum):
    PLAYER_MOVE = auto()
    CPU_MOVE = auto()
    WIN = auto()
    DRAW = auto()

class Colour(IntEnum):
    BLUE = 0
    RED = 1

    def get_flipped_colour(self):
        if self == Colour.BLUE:
            return Colour.RED
        elif self == Colour.RED:
            return Colour.BLUE

class Piece(StrEnum):
    SPHINX = 's'
    PYRAMID = 'p'
    ANUBIS = 'n'
    SCARAB = 'r'
    PHARAOH = 'f'

class Score(IntEnum):
    PHARAOH = 0
    SPHINX = 0
    PYRAMID = 100
    ANUBIS = 110
    SCARAB = 200

    MOVE = 4
    POSITION = 11
    PHARAOH_SAFETY = 31
    CHECKMATE = 100000
    INFINITE = 6969696969

class Rank(IntEnum):
    ONE = 0
    TWO = 1
    THREE = 2
    FOUR = 3
    FIVE = 4
    SIX = 5
    SEVEN = 6
    EIGHT = 7

class File(IntEnum):
    A = 0
    B = 1
    C = 2
    D = 3
    E = 4
    F = 5
    G = 6
    H = 7
    I = 8
    J = 9

class Rotation(StrEnum):
    UP = 'a'
```

```
    RIGHT = 'b'
    DOWN = 'c'
    LEFT = 'd'

    def to_angle(self):
        if self == Rotation.UP:
            return 0
        elif self == Rotation.RIGHT:
            return 270
        elif self == Rotation.DOWN:
            return 180
        elif self == Rotation.LEFT:
            return 90

    def get_clockwise(self):
        if self == Rotation.UP:
            return Rotation.RIGHT
        elif self == Rotation.RIGHT:
            return Rotation.DOWN
        elif self == Rotation.DOWN:
            return Rotation.LEFT
        elif self == Rotation.LEFT:
            return Rotation.UP

    def get_anticlockwise(self):
        if self == Rotation.UP:
            return Rotation.LEFT
        elif self == Rotation.RIGHT:
            return Rotation.UP
        elif self == Rotation.DOWN:
            return Rotation.RIGHT
        elif self == Rotation.LEFT:
            return Rotation.DOWN

    def get_opposite(self):
        return self.get_clockwise().get_clockwise()

class RotationIndex(IntEnum):
    FIRSTBIT = 0
    SECONDBIT = 1

class RotationDirection(StrEnum):
    CLOCKWISE = 'cw'
    ANTICLOCKWISE = 'acw'

    def get_opposite(self):
        if self == RotationDirection.CLOCKWISE:
            return RotationDirection.ANTICLOCKWISE
        elif self == RotationDirection.ANTICLOCKWISE:
            return RotationDirection.CLOCKWISE

class MoveType(StrEnum):
    MOVE = 'm'
    ROTATE = 'r'

class LaserType(IntEnum):
    END = 0
    STRAIGHT = 1
    CORNER = 2

class LaserDirection(IntEnum):
    FROM_TOP = 1
```

```
    FROM_RIGHT = 2
    FROM_BOTTOM = 3
    FROM_LEFT = 4
```

### B.24.4 event_types.py

```
from enum import StrEnum, auto

class EditorEventType(StrEnum):
    MENU_CLICK = auto()
    PICK_PIECE_CLICK = auto()
    ROTATE_PIECE_CLICK = auto()
    COPY_CLICK = auto()
    EMPTY_CLICK = auto()
    RESET_CLICK = auto()
    BLUE_START_CLICK = auto()
    RED_START_CLICK = auto()
    START_CLICK = auto()
    CONFIG_CLICK = auto()
    ERASE_CLICK = auto()
    MOVE_CLICK = auto()
    HELP_CLICK = auto()

class ReviewEventType(StrEnum):
    MENU_CLICK = auto()
    PREVIOUS_CLICK = auto()
    NEXT_CLICK = auto()
    HELP_CLICK = auto()

class BrowserEventType(StrEnum):
    MENU_CLICK = auto()
    BROWSER_STRIP_CLICK = auto()
    COPY_CLICK = auto()
    DELETE_CLICK = auto()
    REVIEW_CLICK = auto()
    FILTER_COLUMN_CLICK = auto()
    FILTER_ASCEND_CLICK = auto()
    PAGE_CLICK = auto()
    HELP_CLICK = auto()

class GameEventType(StrEnum):
    BOARD_CLICK = auto()
    PIECE_CLICK = auto()
    PAUSE_CLICK = auto()
    MENU_CLICK = auto()
    GAME_CLICK = auto()
    HELP_CLICK = auto()
    TUTORIAL_CLICK = auto()
    RESIGN_CLICK = auto()
    DRAW_CLICK = auto()
    REVIEW_CLICK = auto()
    PIECE_DROP = auto()
    UPDATE_PIECES = auto()
    ROTATE_PIECE = auto()
    SET_LASER = auto()
    TIMER_END = auto()

class MenuEventType(StrEnum):
    CONFIG_CLICK = auto()
    SETTINGS_CLICK = auto()
    BROWSER_CLICK = auto()
    QUIT_CLICK = auto()
```

```
    CREDITS_CLICK = auto()

class SettingsEventType(StrEnum):
    RESET_DEFAULT = auto()
    RESET_USER = auto()
    MENU_CLICK = auto()
    COLOUR_SLIDER_SLIDE = auto()
    COLOUR_SLIDER_CLICK = auto()
    COLOUR_PICKER_HOVER = auto()
    PRIMARY_COLOUR_PICKER_CLICK = auto()
    SECONDARY_COLOUR_PICKER_CLICK = auto()
    PRIMARY_COLOUR_BUTTON_CLICK = auto()
    SECONDARY_COLOUR_BUTTON_CLICK = auto()
    VOLUME_SLIDER_SLIDE = auto()
    VOLUME_SLIDER_CLICK = auto()
    SHADER_PICKER_CLICK = auto()
    OPENGL_CLICK = auto()
    DROPDOWN_CLICK = auto()
    PARTICLES_CLICK = auto()

class ConfigEventType(StrEnum):
    GAME_CLICK = auto()
    MENU_CLICK = auto()
    FEN_STRING_TYPE = auto()
    TIME_TYPE = auto()
    TIME_CLICK = auto()
    PVP_CLICK = auto()
    PVC_CLICK = auto()
    CPU_DEPTH_CLICK = auto()
    PRESET_CLICK = auto()
    SETUP_CLICK = auto()
    COLOUR_CLICK = auto()
    HELP_CLICK = auto()
```

## B.25 data\widgets

### B.25.1 board_thumbnail.py

```
import pygame
from data.widgets.bases.widget import _Widget
from data.widgets.chessboard import Chessboard
from data.states.game.components.piece_group import PieceGroup
from data.states.game.components.bitboard_collection import BitboardCollection

class BoardThumbnail(_Widget):
    def __init__(self, relative_width, fen_string='', **kwargs):
        super().__init__(relative_size=(relative_width, relative_width * 0.8), **
    kwargs)

        self._board = Chessboard(
            parent=self._parent,
            relative_position=(0, 0),
            scale_mode=kwargs.get('scale_mode'),
            relative_width=relative_width
        )

        self._empty_surface = pygame.Surface((0, 0), pygame.SRCALPHA)

        self.initialise_board(fen_string)
        self.set_image()
        self.set_geometry()
```

```python

    def initialise_board(self, fen_string):
        if len(fen_string) == 0:
            piece_list = []
        else:
            piece_list = BitboardCollection(fen_string).convert_to_piece_list()

        self._piece_group = PieceGroup()
        self._piece_group.initialise_pieces(piece_list, (0, 0), self.size)

        self._board.refresh_board()
        self.set_image()

    def set_image(self):
        self.image = pygame.transform.scale(self._empty_surface, self.size)

        self._board.set_image()
        self.image.blit(self._board.image, (0, 0))

        self._piece_group.draw(self.image)

    def set_geometry(self):
        super().set_geometry()
        self._board.set_geometry()

    def set_surface_size(self, new_surface_size):
        super().set_surface_size(new_surface_size)
        self._board.set_surface_size(new_surface_size)
        self._piece_group.handle_resize((0, 0), self.size)

    def process_event(self, event):
        pass
```

### B.25.2 board_thumbnail_button.py

```python
from data.widgets.bases.pressable import _Pressable
from data.widgets.board_thumbnail import BoardThumbnail
from data.utils.constants import WidgetState
from data.components.custom_event import CustomEvent

class BoardThumbnailButton(_Pressable, BoardThumbnail):
    def __init__(self, event, **kwargs):
        _Pressable.__init__(
            self,
            event=CustomEvent(**vars(event), fen_string=kwargs.get('fen_string')),
            hover_func=lambda: self.set_state_colour(WidgetState.HOVER),
            down_func=lambda: self.set_state_colour(WidgetState.PRESS),
            up_func=lambda: self.set_state_colour(WidgetState.BASE),
        )
        BoardThumbnail.__init__(self, **kwargs)

        self.initialise_new_colours(self._fill_colour)
        self.set_state_colour(WidgetState.BASE)
```

### B.25.3 browser_item.py

```python
import pygame
from data.helpers.font_helpers import text_width_to_font_size
from data.helpers.browser_helpers import get_winner_string
from data.widgets.board_thumbnail import BoardThumbnail
from data.helpers.asset_helpers import scale_and_cache
```

```python
from data.widgets.bases.widget import _Widget

FONT_DIVISION = 7

class BrowserItem(_Widget):
    def __init__(self, relative_width, game, **kwargs):
        super().__init__(relative_size=(relative_width, relative_width * 2), scale_mode='height', **kwargs)

        self._relative_font_size = text_width_to_font_size('YYYY-MM-DD HH:MM:SS', self._font, self.size[0]) / self.surface_size[1]

        self._game = game
        self._board_thumbnail = BoardThumbnail(
            relative_position=(0, 0),
            scale_mode='height',
            relative_width=relative_width,
            fen_string=self._game['final_fen_string']
        )

        self.set_image()
        self.set_geometry()

    def get_text_to_render(self):
        depth_to_text = {
            2: 'EASY',
            3: 'MEDIUM',
            4: 'HARD'
        }

        format_moves = lambda no_of_moves:  int(no_of_moves / 2) if (no_of_moves / 2 % 1 == 0) else round(no_of_moves / 2, 1)

        if self._game['cpu_enabled'] == 1:
            depth_text = depth_to_text[self._game['cpu_depth']]
            cpu_text = f'PVC ({depth_text})'
        else:
            cpu_text = 'PVP'

        return [
            cpu_text,
            self._game['created_dt'].strftime('%Y-%m-%d %H:%M:%S'),
            f'WINNER: {get_winner_string(self._game['winner'])}',
            f'NO. MOVES: {format_moves(self._game['number_of_ply'])}'
        ]

    def set_image(self):
        self.image = pygame.Surface(self.size, pygame.SRCALPHA)
        resized_board = scale_and_cache(self._board_thumbnail.image, (self.size[0], self.size[0] * 0.8))
        self.image.blit(resized_board, (0, 0))

        get_line_y = lambda line: (self.size[0] * 0.8) + ((self.size[0] * 0.8) / FONT_DIVISION) * (line + 0.5)

        text_to_render = self.get_text_to_render()

        for index, text in enumerate(text_to_render):
            self._font.render_to(self.image, (0, get_line_y(index)), text, fgcolor=self._text_colour, size=self.font_size)

    def process_event(self, event):
```

```
        pass
```

### B.25.4 browser_strip.py

```
import pygame
from data.components.custom_event import CustomEvent
from data.utils.event_types import BrowserEventType
from data.widgets.browser_item import BrowserItem
from data.widgets.bases.widget import _Widget

WIDTH_FACTOR = 0.3

class BrowserStrip(_Widget):
    def __init__(self, relative_height, games_list, **kwargs):
        super().__init__(relative_size=None, **kwargs)
        self._relative_item_width = relative_height / 2
        self._get_rect = None

        self._games_list = []
        self._items_list = []
        self._selected_index = None

        self.initialise_games_list(games_list)

    @property
    def item_width(self):
        return self._relative_item_width * self.surface_size[1]

    @property
    def size(self):
        if self._get_rect:
            height = self._get_rect().height
        else:
            height = 0
        width = max(0, len(self._games_list) * (self.item_width + self.margin) +
    self.margin)

        return (width, height)

    def register_get_rect(self, get_rect_func):
        self._get_rect = get_rect_func

    def initialise_games_list(self, games_list):
        self._items_list = []
        self._games_list = games_list
        self._selected_index = None

        for game in games_list:
            browser_item = BrowserItem(relative_position=(0, 0), game=game,
    relative_width=self._relative_item_width)
            self._items_list.append(browser_item)

        self.set_image()
        self.set_geometry()

    def set_image(self):
        self.image = pygame.Surface(self.size, pygame.SRCALPHA)
        browser_list = []

        for index, item in enumerate(self._items_list):
            item.set_image()
```

```
            browser_list.append((item.image, (index * (self.item_width + self.margin) + self.margin, self.margin)))

        self.image.blits(browser_list)

        if self._selected_index is not None:
            border_position = (self._selected_index * (self.item_width + self.margin), 0)
            border_size = (self.item_width + 2 * self.margin, self.size[1])
            pygame.draw.rect(self.image, (255, 255, 255), (*border_position, *border_size), width=int(self.item_width / 20))

    def set_geometry(self):
        super().set_geometry()
        for item in self._items_list:
            item.set_geometry()

    def set_surface_size(self, new_surface_size):
        super().set_surface_size(new_surface_size)

        for item in self._items_list:
            item.set_surface_size(new_surface_size)

    def process_event(self, event, scrolled_pos):
        parent_pos = self._get_rect().topleft
        self.rect.topleft = parent_pos

        if event.type == pygame.KEYDOWN and event.key == pygame.K_ESCAPE:
            self._selected_index = None
            self.set_image()
            return CustomEvent(BrowserEventType.BROWSER_STRIP_CLICK, selected_index=None)

        if event.type == pygame.MOUSEBUTTONDOWN and self.rect.collidepoint(event.pos):
            relative_mouse_pos = (event.pos[0] - parent_pos[0], event.pos[1] - parent_pos[1])
            self._selected_index = int(max(0, (relative_mouse_pos[0] - self.margin) // (self.item_width + self.margin)))
            self.set_image()
            return CustomEvent(BrowserEventType.BROWSER_STRIP_CLICK, selected_index=self._selected_index)
```

### B.25.5 carousel.py

```
import pygame
from data.widgets.reactive_icon_button import ReactiveIconButton
from data.components.custom_event import CustomEvent
from data.widgets.bases.circular import _Circular
from data.widgets.bases.widget import _Widget
from data.utils.assets import GRAPHICS, SFX
from data.utils.enums import Miscellaneous

class Carousel(_Circular, _Widget):
    def __init__(self, event, widgets_dict, **kwargs):
        _Circular.__init__(self, items_dict=widgets_dict)
        _Widget.__init__(self, relative_size=None, **kwargs)

        max_widget_size = (
            max([widget.rect.width for widget in widgets_dict.values()]),
            max([widget.rect.height for widget in widgets_dict.values()])
        )
```

```python

        self._relative_max_widget_size = (max_widget_size[0] / self.surface_size[1], max_widget_size[1] / self.surface_size[1])
        self._relative_size = ((max_widget_size[0] + 2 * (self.margin + self.arrow_size[0])) / self.surface_size[1], (max_widget_size[1]) / self.surface_size[1])

        self._left_arrow = ReactiveIconButton(
            relative_position=(0, 0),
            relative_size=(0, self.arrow_size[1] / self.surface_size[1]),
            scale_mode='height',
            base_icon=GRAPHICS['left_arrow_base'],
            hover_icon=GRAPHICS['left_arrow_hover'],
            press_icon=GRAPHICS['left_arrow_press'],
            event=CustomEvent(Miscellaneous.PLACEHOLDER),
            sfx=SFX['carousel_click']
        )
        self._right_arrow = ReactiveIconButton(
            relative_position=(0, 0),
            relative_size=(0, self.arrow_size[1] / self.surface_size[1]),
            scale_mode='height',
            base_icon=GRAPHICS['right_arrow_base'],
            hover_icon=GRAPHICS['right_arrow_hover'],
            press_icon=GRAPHICS['right_arrow_press'],
            event=CustomEvent(Miscellaneous.PLACEHOLDER),
            sfx=SFX['carousel_click']
        )

        self._event = event
        self._empty_surface = pygame.Surface((0, 0), pygame.SRCALPHA)

        self.set_image()
        self.set_geometry()

    @property
    def max_widget_size(self):
        return (self._relative_max_widget_size[0] * self.surface_size[1], self._relative_max_widget_size[1] * self.surface_size[1])

    @property
    def arrow_size(self):
        height = self.max_widget_size[1] * 0.75
        width = (GRAPHICS['left_arrow_base'].width / GRAPHICS['left_arrow_base'].height) * height
        return (width, height)

    @property
    def size(self):
        return ((self.arrow_size[0] + self.margin) * 2 + self.max_widget_size[0], self.max_widget_size[1])

    @property
    def left_arrow_position(self):
        return (0, (self.size[1] - self.arrow_size[1]) / 2)

    @property
    def right_arrow_position(self):
        return (self.size[0] - self.arrow_size[0], (self.size[1] - self.arrow_size[1]) / 2)

    def set_image(self):
        self.image = pygame.transform.scale(self._empty_surface, self.size)
```

```
        self.image.fill(self._fill_colour)

        if self.border_width:
            pygame.draw.rect(self.image, self._border_colour, (0, 0, *self.size),
    width=int(self.border_width), border_radius=int(self.border_radius))

        self._left_arrow.set_image()
        self.image.blit(self._left_arrow.image, self.left_arrow_position)

        self.current_item.set_image()
        self.image.blit(self.current_item.image, ((self.size[0] - self.
    current_item.rect.size[0]) / 2, (self.size[1] - self.current_item.rect.size
    [1]) / 2))

        self._right_arrow.set_image()
        self.image.blit(self._right_arrow.image, self.right_arrow_position)

    def set_geometry(self):
        super().set_geometry()

        self.current_item.set_geometry()
        self._left_arrow.set_geometry()
        self._right_arrow.set_geometry()

        self.current_item.rect.center = self.rect.center
        self._left_arrow.rect.topleft = (self.position[0] + self.
    left_arrow_position[0], self.position[1] + self.left_arrow_position[1])
        self._right_arrow.rect.topleft = (self.position[0] + self.
    right_arrow_position[0], self.position[1] + self.right_arrow_position[1])

    def set_surface_size(self, new_surface_size):
        super().set_surface_size(new_surface_size)
        self._left_arrow.set_surface_size(new_surface_size)
        self._right_arrow.set_surface_size(new_surface_size)

        for item in self._items_dict.values():
            item.set_surface_size(new_surface_size)

    def process_event(self, event):
        self.current_item.process_event(event)
        left_arrow_event = self._left_arrow.process_event(event)
        right_arrow_event = self._right_arrow.process_event(event)

        if left_arrow_event:
            self.set_previous_item()
            self.current_item.set_surface_size(self._raw_surface_size)

        elif right_arrow_event:
            self.set_next_item()
            self.current_item.set_surface_size(self._raw_surface_size)

        if left_arrow_event or right_arrow_event:
            self.set_image()
            self.set_geometry()

            return CustomEvent(**vars(self._event), data=self.current_key)

        elif event.type in [pygame.MOUSEBUTTONDOWN, pygame.MOUSEBUTTONUP, pygame.
    MOUSEMOTION]:
            self.set_image()
            self.set_geometry()
```

### B.25.6 chessboard.py

```
import pygame
from data.helpers.data_helpers import get_user_settings
from data.helpers.board_helpers import create_board
from data.widgets.bases.widget import _Widget
from data.utils.enums import CursorMode
from data.managers.cursor import cursor

class Chessboard(_Widget):
    def __init__(self, relative_width, change_cursor=True, **kwargs):
        super().__init__(relative_size=(relative_width, relative_width * 0.8), **
    kwargs)

        self._board_surface = None
        self._change_cursor = change_cursor
        self._cursor_is_hand = False

        self.refresh_board()
        self.set_image()
        self.set_geometry()

    def refresh_board(self):
        user_settings = get_user_settings()
        self._board_surface = create_board(self.size, user_settings['
    primaryBoardColour'], user_settings['secondaryBoardColour'])

        self.set_image()

    def set_image(self):
        self.image = pygame.transform.smoothscale(self._board_surface, self.size)

    def process_event(self, event):
        if self._change_cursor and event.type in [pygame.MOUSEMOTION, pygame.
    MOUSEBUTTONUP, pygame.MOUSEBUTTONDOWN]:
            current_cursor = cursor.get_mode()

            if self.rect.collidepoint(event.pos):
                if current_cursor == CursorMode.ARROW:
                    cursor.set_mode(CursorMode.OPENHAND)
                elif current_cursor == CursorMode.OPENHAND and (pygame.mouse.
    get_pressed()[0] is True or event.type == pygame.MOUSEBUTTONDOWN):
                    cursor.set_mode(CursorMode.CLOSEDHAND)
                elif current_cursor == CursorMode.CLOSEDHAND and (pygame.mouse.
    get_pressed()[0] is False or event.type == pygame.MOUSEBUTTONUP):
                    cursor.set_mode(CursorMode.OPENHAND)
            else:
                if current_cursor == CursorMode.OPENHAND or (current_cursor ==
    CursorMode.CLOSEDHAND and event.type == pygame.MOUSEBUTTONUP):
                    cursor.set_mode(CursorMode.ARROW)
```

### B.25.7 colour_button.py

```
import pygame
from data.widgets.bases.widget import _Widget
from data.widgets.bases.pressable import _Pressable
from data.utils.constants import WidgetState

class ColourButton(_Pressable, _Widget):
    def __init__(self, event, **kwargs):
        _Pressable.__init__(
```

```
            self,
            event=event,
            hover_func=lambda: self.set_state_colour(WidgetState.HOVER),
            down_func=lambda: self.set_state_colour(WidgetState.PRESS),
            up_func=lambda: self.set_state_colour(WidgetState.BASE),
            sfx=None
        )
        _Widget.__init__(self, **kwargs)

        self._empty_surface = pygame.Surface(self.size)

        self.initialise_new_colours(self._fill_colour)
        self.set_state_colour(WidgetState.BASE)

        self.set_image()
        self.set_geometry()

    def set_image(self):
        self.image = pygame.transform.scale(self._empty_surface, self.size)
        self.image.fill(self._fill_colour)
        pygame.draw.rect(self.image, self._border_colour, (0, 0, self.size[0],
    self.size[1]), width=int(self.border_width))
```

### B.25.8 colour_display.py

```
import pygame
from data.widgets.bases.widget import _Widget

class _ColourDisplay(_Widget):
    def __init__(self, **kwargs):
        super().__init__(**kwargs)

        self._colour = None

        self._empty_surface = pygame.Surface(self.size)

    def set_colour(self, new_colour):
        self._colour = new_colour

    def set_image(self):
        self.image = pygame.transform.scale(self._empty_surface, self.size)
        self.image.fill(self._colour)

    def process_event(self, event):
        pass
```

### B.25.9 colour_picker.py

```
import pygame
from data.widgets.bases.widget import _Widget
from data.widgets.colour_square import _ColourSquare
from data.widgets.colour_slider import _ColourSlider
from data.widgets.colour_display import _ColourDisplay
from data.components.custom_event import CustomEvent

class ColourPicker(_Widget):
    def __init__(self, relative_width, event_type, **kwargs):
        super().__init__(relative_size=(relative_width, relative_width),
    scale_mode='width', **kwargs)

        self.image = pygame.Surface(self.size)
```

```
        self.rect = self.image.get_rect()

        self._square = _ColourSquare(
            parent=self,
            relative_position=(0.1, 0.1),
            relative_width=0.5,
            event_type=event_type
        )
        self._square.set_colour(kwargs.get('selected_colour'))

        self._slider = _ColourSlider(
            parent=self,
            relative_position=(0.0, 0.7),
            relative_width=1.0,
            border_width=self.border_width,
            border_colour=self._border_colour
        )
        self._slider.set_colour(kwargs.get('selected_colour'))

        self._display = _ColourDisplay(
            parent=self,
            relative_position=(0.7, 0.1),
            relative_size=(0.2, 0.5)
        )
        self._display.set_colour(kwargs.get('selected_colour'))

        self._event_type = event_type
        self._hover_event_type = event_type

        self.set_image()
        self.set_geometry()

    def global_to_relative_pos(self, global_pos):
        return (global_pos[0] - self.position[0], global_pos[1] - self.position
    [1])

    def set_image(self):
        self.image = pygame.Surface(self.size)
        self.image.fill(self._fill_colour)

        self._square.set_image()
        self._square.set_geometry()
        self.image.blit(self._square.image, self.global_to_relative_pos(self.
    _square.position))

        self._slider.set_image()
        self._slider.set_geometry()
        self.image.blit(self._slider.image, self.global_to_relative_pos(self.
    _slider.position))

        self._display.set_image()
        self._display.set_geometry()
        self.image.blit(self._display.image, self.global_to_relative_pos(self.
    _display.position))

        pygame.draw.rect(self.image, self._border_colour, (0, 0, self.size[0],
    self.size[1]), width=int(self.border_width))

    def set_surface_size(self, new_surface_size):
        super().set_surface_size(new_surface_size)
        self._square.set_surface_size(self.size)
        self._slider.set_surface_size(self.size)
```

```
        self._display.set_surface_size(self.size)

    def get_picker_position(self):
        return self.position

    def process_event(self, event):
        slider_colour = self._slider.process_event(event)
        square_colour = self._square.process_event(event)

        if square_colour:
            self._display.set_colour(square_colour)
            self.set_image()

        if slider_colour:
            self._square.set_colour(slider_colour)
            self.set_image()

        if event.type in [pygame.MOUSEBUTTONUP, pygame.MOUSEBUTTONDOWN, pygame.MOUSEMOTION] and self.rect.collidepoint(event.pos):
            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

```
import pygame
from data.widgets.bases.widget import _Widget
from data.helpers.widget_helpers import create_square_gradient

class _ColourSquare(_Widget):
    def __init__(self, relative_width, **kwargs):
        super().__init__(relative_size=(relative_width, relative_width), scale_mode='width', **kwargs)

        self._colour = None

    def set_colour(self, new_colour):
        self._colour = pygame.Color(new_colour)

    def get_colour(self):
        return self._colour

    def set_image(self):
        self.image = create_square_gradient(side_length=self.size[0], colour=self._colour)

    def process_event(self, event):
        if event.type == pygame.MOUSEBUTTONDOWN:
            relative_mouse_pos = (event.pos[0] - self.position[0], event.pos[1] - self.position[1])

            if (
                0 > relative_mouse_pos[0] or
                self.size[0] < relative_mouse_pos[0] or
                0 > relative_mouse_pos[1] or
                self.size[1] < relative_mouse_pos[1]
            ): return None

```

```
            self.set_colour(self.image.get_at(relative_mouse_pos))

            return self._colour

        return None
```

### B.25.12 dropdown.py

```
import pygame
from data.widgets.bases.widget import _Widget
from data.widgets.bases.pressable import _Pressable
from data.utils.constants import WidgetState
from data.helpers.data_helpers import get_user_settings
from data.helpers.font_helpers import text_width_to_font_size,
    text_height_to_font_size
from data.utils.assets import GRAPHICS

user_settings = get_user_settings()

class Dropdown(_Pressable, _Widget):
    def __init__(self, word_list, event=None, **kwargs):
        _Pressable.__init__(
            self,
            event=event,
            hover_func=self.hover_func,
            down_func=lambda: self.set_state_colour(WidgetState.PRESS),
            up_func=self.up_func,
            sfx=None
        )
        _Widget.__init__(self, relative_size=None, **kwargs)

        if kwargs.get('relative_width'):
            self._relative_font_size = text_width_to_font_size(max(word_list, key=
    len), self._font, kwargs.get('relative_width') * self.surface_size[0] - self.
    margin) / self.surface_size[1]
        elif kwargs.get('relative_height'):
            self._relative_font_size = text_height_to_font_size(max(word_list, key
    =len), self._font, kwargs.get('relative_height') * self.surface_size[1] - self
    .margin) / self.surface_size[1]

        self._word_list = [word_list[0].capitalize()]
        self._word_list_copy = [word.capitalize() for word in word_list]

        self._expanded = False
        self._hovered_index = None

        self._empty_surface = pygame.Surface((0, 0))
        self._background_colour = self._fill_colour

        self.initialise_new_colours(self._fill_colour)
        self.set_state_colour(WidgetState.BASE)

        self.set_image()
        self.set_geometry()

    @property
    def size(self):
        max_word = sorted(self._word_list_copy, key=len)[-1]
        max_word_rect = self._font.get_rect(max_word, size=self.font_size)
        all_words_rect = pygame.FRect(0, 0, max_word_rect.size[0], (max_word_rect.
    size[1] * len(self._word_list)) + (self.margin * (len(self._word_list) - 1)))
        all_words_rect = all_words_rect.inflate(2 * self.margin, 2 * self.margin)
```

```
        return (all_words_rect.size[0] + max_word_rect.size[1], all_words_rect.size[1])

    def get_selected_word(self):
        return self._word_list[0].lower()

    def toggle_expanded(self):
        if self._expanded:
            self._word_list = [self._word_list_copy[0]]
        else:
            self._word_list = [*self._word_list_copy]

        self._expanded = not(self._expanded)

    def hover_func(self):
        mouse_position = pygame.mouse.get_pos()
        relative_position = (mouse_position[0] - self.position[0], mouse_position[1] - self.position[1])
        self._hovered_index = self.calculate_hovered_index(relative_position)
        self.set_state_colour(WidgetState.HOVER)

    def set_selected_word(self, word):
        index = self._word_list_copy.index(word.capitalize())
        selected_word = self._word_list_copy.pop(index)
        self._word_list_copy.insert(0, selected_word)

        if self._expanded:
            self._word_list.pop(index)
            self._word_list.insert(0, selected_word)
        else:
            self._word_list = [selected_word]

        self.set_image()

    def up_func(self):
        if self.get_widget_state() == WidgetState.PRESS:
            if self._expanded and self._hovered_index is not None:
                self.set_selected_word(self._word_list_copy[self._hovered_index])

            self.toggle_expanded()

        self._hovered_index = None

        self.set_state_colour(WidgetState.BASE)
        self.set_geometry()

    def calculate_hovered_index(self, mouse_pos):
        return int(mouse_pos[1] // (self.size[1] / len(self._word_list)))

    def set_image(self):
        text_surface = pygame.transform.scale(self._empty_surface, self.size)
        self.image = text_surface

        fill_rect = pygame.FRect(0, 0, self.size[0], self.size[1])
        pygame.draw.rect(self.image, self._background_colour, fill_rect)
        pygame.draw.rect(self.image, self._border_colour, fill_rect, width=int(self.border_width))

        word_box_height = (self.size[1] - (2 * self.margin) - ((len(self._word_list) - 1) * self.margin)) / len(self._word_list)

        arrow_size = (GRAPHICS['dropdown_arrow_open'].width / GRAPHICS['
```

```
dropdown_arrow_open'].height * word_box_height, word_box_height)
        open_arrow_surface = pygame.transform.scale(GRAPHICS['dropdown_arrow_open'], arrow_size)
        closed_arrow_surface = pygame.transform.scale(GRAPHICS['dropdown_arrow_close'], arrow_size)
        arrow_position = (self.size[0] - arrow_size[0] - self.margin, (word_box_height) / 3)

        if self._expanded:
            self.image.blit(closed_arrow_surface, arrow_position)
        else:
            self.image.blit(open_arrow_surface, arrow_position)

        for index, word in enumerate(self._word_list):
            word_position = (self.margin, self.margin + (word_box_height + self.margin) * index)
            self._font.render_to(self.image, word_position, word, fgcolor=self._text_colour, size=self.font_size)

        if self._hovered_index is not None:
            overlay_surface = pygame.Surface((self.size[0], word_box_height + 2 * self.margin), pygame.SRCALPHA)
            overlay_surface.fill((*self._fill_colour.rgb, 128))
            overlay_position = (0, (word_box_height + self.margin) * self._hovered_index)
            self.image.blit(overlay_surface, overlay_position)
```

### B.25.13 icon.py

```
import pygame
from data.widgets.bases.widget import _Widget
from data.helpers.widget_helpers import create_text_box

class Icon(_Widget):
    def __init__(self, icon, stretch=False, is_mask=False, smooth=False, fit_icon=False, box_colours=None, **kwargs):
        super().__init__(**kwargs)

        if fit_icon:
            aspect_ratio = icon.width / icon.height
            self._relative_size = (self._relative_size[1] * aspect_ratio, self._relative_size[1])

        self._icon = icon
        self._is_mask = is_mask
        self._stretch = stretch
        self._smooth = smooth
        self._box_colours = box_colours

        self._empty_surface = pygame.Surface((0, 0), pygame.SRCALPHA)

        self.set_image()
        self.set_geometry()

    def set_icon(self, icon):
        self._icon = icon
        self.set_image()

    def set_image(self):
        if self._box_colours:
            self.image = create_text_box(self.size, self.border_width, self._box_colours)
```

```
        else:
            self.image = pygame.transform.scale(self._empty_surface, self.size)

            if self._fill_colour:
                pygame.draw.rect(self.image, self._fill_colour, self.image.get_rect(), border_radius=int(self.border_radius))

        if self._stretch:
            if self._smooth:
                scaled_icon = pygame.transform.smoothscale(self._icon, (self.size[0] - (2 * self.margin), self.size[1] - (2 * self.margin)))
            else:
                scaled_icon = pygame.transform.scale(self._icon, (self.size[0] - (2 * self.margin), self.size[1] - (2 * self.margin)))

            icon_position = (self.margin, self.margin)
        else:
            max_height = self.size[1] - (2 * self.margin)
            max_width = self.size[0] - (2 * self.margin)
            scale_factor = min(max_width / self._icon.width, max_height / self._icon.height)

            if self._smooth:
                scaled_icon = pygame.transform.smoothscale_by(self._icon, (scale_factor, scale_factor))
            else:
                scaled_icon = pygame.transform.scale_by(self._icon, (scale_factor, scale_factor))
            icon_position = ((self.size[0] - scaled_icon.width) / 2, (self.size[1] - scaled_icon.height) / 2)

        if self._is_mask:
            self.image.blit(scaled_icon, icon_position, None, pygame.BLEND_RGBA_MULT)
        else:
            self.image.blit(scaled_icon, icon_position)

        if self._box_colours is None and self.border_width:
            pygame.draw.rect(self.image, self._border_colour, self.image.get_rect(), width=int(self.border_width), border_radius=int(self.border_radius))

    def process_event(self, event):
        pass
```

### B.25.14 icon_button.py

```
from data.widgets.bases.pressable import _Pressable
from data.widgets.bases.box import _Box
from data.widgets.icon import Icon
from data.utils.constants import WidgetState, RED_BUTTON_COLOURS

class IconButton(_Box, _Pressable, Icon):
    def __init__(self, event, box_colours=RED_BUTTON_COLOURS, **kwargs):
        _Box.__init__(self, box_colours=box_colours)
        _Pressable.__init__(
            self,
            event=event,
            hover_func=lambda: self.set_state_colour(WidgetState.HOVER),
            down_func=lambda: self.set_state_colour(WidgetState.PRESS),
            up_func=lambda: self.set_state_colour(WidgetState.BASE),
        )
        Icon.__init__(self, box_colours=box_colours[WidgetState.BASE], **kwargs)
```

```
        self.initialise_new_colours(self._fill_colour)
        self.set_state_colour(WidgetState.BASE)
```

### B.25.15 move_list.py

```
import pygame
from data.widgets.bases.widget import _Widget
from data.helpers.font_helpers import width_to_font_size

class MoveList(_Widget):
    def __init__(self, relative_width, minimum_height=0, move_list=[], **kwargs):
        super().__init__(relative_size=None, **kwargs)

        self._relative_width = relative_width * self.surface_size[0] / self.
    surface_size[1]
        self._relative_minimum_height = minimum_height / self.surface_size[1]
        self._move_list = move_list
        self._relative_font_size = width_to_font_size(self._font, self.
    surface_size[0] / 3.5) / self.surface_size[1]

        self._empty_surface = pygame.Surface((0, 0), pygame.SRCALPHA)

        self.set_image()
        self.set_geometry()

    @property
    def size(self):
        font_metrics = self._font.get_metrics('j', size=self.font_size)

        width = self._relative_width * self.surface_size[1]
        minimum_height = self._relative_minimum_height * self.surface_size[1]
        row_gap = font_metrics[0][3] - font_metrics[0][2]
        number_of_rows = 2 * ((len(self._move_list) + 1) // 2) + 1

        return (width, max(minimum_height, row_gap * number_of_rows))

    def register_get_rect(self, get_rect_func):
        pass

    def reset_move_list(self):
        self._move_list = []
        self.set_image()
        self.set_geometry()

    def append_to_move_list(self, new_move):
        self._move_list.append(new_move)
        self.set_image()
        self.set_geometry()

    def pop_from_move_list(self):
        self._move_list.pop()
        self.set_image()
        self.set_geometry()

    def set_image(self):
        self.image = pygame.transform.scale(self._empty_surface, self.size)
        self.image.fill(self._fill_colour)

        font_metrics = self._font.get_metrics('j', size=self.font_size)
        row_gap = font_metrics[0][3] - font_metrics[0][2]

```

```
        for index, move in enumerate(self._move_list):
            if index % 2 == 0:
                text_position = (self.size[0] / 7, row_gap * (1 + 2 * (index // 2)))
            else:
                text_position = (self.size[0] * 4 / 7, row_gap * (1 + 2 * (index // 2)))

            self._font.render_to(self.image, text_position, text=move, size=self.font_size, fgcolor=self._text_colour)

            move_number = (index // 2) + 1
            move_number_position = (self.size[0] / 14, row_gap * (1 + 2 * (index // 2)))
            self._font.render_to(self.image, move_number_position, text=str(move_number), size=self.font_size, fgcolor=self._text_colour)

    def process_event(self, event, scrolled_pos=None):
        pass
```

### B.25.16 multiple_icon_button.py

```
import pygame
from data.utils.constants import WidgetState, LOCKED_BLUE_BUTTON_COLOURS, LOCKED_RED_BUTTON_COLOURS, RED_BUTTON_COLOURS, BLUE_BUTTON_COLOURS
from data.components.custom_event import CustomEvent
from data.widgets.bases.circular import _Circular
from data.widgets.icon_button import IconButton
from data.widgets.bases.box import _Box

class MultipleIconButton(_Circular, IconButton):
  def __init__(self, icons_dict, **kwargs):
    _Circular.__init__(self, items_dict=icons_dict)
    IconButton.__init__(self, icon=self.current_item, **kwargs)

    self._fill_colour_copy = self._fill_colour

    self._locked = None

  def set_locked(self, is_locked):
    self._locked = is_locked
    if self._locked:
      r, g, b, a  = pygame.Color(self._fill_colour_copy).rgba
      if self._box_colours_dict == BLUE_BUTTON_COLOURS:
        _Box.__init__(self, box_colours=LOCKED_BLUE_BUTTON_COLOURS)
      elif self._box_colours_dict == RED_BUTTON_COLOURS:
        _Box.__init__(self, box_colours=LOCKED_RED_BUTTON_COLOURS)
      else:
        self.initialise_new_colours((max(r + 50, 0), max(g + 50, 0), max(b + 50, 0), a))
    else:
      if self._box_colours_dict == LOCKED_BLUE_BUTTON_COLOURS:
        _Box.__init__(self, box_colours=BLUE_BUTTON_COLOURS)
      elif self._box_colours_dict == LOCKED_RED_BUTTON_COLOURS:
        _Box.__init__(self, box_colours=RED_BUTTON_COLOURS)
      else:
        self.initialise_new_colours(self._fill_colour_copy)

    if self.rect.collidepoint(pygame.mouse.get_pos()):
      self.set_state_colour(WidgetState.HOVER)
    else:
      self.set_state_colour(WidgetState.BASE)
```

```
  def set_next_icon(self):
    super().set_next_item()
    self._icon = self.current_item
    self.set_image()

  def process_event(self, event):
    widget_event = super().process_event(event)

    if widget_event:
      return CustomEvent(**vars(widget_event), data=self.current_key)
```

### B.25.17 piece_display.py

```
import pygame
from data.utils.constants import WidgetState, BLUE_BUTTON_COLOURS,
    RED_BUTTON_COLOURS
from data.states.game.components.piece_sprite import PieceSprite
from data.helpers.widget_helpers import create_text_box
from data.helpers.asset_helpers import scale_and_cache
from data.utils.enums import  Score, Rotation, Colour
from data.widgets.bases.widget import _Widget

class PieceDisplay(_Widget):
    def __init__(self, active_colour, **kwargs):
        super().__init__(**kwargs)

        self._active_colour = active_colour
        self._piece_list = []
        self._piece_surface = None
        self._box_colours = BLUE_BUTTON_COLOURS[WidgetState.BASE] if active_colour
 == Colour.BLUE else RED_BUTTON_COLOURS[WidgetState.BASE]

        self.initialise_piece_surface()

        self.set_image()
        self.set_geometry()

    def add_piece(self, piece):
        self._piece_list.append(piece)
        self._piece_list.sort(key=lambda piece: Score[piece.name])
        self.initialise_piece_surface()

    def remove_piece(self, piece):
        self._piece_list.remove(piece)
        self.initialise_piece_surface()

    def reset_piece_list(self):
        self._piece_list = []
        self.initialise_piece_surface()

    def initialise_piece_surface(self):
        self._piece_surface = pygame.Surface((self.size[0] - 2 * self.margin, self
    .size[1] - 2 * self.margin), pygame.SRCALPHA)

        if (len(self._piece_list) == 0):
            self.set_image()
            return

        piece_width = min(self.size[1] - 2 * self.margin, (self.size[0] - 2 * self
    .margin) / len(self._piece_list))
        piece_list = []
```

```python

        for index, piece in enumerate(self._piece_list):
            piece_instance = PieceSprite(piece, self._active_colour.get_flipped_colour(), Rotation.UP)
            piece_instance.set_geometry((0, 0), piece_width)
            piece_instance.set_image()
            piece_list.append((piece_instance.image, (piece_width * index, (self._piece_surface.height - piece_width) / 2)))

        self._piece_surface.fblits(piece_list)

        self.set_image()

    def set_image(self):
        self.image = create_text_box(self.size, self.border_width, self._box_colours)

        resized_piece_surface = scale_and_cache(self._piece_surface, (self.size[0] - 2 * self.margin, self.size[1] - 2 * self.margin))
        self.image.blit(resized_piece_surface, (self.margin, self.margin))

    def process_event(self, event):
        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

```python
import pygame
from data.widgets.bases.widget import _Widget

class Rectangle(_Widget):
    def __init__(self, visible=False, **kwargs):
        super().__init__(**kwargs)

        self._empty_surface = pygame.Surface((0, 0), pygame.SRCALPHA)
        self._visible = visible

        self.set_image()
        self.set_geometry()

    def set_image(self):
        self.image = pygame.transform.scale(self._empty_surface, self.size)
        if self._visible:
            pygame.draw.rect(self.image, self._fill_colour, self.image.get_rect(), border_radius=int(self.border_radius))

            if self.border_width:
                pygame.draw.rect(self.image, self._border_colour, self.image.get_rect(), width=int(self.border_width), border_radius=int(self.border_radius))

    def process_event(self, event):
        pass
```

### B.25.21 scrollbar.py

```
import pygame
from data.widgets.bases.pressable import _Pressable
from data.widgets.bases.widget import _Widget
from data.utils.constants import WidgetState
from data.utils.enums import Miscellaneous

class _Scrollbar(_Pressable, _Widget):
    def __init__(self, vertical, **kwargs):
        _Pressable.__init__(
            self,
            event=Miscellaneous.PLACEHOLDER,
            hover_func=lambda: self.set_state_colour(WidgetState.HOVER),
            down_func=self.down_func,
            up_func=self.up_func,
            prolonged=True,
            sfx=None
        )
        _Widget.__init__(self, **kwargs)

        self._vertical = vertical
        self._last_mouse_px = None

        self._empty_surface = pygame.Surface(self.size, pygame.SRCALPHA)

        self.initialise_new_colours(self._fill_colour)
        self.set_state_colour(WidgetState.BASE)

        self.set_image()
        self.set_geometry()

    def down_func(self):
        if self._vertical:
            self._last_mouse_px = pygame.mouse.get_pos()[1]
        else:
            self._last_mouse_px = pygame.mouse.get_pos()[0]

        self.set_state_colour(WidgetState.PRESS)

    def up_func(self):
        self._last_mouse_px = None
        self.set_state_colour(WidgetState.BASE)

    def set_relative_position(self, relative_position):
        self._relative_position = relative_position
        self.set_geometry()

    def set_relative_size(self, new_relative_size):
        self._relative_size = new_relative_size

    def set_image(self):
        self.image = pygame.transform.scale(self._empty_surface, self.size)

        if self._vertical:
            rounded_radius = self.size[0] / 2
        else:
            rounded_radius = self.size[1] / 2

        pygame.draw.rect(self.image, self._fill_colour, (0, 0, self.size[0], self.
    size[1]), border_radius=int(rounded_radius))

```

```
    def process_event(self, event):
        before_state = self.get_widget_state()
        widget_event = super().process_event(event)
        after_state = self.get_widget_state()

        if event.type == pygame.MOUSEMOTION and self._last_mouse_px:
            if self._vertical:
                offset_from_last_frame = event.pos[1] - self._last_mouse_px
                self._last_mouse_px = event.pos[1]

                return offset_from_last_frame
            else:
                offset_from_last_frame = event.pos[0] - self._last_mouse_px
                self._last_mouse_px = event.pos[0]

                return offset_from_last_frame


        if widget_event or before_state != after_state:
            return 0
```

### B.25.22 scroll_area.py

```
import pygame
from data.widgets.bases.widget import _Widget
from data.widgets.scrollbar import _Scrollbar
from data.managers.theme import theme

SCROLLBAR_WIDTH_FACTOR = 0.05

class ScrollArea(_Widget):
    def __init__(self, widget, vertical, scroll_factor=15, **kwargs):
        super().__init__(**kwargs)
        if vertical is False:
            self._relative_size = kwargs.get('relative_size')

        self._relative_scroll_factor = scroll_factor / self.surface_size[1]

        self._scroll_percentage = 0
        self._widget = widget
        self._vertical = vertical

        self._widget.register_get_rect(self.calculate_widget_rect)

        if self._vertical:
            anchor_x = 'right'
            anchor_y = 'top'
            scale_mode = 'height'
        else:
            anchor_x = 'left'
            anchor_y = 'bottom'
            scale_mode = 'width'

        self._scrollbar = _Scrollbar(
            parent=self,
            relative_position=(0, 0),
            relative_size=None,
            anchor_x=anchor_x,
            anchor_y=anchor_y,
            fill_colour=theme['borderPrimary'],
            scale_mode=scale_mode,
            vertical=vertical,
```

```
        )

        self._empty_surface = pygame.Surface((0, 0), pygame.SRCALPHA)

        self.set_image()
        self.set_geometry()

    @property
    def scroll_factor(self):
        return self._relative_scroll_factor * self.surface_size[1]

    @property
    def scrollbar_size(self):
        if self._vertical:
            return (self.size[0] * SCROLLBAR_WIDTH_FACTOR, min(1, self.size[1] / self._widget.rect.height) * self.size[1])
        else:
            return (min(1, self.size[0] / (self._widget.rect.width + 0.001)) * self.size[0], self.size[1] * SCROLLBAR_WIDTH_FACTOR)

    @property
    def size(self):
        if self._vertical is False:
            return (self._relative_size[0] * self.surface_size[0], self._relative_size[1] * self.surface_size[1]) # scale with horizontal width to always fill entire length of screen
        else:
            return super().size

    def calculate_scroll_percentage(self, offset, scrollbar=False):
        if self._vertical:
            widget_height = self._widget.rect.height

            if widget_height < self.size[1]:
                return 0

            if scrollbar:
                self._scroll_percentage += offset / (self.size[1] - self.scrollbar_size[1] + 0.001)
            else:
                max_scroll_height = widget_height - self.size[1]
                current_scroll_height = self._scroll_percentage * max_scroll_height
                self._scroll_percentage = (current_scroll_height + offset) / (max_scroll_height + 0.001)
        else:
            widget_width = self._widget.rect.width

            if widget_width < self.size[0]:
                return 0

            if scrollbar:
                self._scroll_percentage += offset / (self.size[0] - self.scrollbar_size[0] + 0.001)
            else:
                max_scoll_width = widget_width - self.size[0]
                current_scroll_width = self._scroll_percentage * max_scoll_width
                self._scroll_percentage = (current_scroll_width + offset) / max_scoll_width

        return min(1, max(0, self._scroll_percentage))

```

```python
    def calculate_widget_rect(self):
        widget_position = self.calculate_widget_position()
        return pygame.FRect(widget_position[0] - self.position[0], self.position[1] + widget_position[1], self.size[0], self.size[1])

    def calculate_widget_position(self):
        if self._vertical:
            return (0, -self._scroll_percentage * (self._widget.rect.height - self.size[1]))
        else:
            return (-self._scroll_percentage * (self._widget.rect.width - self.size[0]), 0)

    def calculate_relative_scrollbar_position(self):
        if self._vertical:
            vertical_offset = (self.size[1] - self.scrollbar_size[1]) * self._scroll_percentage
            scrollbar_position = (0, vertical_offset)
        else:
            horizontal_offset = (self.size[0] - self.scrollbar_size[0]) * self._scroll_percentage
            scrollbar_position = (horizontal_offset, 0)

        return (scrollbar_position[0] / self.size[0], scrollbar_position[1] / self.size[1])

    def set_widget(self, new_widget):
        self._widget = new_widget
        self.set_image()
        self.set_geometry()

    def set_image(self):
        self.image = pygame.transform.scale(self._empty_surface, self.size)
        self.image.fill(theme['fillPrimary'])

        self._widget.set_image()
        self.image.blit(self._widget.image, self.calculate_widget_position())

        self._scrollbar.set_relative_position(self.calculate_relative_scrollbar_position()) # WRONG USING RELATIVE
        self._scrollbar.set_relative_size((self.scrollbar_size[0] / self.size[1], self.scrollbar_size[1] / self.size[1]))
        self._scrollbar.set_image()
        relative_scrollbar_position = (self._scrollbar.rect.left - self.position[0], self._scrollbar.rect.top - self.position[1])
        self.image.blit(self._scrollbar.image, relative_scrollbar_position)

    def set_geometry(self):
        super().set_geometry()
        self._widget.set_geometry()
        self._scrollbar.set_geometry()

    def set_surface_size(self, new_surface_size):
        super().set_surface_size(new_surface_size)
        self._widget.set_surface_size(new_surface_size)
        self._scrollbar.set_surface_size(new_surface_size)

    def process_event(self, event):
        # WAITING FOR PYGAME-CE 2.5.3 TO RELEASE TO FIX SCROLL FLAGS
        # self.image.scroll(0, SCROLL_FACTOR)
        # self.image.scroll(0, -SCROLL_FACTOR)

```

```
        offset = self._scrollbar.process_event(event)

        if offset is not None:
            self.set_image()

            if abs(offset) > 0:
                self._scroll_percentage = self.calculate_scroll_percentage(offset, scrollbar=True)

        if self.rect.collidepoint(pygame.mouse.get_pos()):
            if event.type == pygame.MOUSEBUTTONDOWN:
                if event.button == 4:
                    self._scroll_percentage = self.calculate_scroll_percentage(-self.scroll_factor)
                    self.set_image()
                    return
                elif event.button == 5:
                    if self._scroll_percentage == 100:
                        return

                    self._scroll_percentage = self.calculate_scroll_percentage(self.scroll_factor)
                    self.set_image()
                    return

        widget_event = self._widget.process_event(event, scrolled_pos=self.calculate_widget_position())
        if widget_event is not None:
            self.set_image()
        return widget_event
```

### B.25.23 slider_thumb.py

```
from data.widgets.bases.pressable import _Pressable
from data.utils.constants import WidgetState
from data.helpers.widget_helpers import create_slider_thumb
from data.managers.theme import theme

class _SliderThumb(_Pressable):
    def __init__(self, radius, border_colour=theme['borderPrimary'], fill_colour=theme['fillPrimary']):
        super().__init__(
            event=None,
            down_func=self.down_func,
            up_func=self.up_func,
            hover_func=self.hover_func,
            prolonged=True,
            sfx=None
        )
        self._border_colour = border_colour
        self._radius = radius
        self._percent = None

        self.state = WidgetState.BASE
        self.initialise_new_colours(fill_colour)

    def get_position(self):
        return (self.rect.x, self.rect.y)

    def set_position(self, position):
        self.rect = self._thumb_surface.get_rect()
        self.rect.topleft = position
```

```python

    def get_surface(self):
        return self._thumb_surface

    def set_surface(self, radius, border_width):
        self._thumb_surface = create_slider_thumb(radius, self._colours[self.state
], self._border_colour, border_width)

    def get_pressed(self):
        return self._pressed

    def down_func(self):
        self.state = WidgetState.PRESS

    def up_func(self):
        self.state = WidgetState.BASE

    def hover_func(self):
        self.state = WidgetState.HOVER
```

### B.25.24 switch.py

```python
import pygame
from data.widgets.bases.widget import _Widget
from data.widgets.bases.pressable import _Pressable
from data.utils.constants import WidgetState
from data.helpers.widget_helpers import create_switch
from data.components.custom_event import CustomEvent
from data.managers.theme import theme

class Switch(_Pressable, _Widget):
    def __init__(self, relative_height, event, fill_colour=theme['fillTertiary'],
on_colour=theme['fillSecondary'], off_colour=theme['fillPrimary'], **kwargs):
        _Pressable.__init__(
            self,
            event=event,
            hover_func=self.hover_func,
            down_func=lambda: self.set_state_colour(WidgetState.PRESS),
            up_func=self.up_func,
        )
        _Widget.__init__(self, relative_size=(relative_height * 2, relative_height
), scale_mode='height',fill_colour=fill_colour, **kwargs)

        self._on_colour = on_colour
        self._off_colour = off_colour
        self._background_colour = None

        self._is_toggled = None
        self.set_toggle_state(False)

        self.initialise_new_colours(self._fill_colour)
        self.set_state_colour(WidgetState.BASE)

        self.set_image()
        self.set_geometry()

    def hover_func(self):
        self.set_state_colour(WidgetState.HOVER)

    def set_toggle_state(self, is_toggled):
        self._is_toggled = is_toggled
        if is_toggled:
```

```
            self._background_colour = self._on_colour
        else:
            self._background_colour = self._off_colour

        self.set_image()

    def up_func(self):
        if self.get_widget_state() == WidgetState.PRESS:
            toggle_state = not(self._is_toggled)
            self.set_toggle_state(toggle_state)

        self.set_state_colour(WidgetState.BASE)

    def draw_thumb(self):
        margin = self.size[1] * 0.1
        thumb_radius = (self.size[1] / 2) - margin

        if self._is_toggled:
            thumb_center = (self.size[0] - margin - thumb_radius, self.size[1] /
    2)
        else:
            thumb_center = (margin + thumb_radius, self.size[1] / 2)

        pygame.draw.circle(self.image, self._fill_colour, thumb_center,
    thumb_radius)

    def set_image(self):
        self.image = create_switch(self.size, self._background_colour)
        self.draw_thumb()

    def process_event(self, event):
        data = super().process_event(event)

        if data:
            return CustomEvent(**vars(data), toggled=self._is_toggled)
```

### B.25.25 text.py

```
import pygame
from data.widgets.bases.widget import _Widget
from data.helpers.font_helpers import text_width_to_font_size,
    text_height_to_font_size, height_to_font_size
from data.helpers.widget_helpers import create_text_box

class Text(_Widget): # Pure text
    def __init__(self, text, center=True, fit_vertical=True, box_colours=None,
    strength=0.05, font_size=None, **kwargs):
        super().__init__(**kwargs)
        self._text = text
        self._fit_vertical = fit_vertical
        self._strength = strength
        self._box_colours = box_colours

        if fit_vertical:
            self._relative_font_size = text_height_to_font_size(self._text, self.
    _font, (self.size[1] - 2 * (self.margin + self.border_width))) / self.
    surface_size[1]
        else:
            self._relative_font_size = text_width_to_font_size(self._text, self.
    _font, (self.size[0] - 2 * (self.margin + self.border_width))) / self.
    surface_size[1]

```

```
        if font_size:
            self._relative_font_size = font_size / self.surface_size[1]

        self._center = center
        self.rect = self._font.get_rect(self._text, size=self.font_size)
        self.rect.topleft = self.position

        self._empty_surface = pygame.Surface((0, 0), pygame.SRCALPHA)

        self.set_image()
        self.set_geometry()

    def resize_text(self):
        if self._fit_vertical:
            self._relative_font_size = text_height_to_font_size(self._text, self._font, (self.size[1] - 2 * (self.margin + self.border_width))) / self.surface_size[1]
        else:
            ideal_font_size = height_to_font_size(self._font, target_height=(self.size[1] - (self.margin + self.border_width))) / self.surface_size[1]
            new_font_size = text_width_to_font_size(self._text, self._font, (self.size[0] - (self.margin + self.border_width))) / self.surface_size[1]

            if new_font_size < ideal_font_size:
                self._relative_font_size = new_font_size
            else:
                self._relative_font_size = ideal_font_size

    def set_text(self, new_text):
        self._text = new_text

        self.resize_text()
        self.set_image()

    def set_image(self):
        if self._box_colours:
            self.image = create_text_box(self.size, self.border_width, self._box_colours)
        else:
            text_surface = pygame.transform.scale(self._empty_surface, self.size)
            self.image = text_surface

            if self._fill_colour:
                fill_rect = pygame.FRect(0, 0, self.size[0], self.size[1])
                pygame.draw.rect(self.image, self._fill_colour, fill_rect, border_radius=int(self.border_radius))

        self._font.strength = self._strength
        font_rect_size = self._font.get_rect(self._text, size=self.font_size).size
        if self._center:
            font_position = ((self.size[0] - font_rect_size[0]) / 2, (self.size[1] - font_rect_size[1]) / 2)
        else:
            font_position = (self.margin / 2, (self.size[1] - font_rect_size[1]) / 2)
        self._font.render_to(self.image, font_position, self._text, fgcolor=self._text_colour, size=self.font_size)

        if self._box_colours is None and self.border_width:
            fill_rect = pygame.FRect(0, 0, self.size[0], self.size[1])
            pygame.draw.rect(self.image, self._border_colour, fill_rect, width=int(self.border_width), border_radius=int(self.border_radius))
```

```
    def process_event(self, event):
        pass
```

### B.25.26 text_button.py

```
from data.widgets.bases.pressable import _Pressable
from data.widgets.bases.box import _Box
from data.widgets.text import Text
from data.utils.constants import WidgetState, BLUE_BUTTON_COLOURS

class TextButton(_Box, _Pressable, Text):
    def __init__(self, event, **kwargs):
        _Box.__init__(self, box_colours=BLUE_BUTTON_COLOURS)
        _Pressable.__init__(
            self,
            event=event,
            hover_func=lambda: self.set_state_colour(WidgetState.HOVER),
            down_func=lambda: self.set_state_colour(WidgetState.PRESS),
            up_func=lambda: self.set_state_colour(WidgetState.BASE),
        )
        Text.__init__(self, box_colours=BLUE_BUTTON_COLOURS[WidgetState.BASE], **kwargs)

        self.initialise_new_colours(self._fill_colour)
        self.set_state_colour(WidgetState.BASE)
```

### B.25.27 text_input.py

See Section 3.4.4.

### B.25.28 timer.py

```
import pygame
from data.utils.constants import WidgetState, BLUE_BUTTON_COLOURS, RED_BUTTON_COLOURS
from data.components.custom_event import CustomEvent
from data.managers.animation import animation
from data.utils.enums import Colour
from data.widgets.text import Text

class Timer(Text):
    def __init__(self, active_colour, event=None, start_mins=60, **kwargs):
        box_colours = BLUE_BUTTON_COLOURS[WidgetState.BASE] if active_colour == Colour.BLUE else RED_BUTTON_COLOURS[WidgetState.BASE]

        self._current_ms = float(start_mins) * 60 * 1000
        self._active_colour = active_colour
        self._active = False
        self._timer_running = False
        self._event = event

        super().__init__(text=self.format_to_text(), fit_vertical=False, box_colours=box_colours, **kwargs)

    def set_active(self, is_active):
        if self._active == is_active:
            return

        if is_active and self._timer_running is False:
```

```
            self._timer_running = True
            animation.set_timer(1000, self.decrement_second)

        self._active = is_active

    def set_time(self, milliseconds):
        self._current_ms = milliseconds
        self._text = self.format_to_text()
        self.set_image()
        self.set_geometry()

    def get_time(self):
        return self._current_ms / (1000 * 60)

    def decrement_second(self):
        if self._active:
            self.set_time(self._current_ms - 1000)

            if self._current_ms <= 0:
                self._active = False
                self._timer_running = False
                self.set_time(0)
                pygame.event.post(pygame.event.Event(pygame.MOUSEMOTION, pos=
    pygame.mouse.get_pos())) # RANDOM EVENT TO TRIGGER process_event
            else:
                animation.set_timer(1000, self.decrement_second)
        else:
            self._timer_running = False

    def format_to_text(self):
        raw_seconds = self._current_ms / 1000
        minutes, seconds = divmod(raw_seconds, 60)
        return f'{str(int(minutes)).zfill(2)}:{str(int(seconds)).zfill(2)}'

    def process_event(self, event):
        if self._current_ms <= 0:
            return CustomEvent(**vars(self._event), active_colour=self.
    _active_colour)
```

### B.25.29 volume_slider.py

```
import pygame
from data.helpers.asset_helpers import scale_and_cache
from data.helpers.widget_helpers import create_slider
from data.utils.event_types import SettingsEventType
from data.components.custom_event import CustomEvent
from data.widgets.slider_thumb import _SliderThumb
from data.widgets.bases.widget import _Widget
from data.utils.constants import WidgetState
from data.managers.theme import theme

class VolumeSlider(_Widget):
    def __init__(self, relative_length, default_volume, volume_type, thumb_colour=
    theme['fillSecondary'], **kwargs):
        super().__init__(relative_size=(relative_length, relative_length * 0.2),
    **kwargs)

        self._volume_type = volume_type
        self._selected_percent = default_volume
        self._last_mouse_x = None

```

```
        self._thumb = _SliderThumb(radius=self.size[1] / 2, border_colour=self._border_colour, fill_colour=thumb_colour)
        self._gradient_surface = create_slider(self.calculate_slider_size(), self._fill_colour, self.border_width, self._border_colour)

        self._empty_surface = pygame.Surface(self.size, pygame.SRCALPHA)

    @property
    def position(self):
        '''Minus so easier to position slider by starting from the left edge of the slider instead of the thumb'''
        return (self._relative_position[0] * self.surface_size[0] - (self.size[1] / 2), self._relative_position[1] * self.surface_size[1])

    def calculate_slider_position(self):
        return (self.size[1] / 2, self.size[1] / 4)

    def calculate_slider_size(self):
        return (self.size[0] - 2 * (self.size[1] / 2), self.size[1] / 2)

    def calculate_selected_percent(self, mouse_pos):
        if self._last_mouse_x is None:
            return

        x_change = (mouse_pos[0] - self._last_mouse_x) / (self.calculate_slider_size()[0] - 2 * self.border_width)
        return max(0, min(self._selected_percent + x_change, 1))

    def calculate_thumb_position(self):
        gradient_size = self.calculate_slider_size()
        x = gradient_size[0] * self._selected_percent
        y = 0

        return (x, y)

    def relative_to_global_position(self, position):
        relative_x, relative_y = position
        return (relative_x + self.position[0], relative_y + self.position[1])

    def set_image(self):
        gradient_scaled = scale_and_cache(self._gradient_surface, self.calculate_slider_size())
        gradient_position = self.calculate_slider_position()

        self.image = pygame.transform.scale(self._empty_surface, (self.size))
        self.image.blit(gradient_scaled, gradient_position)

        thumb_position = self.calculate_thumb_position()
        self._thumb.set_surface(radius=self.size[1] / 2, border_width=self.border_width)
        self._thumb.set_position(self.relative_to_global_position((thumb_position[0], thumb_position[1])))

        thumb_surface = self._thumb.get_surface()
        self.image.blit(thumb_surface, thumb_position)

    def set_volume(self, volume):
        self._selected_percent = volume
        self.set_image()

    def process_event(self, event):
        if event.type not in [pygame.MOUSEMOTION, pygame.MOUSEBUTTONDOWN, pygame.
```

```
    MOUSEBUTTONUP]:
            return

        before_state = self._thumb.state
        self._thumb.process_event(event)
        after_state = self._thumb.state

        if before_state != after_state:
            self.set_image()

            if event.type in [pygame.MOUSEBUTTONDOWN, pygame.MOUSEBUTTONUP]:
                self._last_mouse_x = None
                return CustomEvent(SettingsEventType.VOLUME_SLIDER_CLICK, volume=round(self._selected_percent, 3), volume_type=self._volume_type)

        if self._thumb.state == WidgetState.PRESS:
            selected_percent = self.calculate_selected_percent(event.pos)
            self._last_mouse_x = event.pos[0]

            if selected_percent:
                self._selected_percent = selected_percent
                self.set_image()
                return CustomEvent(SettingsEventType.VOLUME_SLIDER_SLIDE)
```

### B.25.30 __init__.py

```
from data.widgets.bases.widget import _Widget
from data.widgets.bases.pressable import _Pressable
from data.widgets.bases.circular import _Circular
from data.widgets.bases.box import _Box
from data.widgets.colour_display import _ColourDisplay
from data.widgets.colour_square import _ColourSquare
from data.widgets.colour_slider import _ColourSlider
from data.widgets.slider_thumb import _SliderThumb
from data.widgets.scrollbar import _Scrollbar

from data.widgets.board_thumbnail_button import BoardThumbnailButton
from data.widgets.multiple_icon_button import MultipleIconButton
from data.widgets.reactive_icon_button import ReactiveIconButton
from data.widgets.board_thumbnail import BoardThumbnail
from data.widgets.reactive_button import ReactiveButton
from data.widgets.volume_slider import VolumeSlider
from data.widgets.colour_picker import ColourPicker
from data.widgets.colour_button import ColourButton
from data.widgets.browser_strip import BrowserStrip
from data.widgets.piece_display import PieceDisplay
from data.widgets.browser_item import BrowserItem
from data.widgets.text_button import TextButton
from data.widgets.icon_button import IconButton
from data.widgets.scroll_area import ScrollArea
from data.widgets.chessboard import Chessboard
from data.widgets.text_input import TextInput
from data.widgets.rectangle import Rectangle
from data.widgets.move_list import MoveList
from data.widgets.dropdown import Dropdown
from data.widgets.carousel import Carousel
from data.widgets.switch import Switch
from data.widgets.timer import Timer
from data.widgets.text import Text
from data.widgets.icon import Icon
```

```
__all__ = ['Text', 'TextButton', 'ColourPicker', 'ColourButton', 'Switch', '
    Dropdown', 'IconButton', 'Icon', 'VolumeSlider', 'TextInput', '
    MultipleIconButton', 'Carousel', 'Timer', 'Rectangle', 'Chessboard', '
    ScrollArea', 'MoveList', 'BoardThumbnail', 'BrowserStrip', 'BrowserItem', '
    PieceDisplay', 'BoardThumbnailButton', 'ReactiveButton', 'ReactiveIconButton']
```

## B.26 data\widgets\bases

### B.26.1 box.py

```
from data.utils.constants import WidgetState

class _Box:
    def __init__(self, box_colours):
        self._box_colours_dict = box_colours
        self._box_colours = self._box_colours_dict[WidgetState.BASE]

    def set_state_colour(self, state):
        self._box_colours = self._box_colours_dict[state]
        super().set_state_colour(state)
```

### B.26.2 circular.py

See Section 3.4.3.

### B.26.3 pressable.py

```
import pygame
from data.utils.constants import WidgetState
from data.managers.audio import audio
from data.utils.assets import SFX

class _Pressable:
    def __init__(self, event, down_func=None, up_func=None, hover_func=None,
    prolonged=False, sfx=SFX['button_click'], **kwargs):
        self._down_func = down_func
        self._up_func = up_func
        self._hover_func = hover_func
        self._pressed = False
        self._prolonged = prolonged
        self._sfx = sfx

        self._event = event

        self._widget_state = WidgetState.BASE

        self._colours = {}

    def set_state_colour(self, state):
        self._fill_colour = self._colours[state]

        self.set_image()

    def initialise_new_colours(self, colour):
        r, g, b, a = pygame.Color(colour).rgba

        self._colours = {
            WidgetState.BASE: pygame.Color(r, g, b, a),
            WidgetState.HOVER: pygame.Color(min(r + 25, 255), min(g + 25, 255),
    min(b + 25, 255), a),
```

```
            WidgetState.PRESS: pygame.Color(min(r + 50, 255), min(g + 50, 255),
    min(b + 50, 255), a)
        }

    def get_widget_state(self):
        return self._widget_state

    def process_event(self, event):
        match event.type:
            case pygame.MOUSEBUTTONDOWN:
                if self.rect.collidepoint(event.pos):
                    self._down_func()
                    self._widget_state = WidgetState.PRESS

            case pygame.MOUSEBUTTONUP:
                if self.rect.collidepoint(event.pos):
                    if self._widget_state == WidgetState.PRESS:
                        if self._sfx:
                            audio.play_sfx(self._sfx)

                        self._up_func()
                        self._widget_state = WidgetState.HOVER
                        return self._event

                    elif self._widget_state == WidgetState.BASE:
                        self._hover_func()

                elif self._prolonged and self._widget_state == WidgetState.PRESS:
                    if self._sfx:
                        audio.play_sfx(self._sfx)
                    self._up_func()
                    self._widget_state = WidgetState.BASE
                    return self._event

            case pygame.MOUSEMOTION:
                if self.rect.collidepoint(event.pos):
                    if self._widget_state == WidgetState.PRESS:
                        return
                    elif self._widget_state == WidgetState.BASE:
                        self._hover_func()
                        self._widget_state = WidgetState.HOVER
                    elif self._widget_state == WidgetState.HOVER:
                        self._hover_func()
                else:
                    if self._prolonged is False:
                        if self._widget_state in [WidgetState.PRESS, WidgetState.
    HOVER]:
                            self._widget_state = WidgetState.BASE
                            self._up_func()
                        elif self._widget_state == WidgetState.BASE:
                            return
                    elif self._prolonged is True:
                        if self._widget_state in [WidgetState.PRESS, WidgetState.
    BASE]:
                            return
                        else:
                            self._widget_state = WidgetState.BASE
                            self._up_func()
```

### B.26.4 widget.py

See Section 3.4.3.