Maze Generation NEA

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Contents

Part I
Analysis

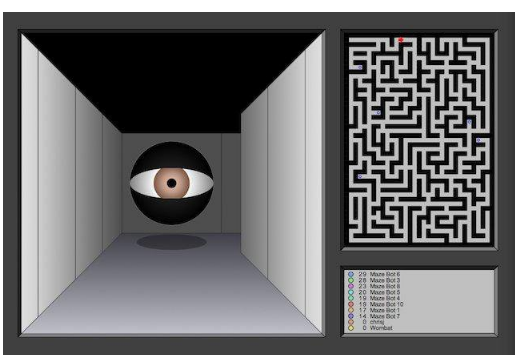
1 Research

1.1 General Research

Research on maze generation algorithms was done using the book "Mazes for Programmers", with "Kruskal's algorithim" being the specific algorithim chosen. It is described as such in the book; "Kruskal's algorithm was developed by the mathematician and computer scientist Joseph Kruskal in 1956 to construct *minimum spanning trees*." "Basically, Kruskal was trying to solve the following problem. Let's say you start with a graph, or grid, where every possible passage that might connect neighboring cells is given a cost." "How do you construct a maze from that initial grid whose passages have costs that sum to the lowest total value? *What's the cheapest tree that can be built?*". Iin the context of maze generation a "spanning tree" is analogous to a "perfect maze" or a maze where any cell can be reached from any other cell. This is useful as it ensures any maze generated is solvable. The word "minimum" means that the spanning tree is generated in the least expensive way possible, with the cost being calculated using weights attached to each individual corridor between maze cells. Corridors having weights allows the program to control how the maze generates while still keeping some randomness, avoiding the mazes becoming reptative immediately. The algorithm also has a tendency to creating hook-like generation patterns, this makes the mazes easier to solve than they actually look, as a lot of possible paths can be immediately discounted. On a much more general level the maze can be thought of as generating and joining together a bunch of smaller mazes.

In terms of actually rendering the maze/player, during research I found two main options, one, using Pygame or, two, making it myself. The former of the two would be easier but it would likely run worse than the latter and give me less control over how the rendering worked. The maze itself would exist entirely within screen space (the actual pixels on screen), making the implementation simpler regardless of what option is picked. It should also be noted that pygame doesn't come pre-installed with python, though it is likely a different external library would be needed to make the rendering work if the second option was chosen. Ultimately, I went with the second option due to the added control, I decied to use Pillow (a fork of P.I.L) along with tkinter to create the implementaion.

1.2 Examples of Maze Games



Here is shown an example of a very early maze game, called "Maze War". While the game is mostly played in first-person there is also a top-down map shown. Thier representation of the maze is seemingly made up of cells that can eithier be walls or non-walls, for my implementation I instead opted to have each cell have four toggleable walls.

This example is much closer to what I wanted, including the font used (excluding the title) and the way the maze is presented. The only major difference to the way the maze looks is that my version doesn't include a blue backing. There is also a slight visual glitch where some of the lines of the maze are rendered thicker than others, which is likely caused by thier renderer not being adjusted for the given screen size.

1.3 Potential Users

Unfortunately, due to the recent pandemic I have been unable to find a potential user. Due to this I've had to leave out this section and also the follow-up section in the evaluation.

2 Objective Outline

The objective of this project is to create a maze-solving game, fully coded in python. This project will need to include, in order of importance;

1. Performative Maze Rendering
   (a) Layer Based Rendering
   (b) Ability to edit any given pixel on a given layer
2. Gameplay Mechanics
   (a) Key input
   (b) Collision detection
   (c) Ability to win
3. Controllable maze generation
4. GUI
   (a) User Select
   (b) Maze Type Select
   (c) Level select
5. System for storing users completed levels

Given the entire project is based around maze generation, the algorithim used to generate the mazes needs to not only be contrallable but also suitably complex (as to avoid predictable generation).

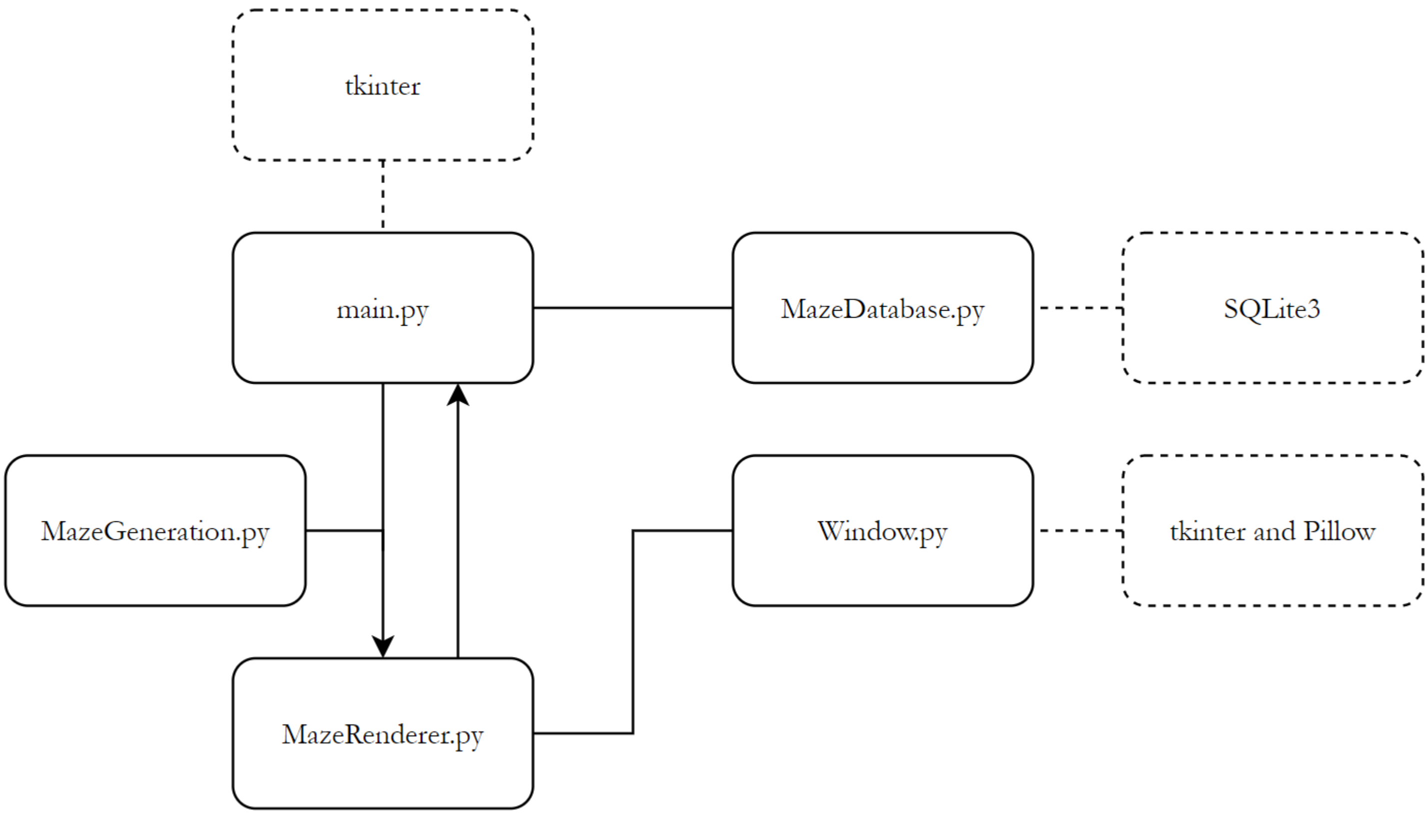
Part II

Documented Design

3 Program Structure Overview Diagram

The project will be organized into five scripts, each handiling sections of the project;

- main.py - Controls/Passes data to the scripts, MazeDatabase, MazeGeneration and MazeRenderer aswell as handiling G.U.I.
- MazeGeneration.py - Handles maze generations, returning maze_data arrays that represent mazes.
- MazeDatabase.py - Controls a user information and completed levels relational database, utilizing SQLite3.
- Window.py - The previously discussed implementation of tkinter and Pillow to create rendering. It will also handle input attached to the windows it creates.
- MazeRenderer.py - Handles game logic (such as collision) and implements the Window.py script to display the visuals on screen and control the player.



Above is a diagram showcasing all the scripts listed in the Organization of Solution section. "main.py" is the starting point, which will also communicate with "MazeDatabase.py" to handle users/saving completed levels. It also has a link to tkinter, though in the diagram the link is dotted as while tkinter is vital to "main.py" script it is not code I have written. This is the same relationship with "MazeDatabase.py" and SQLite3. The final link is to "MazeRenderer.py", however, the link itself is connected to "MazeGeneration.py" this is because while "MazeGeneration.py" is controlled by "main.py" the generated maze is immediately passed to "MazeRenderer.py". "MazeRenderer.py" has a link to "Window.py" which it uses to create the window of editable pixels used to render the game. There is also a link back to "main.py" as the user is returned there after the level is completed or quit. "Window.py" also has a dotted link to tkinter and Pillow for the same reason as "main.py" and "MazeDatabase.py" mentioned above.

4 Database Diagrams

To complete my objective of storing a given users completed levels I decided to use a relational database. My justification for this is two-fold, one, I wanted to demonstrate my ability to use SQLite3 and, two, relational databases allow for a lot more flexibilty/ease-of-use comparaed to storing all of the different users completed levels in a text file.

4.1 Tables

Table: users

Field	Key	Data Type	Validation	Notes
id	Primary	integer		
username		string	NOT NULL	

Table: completedLevels

Field	Key	Data Type	Validation	Notes
id	Primary	integer		
normal_maze		text		
diamond_maze		text		
user_id	Foreign	integer	NOT NULL	

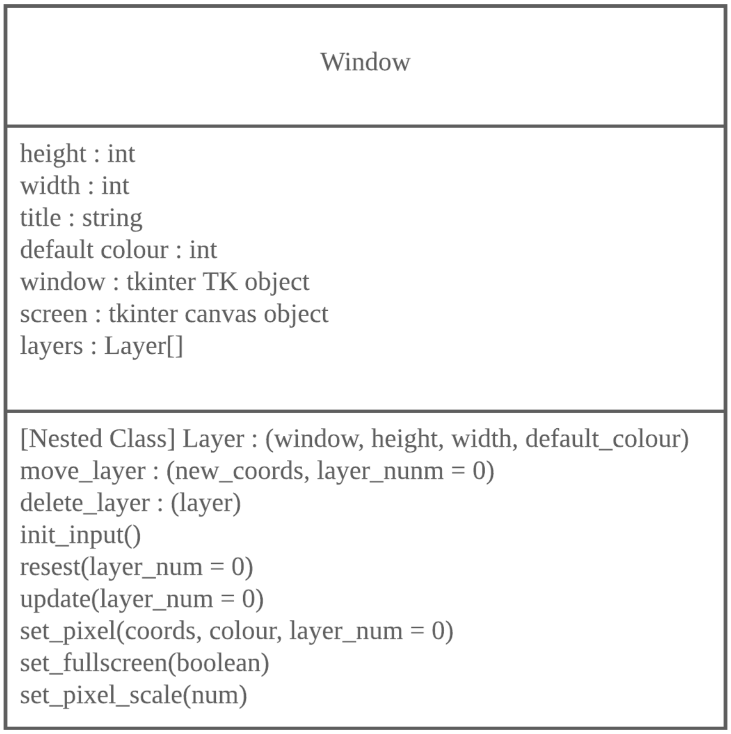
The fields ”normal_maze” and ”diamond_maze” are both meant to be lists, however, you are unable to properly store lists in a database. Hence, they must be converted into text and then also, consequently, be converted back into lists when they need to be accessed. For example, the array [1,2,3,4,5] is converted to ’1#2#3#4#5’ by iterating through the list and appending each entry to a string. The ’#’ would also be appended unless the entry is the last one in the array. To convert back to an array a simple .split(’#’) is used on the string.

4.2 Entity-Relationship Diagram

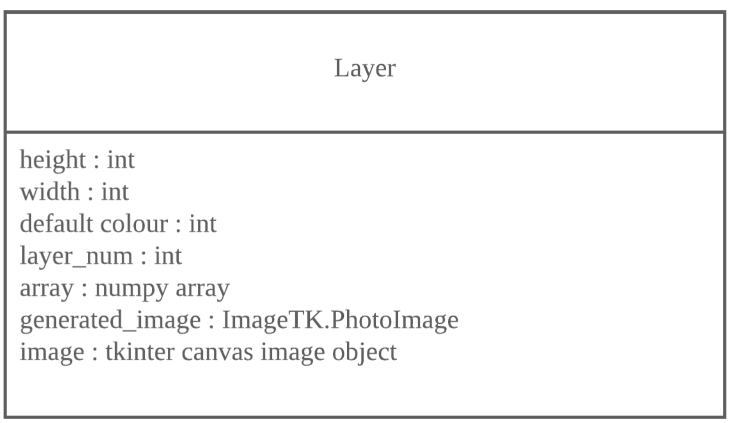
The entity-relationship diagram for the database is very simple as the database itself is simple. There is only one relationship, a one-to-one, between users and completedLevels. This represents the foreign key user_id, and is used to link a user’s completed levels to them.

5 Class Diagrams

5.1 Window

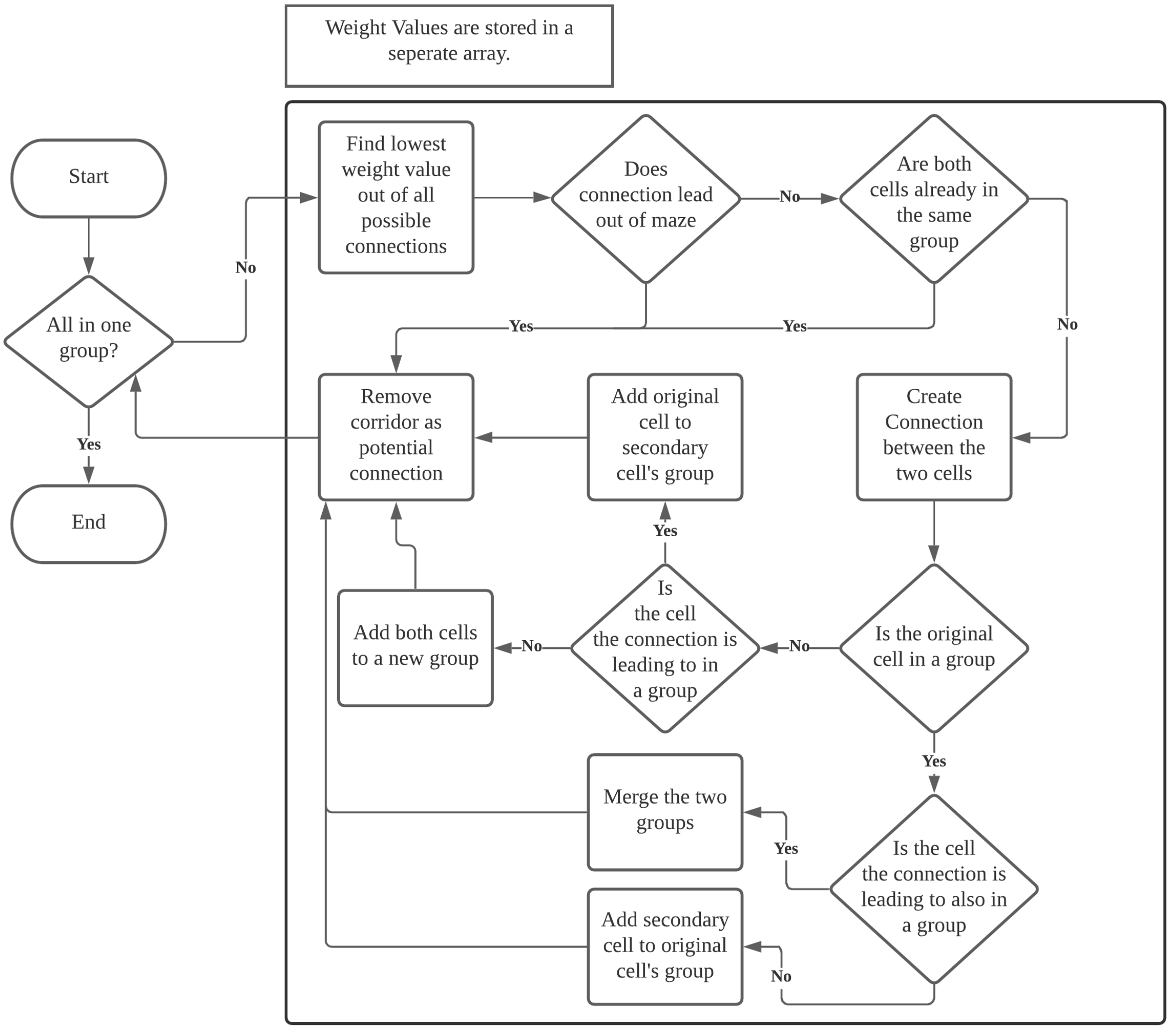


5.2 Layer



(Note: In Python a nested class doesn't imply any relationship)

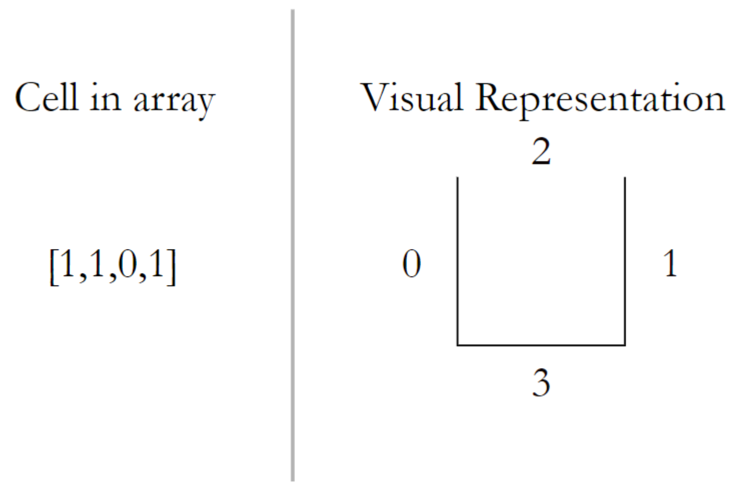
6 Kruskals Algorithm



7 Data Structures

7.1 Maze Array

A ”maze array” is a data structrue meant to represent the maze and is essentially a 2D array. Each cell in the maze has a coordinate and this corresponds to an index in one of the arrays, meaning each 1D array is equivalent to a row of maze cells. Stored within each actual cell is four integers, which can eithier be one or zero and these represent a wall or a lack of a wall respectively. A possible optimization would be for these cells to only contain information about the top and left walls as this would still represent almost every wall in the maze, apart from the very edges on the bottom and right. Given the player isn’t able to walk outside of the maze anyway they could simply be replaced with a two lines. The maze array is output by the ”MazeGeneration.py” script before being transferred to ”MazeRenderer.py” where the maze is then shown on screen.



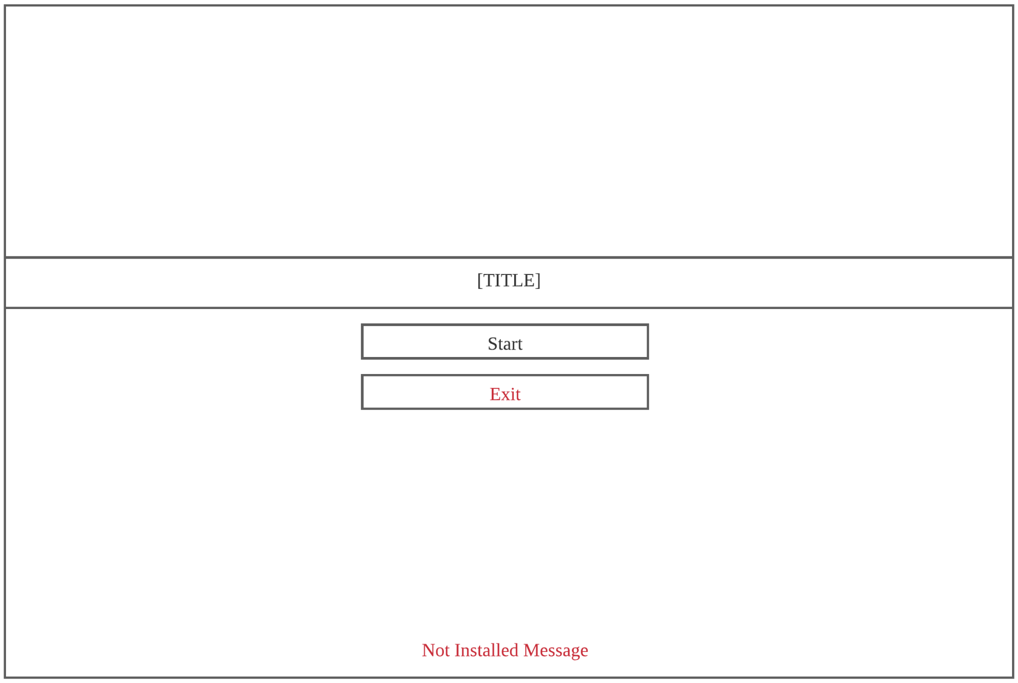
(The numbers on the Visual Representation correlate to the index in the array)

7.2 Weight Array

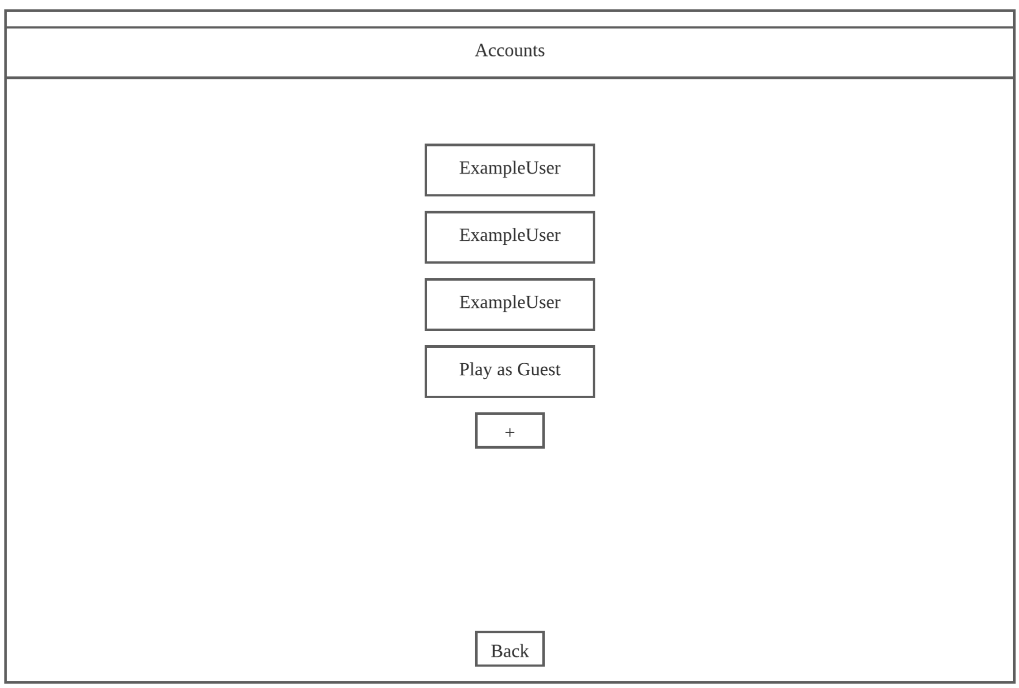
A ”weight array” is a very similar data structure to the maze array as it its also a 2D array. Each index in the maze array has a corresponding index in the weight array, they are only kept in seperate arrays as the data in the weight array does not need to be passed onto ”MazeRenderer.py”. For every cell wall there is a weight value stored, in the same way walls are stored in the ”maze array”, however, there is also a ”group” integer stored with every cell. This group value is used in the Krusklas algorithm used for maze generation and is set to a default/ignored group before maze generation is run. Having this ignored group is important as it allows the check to see if every cell is in one group to not return true before any alterations have been made to the maze.

8 G.U.I

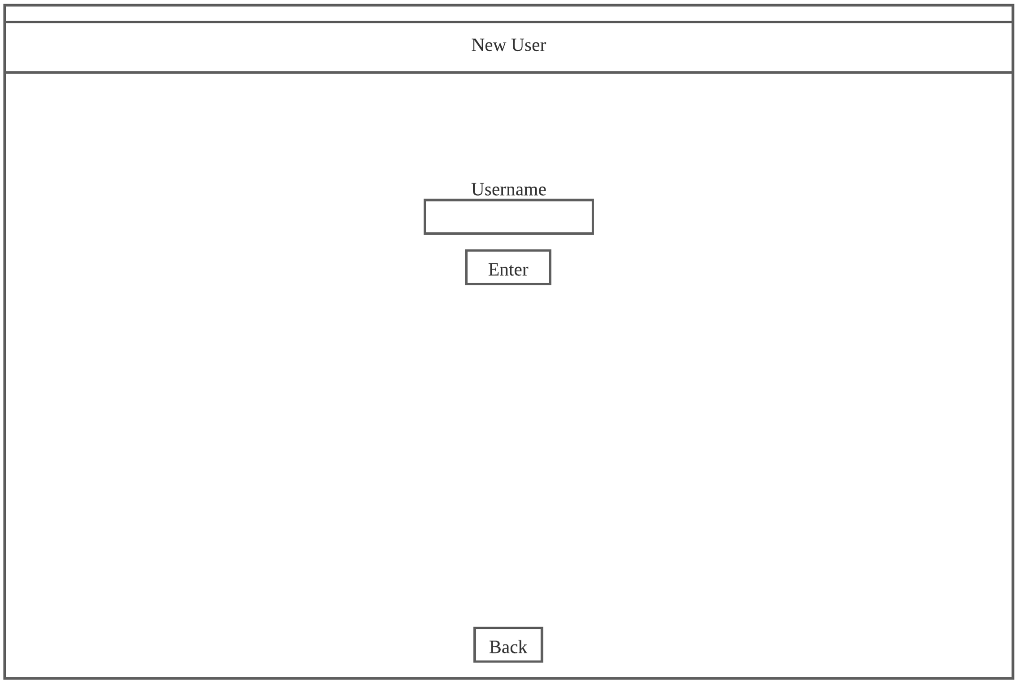
8.1 Maze and User Selection



Above is the start screen, it features the title and two buttons. The first button is the start button which will lead to the user select screen and the second is the exit button which will simply close the button.

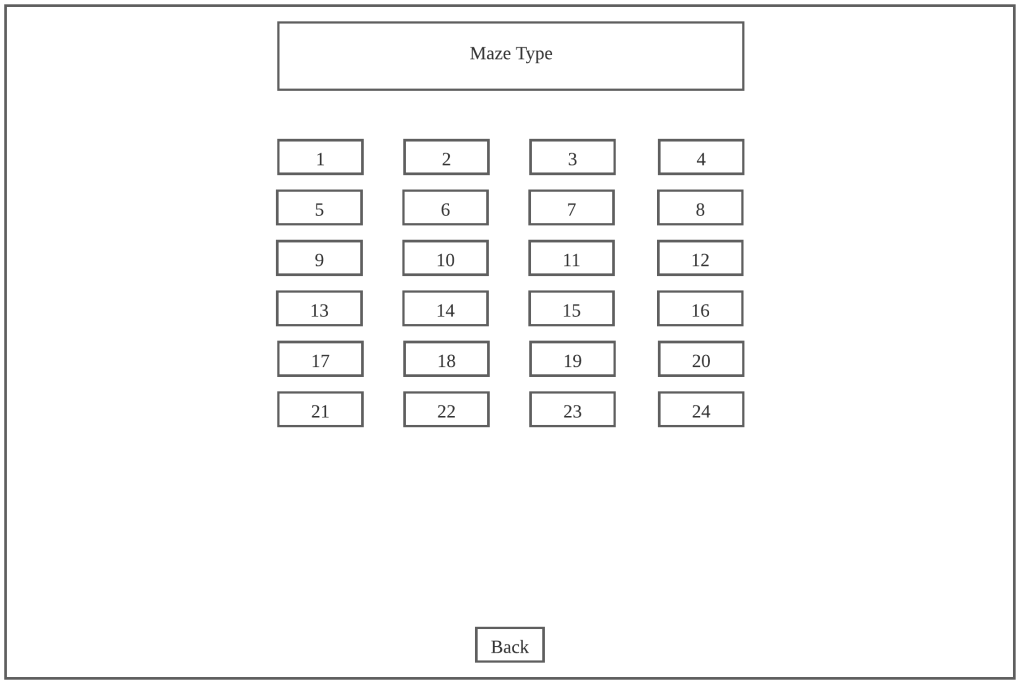


On the user select screen there is a list of created users, a play as guest button, a button to add a new user (the plus) and a back button. The back button will send that user back to the start screen.

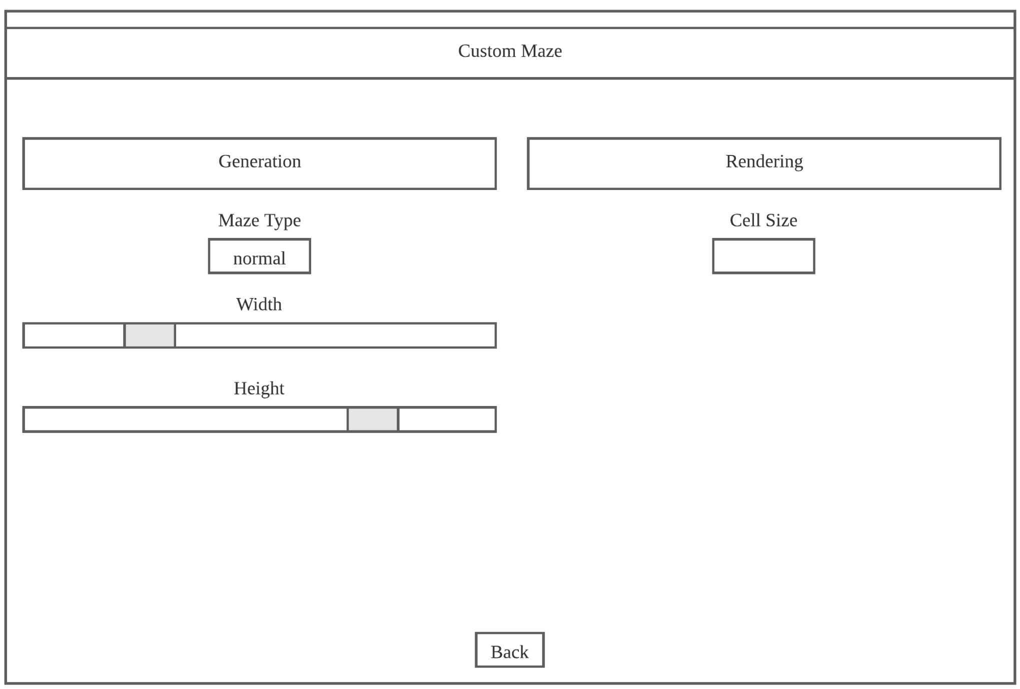


The new user screen only needs to include an entry bar for the name to be typed in, a button to confirm the username and a back button (to take the user back to the user select screen). There is exception handiling to stop a username being entered that is blank.

On the maze select screen all current maze types are displayed as buttons, in the image above these are; "Normal-Style Maze", "Diamond Maze" and "Custom Maze". There is also a "Reset Progress" button that, if the user isn't a guest, will reset their completed levels entry in the maze database. It also has a back button which takes the user back to the user select screen.

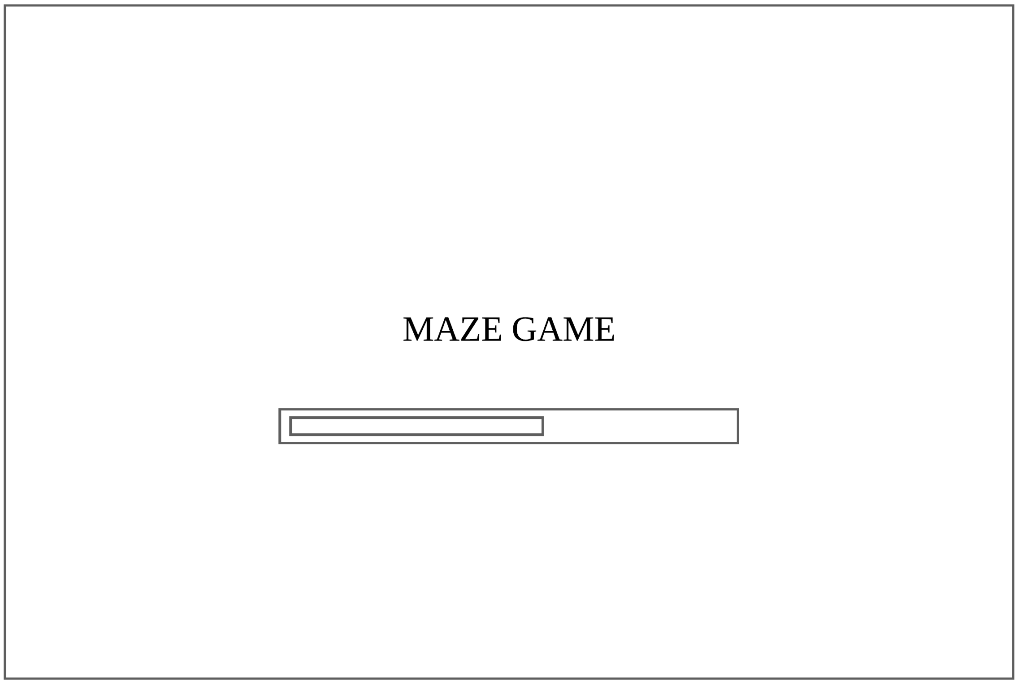


The maze level select screen consists of rows of buttons that are generated iteratively, each button with a number correlating to the difficulty of the level (The actual size of the maze is the number+3). Like the other screens there is a back button, which in this case, leads back to the maze type select screen.

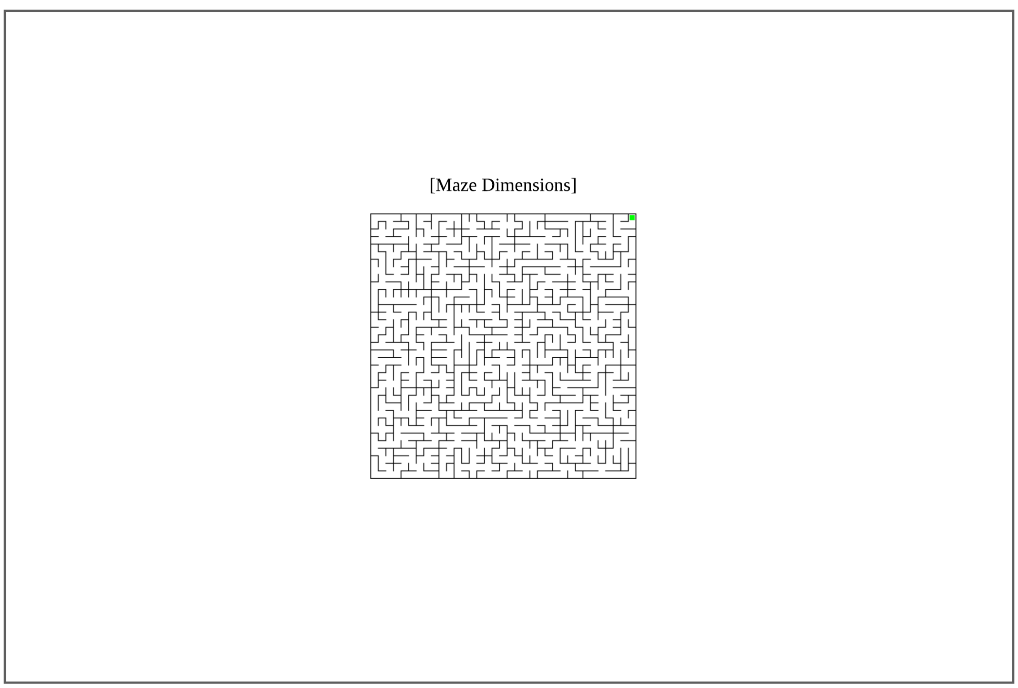


Included on the custom maze screen is halves, one dedicated to rendering and the other to generation. The generation options are maze type, width and height, while the only option for rendering is cell size. More options could certainly be added (as my rendering scripts allow for it) if I had more time.

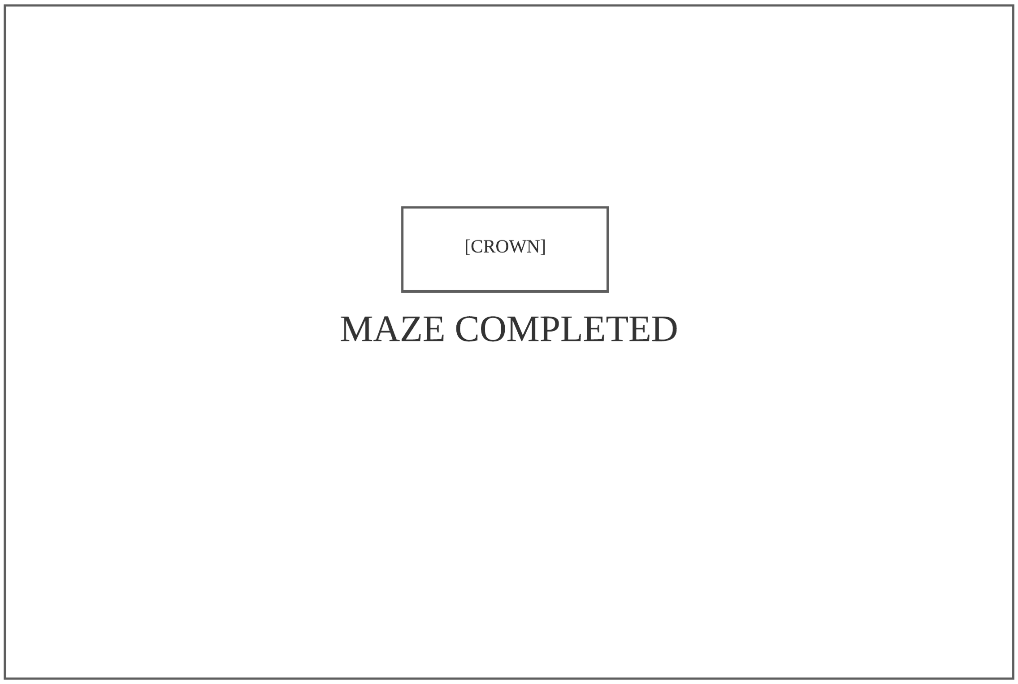
8.2 Game Visuals



Above is the loading/title screen meant to create a slight delay between the level select screen and playing the actual maze, mainly to give the game a nicer feel. In actuality the loading bar isn't actual linked to any loading, though if I had more time, through the use of a recursive function, I could pair it with the maze generation.



The screen above is where the actual maze will be played, with an example 35 by 35 maze shown. Above the maze proper is the maze dimensions, serving as a title.



This screen is displayed for a few seconds after the maze is completed, it features the words "Maze Completed" along with a little pixel art crown.

Part III
Testing

9 Test Table (Post-Development)

Objective	Test	Input	Expected Result	Actual Result	Passed	Comments
GUI						
Create New User	1	ExampleUser	New user is added to database	As expected	Yes	
Select User	2	Click on ExampleUser button	user_id is set to the user id of ExampleUser	As expected	Yes	
Select Maze Type	3	Normal Maze Type Selected	Maze Generated is of Normal Maze type	As expected	Yes	
Select Maze Dimensions	4	Level 5 selected	Should generate a maze of size 8 by 8	As expected	Yes	
Input Maze of non-equal dimensions in custom maze screen	5	Entered dimensions of 16 by 5	Should generate a maze of size 16 by 5	As expected	Yes	
Gameplay						
Arrow Key Input	6	Every arrow key in turn	Should move in one of the four directions depending on arrow key pressed	As expected	Yes	Test was done in a maze without walls so all directions could be tested easily
Collision Detection	7	Attempts to move through wall	Movement is not allowed	As expected	Yes	
Win detection	8	Moves to the win position	Game ends, displaying "Maze Completed" screen	As expected	Yes	

Part IV
Evaluation

10 Were the objectives met?

10.1 Performative Maze Rendering

I believe this objective has been met very well, as both "Layer Based Rendering" and the "ablilty to edit any given pixel on a given layer" have been implemented. The program also runs at about 2000 frames per second, however, the fps calculation is admittely limited. If the time taken to execute a frame is recorded as 0 then the calcualtion cannot be performed as to avoid a zero division error. The code could also be compilied using something such as Cython. This means that the frame rate could be higher, though 2000 frames is certainly enough. The pixels on screen can also be any colour representable in the format (8-bit integer, 8-bit integer,8-bit integer), meaning there are 1,6581,375 possible colours. Currently, the main part of the rendering that could be improved is the dependency on outside packages, specifically Pillow and Numpy.

10.2 Gameplay Mechanics

I also feel that the desired gameplay mechanics have been implemented well, with things such as the input keys and win location being customizable. However, the collision system used very specific to the project with it working entirely off the maze_array. I also think the gameplay can get monotonous and more mechanics would be helpful to break up the gameplay, for example, tunnels that lead to another part of the maze. If there was also a cap on how big groups could get then the maze would instead be spilt into multiple smaller mazes with the tunnels used to connect them. Of course, there would need to be checks in place to make sure the maze was still solvable.

10.3 Controllable maze generation

In my opnion, similar to the Gameplay Mechanics, this objective has been met but ultimately more could be done. For example, the book used for research ("Mazes for Programmers") talks about weaving which could have been an interesting addition to the maze generation. In terms of storing the maze, I think the way of accessing a specific cell is implemented well, with each index being analogous to that given cells coordinate, however, as discussed in the section about the maze_array data structure, there could have been optimizations made to the way information about cell walls was stored.

10.4 GUI

I believe my GUI has everything I outlined as an objective for it. It has a user select screen, a maze type select screen and a level select screen. The user select screen also has a button leading to a user creation screen where a username can be input, however, it does lack the ability to delete users. On the maze typeselect screen there is two maze types avaliable as well as a custom maze maze option, leading to an options menu. Lastly there is the level select screen which features adjustable columns and adjustable number of levels overall. The text on the buttons is turned green when a level is completed, utilizing the database system.

10.5 System for storing users completed levels

I think that the database system works well and it is utilized for various things, as discussed above and it works well for all of those things. However, there is no ability to remove a user from the database, meaning any user created is permanent, though any given user's progress can be reset. Apart from pure functionality, its purpose was to demonstrate that I had the ability to use SQLite3 and I think it does that well.

11 Independent Feedback

As mentioned in the analysis section due to the covid pandemic I was unable to find a third-party to get feedback from, hence, this section has been skipped.

12 Conclusion

Part V

Code breakdown by function

13 main.py

This script handles the creation of the UI as well as running the Maze Database, MazeGenerationNew and MazeRendererNew scripts.

```
def change_state(state):

    des()
    if state == "start":
        title = tk.Label(window, text = "\n Maze Game \n Version 2.0 \n", bg = "white", borderwidth=1,
            relief="groove").pack(fill = "x",pady=(250,20))
        enter_button = tk.Button(window, text = "Enter",bg = "white",width=30, command = lambda:
            change_state("username")).pack()
        exit_button = tk.Button(window, text = "Exit",width=30, bg = "white", fg = "red", command = lambda
            : exit()).pack(pady=3)
        if not installed:
            error_message = tk.Label(window,text="[PIL or Numpy not installed, PIL and Numpy are required
                for current version]",fg="red").pack(side="bottom",pady = 20)
    if state == "username":
        title = tk.Label(window, text = "\n Accounts \n", bg = "white",  borderwidth=1, relief="groove").
            pack(fill = "x",pady=(20,100))
        top_seperator = tk.Canvas(window, height=50,width=0).pack()
        ...
```

The "change state" function takes the argument "state" and uses that to switch to a pre-defined set of UI elements, e.g. a main menu or a user select screen.

```
def create_levels(lower,upper,number_of_columns,title,maze_type,completed):
    des()
    first = tk.Frame(window)
    first.pack(side='top')
    side = first
    title_ = tk.Label(window, text = ("\n" + title + "\nSelect a level\n"), bg = "white", borderwidth = 1,
         relief = "groove").pack(in_ = first,fill = "x",pady=20)
    top_seperator = tk.Canvas(window, height=50,width=0).pack(in_ = side)
    dict_one = {
                "normal":0,
                "diamond":1
                }
    for i in range((lower),(upper+1)):
            text = str(i)
            try:
                if completed[dict_one[maze_type]].count(text) > 0:
                    fg = "green"
                    text += "\n(Complete)"
                else:
                    fg = "black"
            except:
                fg = "black"
            button = tk.Button(window, text=text, width = 10, relief = 'groove', bg = "white",fg = fg)
            button.config(command = lambda mt = maze_type, btn = button : load_maze(lower,upper,title,mt,
                dict_one[maze_type],btn))
            button.pack(in_ = side, side = "left", padx=10,pady=10)
            if (i%number_of_columns) == 0:
                middle = tk.Frame(window)
                middle.pack(side = "top")
                side = middle
    back_button = tk.Button(window, text = "Back", command = lambda: change_state("maze select")).pack(
        side="bottom",pady=10)
```

"Create levels" generates a set of buttons with numbers on them, defined by the range entered in the parameters (lower and upper). If the level has already been completed by the user then the text will be green! It lays them out based on the parameter "number_of_columns". When the user clicks on one of these buttons the actual button is passed to the function so that the text on the button can be properly read.

```
def load_maze(lower,upper,title,maze_type,btn):   #Generates the maze and then passes the data along with
    other parameters to the MazeRenderer script
    maze_size = int((btn['text']).replace("\n(Complete)","")) + 3
    if installed:
        maze_data = main(maze_size,maze_size,1000,maze_type)
        dict_two = {
            "normal":[[len(maze_data[0]) -1],[0],[0,len(maze_data)-1]],
            "diamond":[[len(maze_data[0]) -1],[0],[0,len(maze_data)-1]]
            }
        win_pos_x = (dict_two[maze_type])[0]
        win_pos_y = (dict_two[maze_type])[1]
        start_pos = (dict_two[maze_type])[2]
        dimensions = alter_screen()
        won = play_maze(dimensions[0],dimensions[1],(str(maze_size) + " x " + str(maze_size)),10,win_pos_x
            ,win_pos_y,start_pos,maze_data)
    else:
        won = True  #Maze auto-completes if PIL is not installed
    if won:
        if user_id != 0:
            Db.add_completed_level(connection,maze_size-3, maze_type,user_id)
    completed = Db.get_list_of_completed_levels(connection,user_id)
    create_levels(lower,upper,4,title,maze_type,completed)
```

The main job of "Load Maze" is to translate the parameters entered pass them to the MazeGenerationNew, script take the generated data and then pass that, along with other translated parameters, to the MazeRenderNew script.

```
def custom_maze(maze_type,width,height,cube_size,title):    #Same as the function above but for custom
    mazes
        width = int(width.get())
        height = int(height.get())
        cube_size = int(cube_size.get())
        maze_data = main(width,height,1000,maze_type.get())
        dimensions = alter_screen()
        play_maze(dimensions[0],dimensions[1],(str(width) + " x " + str(height)),cube_size,[len(maze_data
            [0]) -1],[0],[0,len(maze_data)-1],maze_data)
        change_state('custom maze',True)
```

"Custom Maze" is a version of "Load Maze" for cutom mazes with unsual heights and widths. An improvement to the code would be combining the two above functions.

```
def set_user_id(username,guest):    #Sets the user ID
    global user_id
    if guest:
        user_id = 0
    else:
        user_id = username
    change_state("maze select")
```

"Set User ID" is a simple function that sets the global user_id. The user_id is used to retrieve data about the user from maze.db, if the user is a guest then the ID is set to 0 and all code involving the user_id is skipped.

```
def reset_progress():           #Resets the current users progress
    username = Db.delete_user(connection, user_id)
    Db.create_new_user(connection, username)
    change_state("maze select")
```

This functions is also simple. It resets the progress of the user by deleting the user from the and then creating them again, utilizing the below function.

```
def new_user(user_entry_widget):    #Creates a new user named using the entered user name
    name = user_entry_widget.get()
    Db.create_new_user(connection,name)
    change_state("username")
```

Simply, adds a new entry to the database containing a new user.

```
def des(): #Deletes all current widgets in "window"
    widget_list = all_children(window)
    for item in widget_list:
        item.pack_forget()
```

This function deletes all current widgets, this is used to reset the UI so that new UI can be made in its place. It utilizes the below function which creates a list of all widgets pareneted to the entered object. The object entered in the case of "des()" is the whole tkinter window.

```
def all_children(window): # This makes a list of all the current widgets
    list_one = window.winfo_children()
    for item in list_one:
        if item.winfo_children() :
            list_one.extend(item.winfo_children())
    return list_one
```

```
def alter_screen():     #Changes screen dimenions to make the rendering of the maze faster
    const = 2
    dimensions = [0,0]
    dimensions[0] = int(screen_width/const)
    dimensions[1] = int(screen_height/const)
    return dimensions
```

"Alter Screen" shrinks the size of the layers (images created in the renderer) to make the creation of said layers in the rendering section of the code easier and less resource consuming.

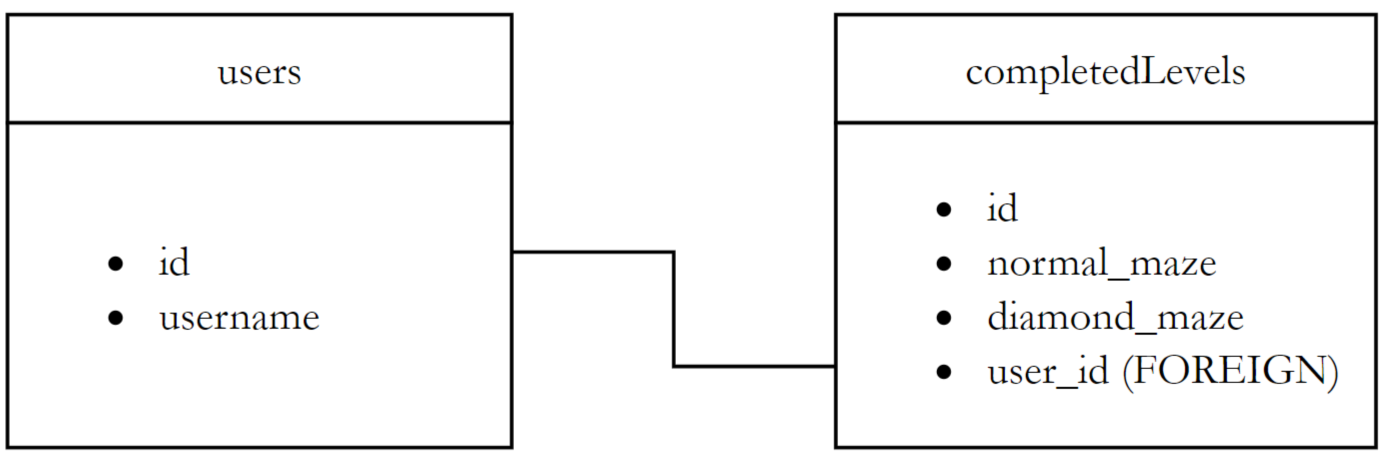
14 MazeDatabase.py

Script for interaction with the maze.db for storing users and completed levels, utilizes SQL.

```
def main_database():    #Creates the database (if it wasn't already created) and establishes a connection
    to it
    user_table = " CREATE TABLE IF NOT EXISTS users (
id integer PRIMARY KEY,
username text NOT NULL
); "
    completed_levels_table = " CREATE TABLE IF NOT EXISTS completedLevels (
id integer PRIMARY KEY,
normal_maze text,
diamond_maze text,
user_id integer NOT NULL,
FOREIGN KEY (user_id) REFERENCES users (id)
); "
    connection = create_connection(r"Maze.db")
    if connection is not None:
        create_table(connection, user_table)
        create_table(connection, completed_levels_table)
    else:
        print("Database Connection Error")
    return connection
```

This function is run to intialize the database, composed of two tables, (if it's not already created) and establish a connection to said database. The comment explaining the datbase is included below, along with a diagram.

```
"DATABASES
Users table stores name and user_id + any additional information needed
CompletedLevels table stores the completed levels linked to the foreign key user_id and a primary key
    completed_id. There will be two columns, one for normal mazes, one for diamond mazes
the completed levels will be serialized as such (1#3#4#12...) and when the string is imported it will be
    split into a list."
```




```
def create_new_user(connection, username):
    #Create the new user
    new_user_sql = "INSERT INTO users(username) VALUES(?)"
    cursor = connection.cursor()
    cursor.execute(new_user_sql, (username,))
    user_id = cursor.lastrowid
    connection.commit()
    #Then create the sibling entry in the CompletedLevels table based of the generated user_id
    new_completed_levels_sql = "INSERT INTO completedLevels(normal_maze, diamond_maze, user_id) VALUES
        (?,?,?)"
    cursor = connection.cursor()
    cursor.execute(new_completed_levels_sql, ("","",user_id))
    connection.commit()
```

"Create New User" inserts a row into the **users** table containing the entered username and then makes a sister entry in **completedLevels**. It uses cursor.lastrowid to get the correct user id.

```python
def delete_user(connection, user_id):
    sql = 'SELECT username FROM users WHERE id = ?'
    cursor = connection.cursor()
    cursor.execute(sql, (user_id))
    result = cursor.fetchall()
    #Delete user entry
    sql = 'DELETE FROM users WHERE id=?'
    cursor = connection.cursor()
    cursor.execute(sql, (user_id))
    connection.commit()
    #Delete completedLevels entry
    sql = 'DELETE FROM completedLevels WHERE user_id=?'
    cursor = connection.cursor()
    cursor.execute(sql, (user_id))
    connection.commit()
    return result[0][0]
```

"Delete User" removes an entry from users and completedLevels based on the entered user_id. It will also return the username from said user so that they can be recreated in the "Reset Progress" function.

```python
def get_list_of_users(connection):
    user_list = []
    cursor = connection.cursor()
    cursor.execute("SELECT * FROM users")
    result = cursor.fetchall()
    for row in result:
        user_list.append((str(row)[1:-1]).split(','))
    return user_list
```

This function is implemented in "Change State" and is used when creating the buttons for the users in the user select screen. Contained within each entry in the list is both the user_id and the username.

```python
def add_completed_level(connection, level_number, maze_type, user_id):    #Uses the user id to alter the
    user's completed levels
    completed = get_list_of_completed_levels(connection, user_id)
    dict_one = {
                "normal":0,
                "diamond":1
                }
    formatted = ''
    for level_num in completed[dict_one[maze_type]]:
        print(level_num)
        formatted = formatted + level_num + "#"
    formatted = formatted + str(level_number)
    if maze_type == "normal":
        sql = "UPDATE completedLevels SET normal_maze = ? WHERE user_id = ?"
    elif maze_type == "diamond":
        sql = "UPDATE completedLevels SET diamond_maze = ? WHERE user_id = ?"
    cursor = connection.cursor()
    cursor.execute(sql,(formatted,user_id))
```

"Add Completed Level" takes the current completed levels list converts it to a string, adds the entered level to the string and then inserts it into the correct entry in the database. It finds the correct entry based off the maze type and user_id.

The below function is implemented in "Add Completed Level" to get the current completed levels for both maze types.

```python
def get_list_of_completed_levels(connection, user_id):
    maze_find_sql = "SELECT normal_maze, diamond_maze FROM completedLevels WHERE user_id = ?"
    cursor = connection.cursor()
    cursor.execute(maze_find_sql,(user_id))
    result = cursor.fetchall()
    return [(result[0][0]).split('#'),(result[0][1]).split('#')]
```

"Get List of Completed Levels" takes the string stored in the database for all maze types and converts them into a 2D array. The format for the string is explained in the comment explaning the database above.

```python
def create_connection(db_file):
    connection = None
    try:
        connection = sqlite3.connect(db_file)
    except Error as e:
        print(e)
    return connection
```

```python
def create_table(connection, create_table):
    try:
        cursor = connection.cursor()
        cursor.execute(create_table)
    except Error as e:
        print(e)
```

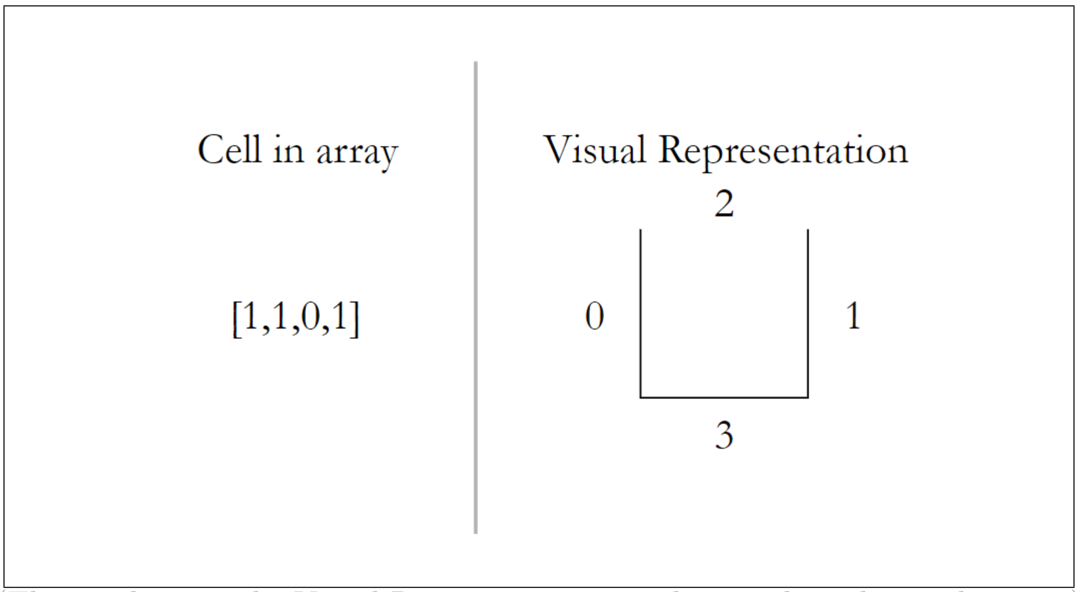
The above two functions are standard functions for interacting with a database. "Create Conncetion" creates a connection with a database file or creates the database file and the establishes a connection with it if it doesn't already exist. The connection is then used the interact with the database itself. "Create Table" actually would execute any SQL passed to it and acts more like an alias/simplification, however, it is only ever used to create tables.

15 MazeGenerationNew.py

Uses Kruskal's algorithm paired with a generated weight array to create the maze.

```
def intialize_array(width, height):
    #Intialize the array
    maze_array = []
    for x in range(0, width):
        maze_array.append([])
        for y in range(0, height):
            maze_array[x].append([1,1,1,1]) #Add a blank cell with all four walls to create an array that
                will be altered to generate a maze, this array is the data we return
    return maze_array
```

"Intialize Array" creates a 2D array formatted in the correct manner to be used as the **maze_array** which represents the maze. This maze is made up of cells, each cell being linked to a coordinate/index in the 2D array, with the cell being represented as a list of length four (i.e. [1,1,1,1]). Each number in this list can be eithier a 1 or 0, representing a wall or empty space respectively. A diagram displaying this is placed below.



(The numbers on the Visual Representation correlate to the index in the array)

```
def generate_random_walls(height, width):    #Random walls for testing maze renderer
    #Intialize the array
    maze_array = []
    temp_list = [0,0,0,0,0,0,1]
    for x in range(0, width):
        maze_array.append([])
        for y in range(0, height):
            maze_array[x].append([random.choice(temp_list), random.choice(temp_list), random.choice(
                temp_list), random.choice(temp_list)])
    return maze_array
```

The above function is used only in testing, it can technically generate unbeatable mazes but due to the weighted chance to generate an empty or a wall (represented using temp_list) it is unlikley. It was mainly used in rendering testing but was also used when testing maze collision.

```python
def kruskals_algorithim(weight_group_array,width,height,max_weight): #Based loosely on the algorithim as
    described in "Mazes for Programmers"
    maze_array = intialize_array(width,height)
    group_designation = 1
    temp_list_empty = False
    while not all_in_one_group(weight_group_array,height,width) and not temp_list_empty: #Only ends loop
        when no new corridors can be checked and all the corriders are in the same group
        temp_list = lowest_values_pos(weight_group_array,width,height,max_weight+1)
        if temp_list == []:
            temp_list_empty = True
        else:
            dict_one = {
                0:[0,-1,1],
                1:[0,1,0],
                2:[-1,0,3],
                3:[1,0,2]
                }
            for pos in temp_list:
                can_connect = True
                difference = dict_one[pos[2]]
                current_pos_group = (weight_group_array[pos[0]][pos[1]])[4]
                try:
                    if pos[0]+difference[0] == -1 or pos[1]+difference[1] == -1:
                        error = pos[100]
                    connected_pos_group = (weight_group_array[pos[0]+difference[0]][pos[1]+difference[1]])
                        [4]
                    if current_pos_group == 0:
                        if connected_pos_group == 0:
                            (weight_group_array[pos[0]][pos[1]])[4] = group_designation
                            (weight_group_array[pos[0]+difference[0]][pos[1]+difference[1]])[4] =
                                group_designation
                            group_designation += 1
                        else:
                            (weight_group_array[pos[0]][pos[1]])[4] = (weight_group_array[pos[0]+
                                difference[0]][pos[1]+difference[1]])[4]
                    else:
                        if current_pos_group == connected_pos_group:
                            can_connect = False
                        elif connected_pos_group == 0:
                            (weight_group_array[pos[0]+difference[0]][pos[1]+difference[1]])[4] =
                                current_pos_group
                        elif connected_pos_group != 0:
                            group_pos = get_all_in_group(weight_group_array,width,height,
                                connected_pos_group)
                            for pos2 in group_pos:
                                (weight_group_array[pos2[0]][pos2[1]])[4] = current_pos_group
                    if(can_connect):
                        (maze_array[pos[0]][pos[1]])[pos[2]] = 0
                        (maze_array[pos[0]+difference[0]][pos[1]+difference[1]])[difference[2]] = 0
                    (weight_group_array[pos[0]][pos[1]])[pos[2]] = max_weight+2
                    (weight_group_array[pos[0]+difference[0]][pos[1]+difference[1]])[difference[2]] =
                        max_weight+2
                except IndexError:
                    (weight_group_array[pos[0]][pos[1]])[pos[2]] = max_weight+2
                    if (weight_group_array[pos[0]][pos[1]])[4] == 0:
                        (weight_group_array[pos[0]][pos[1]])[4] = group_designation
                        group_designation += 1
    return maze_array
```

"Kruskals Algorithim" is the algorithim used to actually generate the mazes. It does this utilizing a **weight_group_array** and by altering the corridors between cells in the **maze_array**. The outline of how it works is this; All cells have a group, at the start this is the default group (i.e. zero). Any cell within a group is reachable by any other cell in a group (unless it is the default group), they are essentially perfect mazes within the larger maze. At the start of each iteration of the while loop the code finds corridors (connections between cells) based on the lowest weight, this is done using the afformentioned **weight_group_array** and the function below.

```
def lowest_values_pos(wg_array,width,height,compared_to):   #Finds all the connections in the maze with
    the lowest weight value
    temp_list = []
    for x in range(0,width):
        for y in range(0,height):
            for i in range(0,4):
                if wg_array[x][y][i] < compared_to:
                    compared_to = wg_array[x][y][i]
                    temp_list = []
                    temp_list.append([x,y,i])
                elif wg_array[x][y][i] == compared_to:
                    temp_list.append([x,y,i])
    return temp_list
```

The actual **weight_group_array** or**wg_array** is generated by functions "Generate Walled Maze" and "Generate Diamond Maze" discussed lower down. Once a corridor is chosen an actual connection is attempted, a connection will only not be made if, 1. The connection is being made to an area outside the maze or 2. The connection is being made to a cell that is already in the same group as the chosen cell. The latter of the two fail states exists so that the generation doesn't remove every single wall. If a connection is made between two cells with non-default but different groups then all cells in the group that doesn't contain the chosen cell are changed to be in the group with the chosen cell. This process is done using "Get All In Group" (shown below).

```
def get_all_in_group(wg_array,width,height,group):  #Gets the positions of all the cells that have the
    group specified
    temp_array = []
    for x in range(0,width):
        for y in range(0,height):
            if (wg_array[x][y])[4] == group:
                temp_array.append([x,y])
    return temp_array
```

The algorithim will run untill all cells are in the same group (and that group is not the default) meaning any cell within the maze can be reached from any other cell. To check that all cells are in the same group the function "All In One Group" is used.

```
def all_in_one_group(wg_array,height,width):    #Checks to see if every cell is in a singular group (a.k.a
     every cell can be reached from any other cell)
    returned = True
    first_group = "null"
    for x in range(0,width):
        for y in range(0,height):
            temp = (wg_array[x][y])[4]
            if first_group == "null":
                first_group = temp
            if temp != first_group or temp == 0:
                returned = False
    return returned
```

```
def generate_walled_maze(width,height,max_weight):
    weight_group_array = []
    for x in range(0,width):
        weight_group_array.append([])
        for y in range(0,height):
            weight_group_array[x].append([random.randint(1,max_weight),random.randint(1,max_weight),random
                .randint(1,max_weight),random.randint(1,max_weight),0])    #Create a "sister" array that
                stores the weight values and group of each cell
    maze_array = kruskals_algorithim(weight_group_array,width,height,max_weight)     #Use the weight array
        to generate an actual maze
    return maze_array
```

"Generate Walled Maze" generates a simple **weight_group_array** by randomly generating weight values for each cell.

```
def generate_diamond_maze(width,height,max_weight):
    weight_group_array = []
    for x in range(0,width):
        weight_group_array.append([])
        for y in range(0,height):
            weight_group_array[x].append([random.randint(1,max_weight),random.randint(1,max_weight),random
                .randint(1,max_weight),random.randint(1,max_weight),0])
    #Manipulate the weight group array to make the algorithim generate a diamond maze with random gaps in
        the walls
    center_of_maze = [int(width/2),int(height/2)]
    pos_to_change = center_of_maze
    counter = 1
    circling = True
    translate_to_displacement = {
        1:[0,1],
        2:[1,0],
        3:[0,-1],
        0:[-1,0]
        }
    translate_to_wall_index = {
        1:2,
        2:1,
        3:3,
        0:0
        }
    while circling:
        modded_counter = counter % 4
        displacement = translate_to_displacement[modded_counter]
        wall_index = int(translate_to_wall_index[modded_counter])
        length_counter = counter // 2 + (counter % 2)
        for i in range(1,length_counter):
            #Check to see if current cell is within maze
            if pos_to_change[0] > width-1 or pos_to_change[1] > height-1:
                pass
            else:
                #If it is then remove the wall leading to the new cell
                weight_group_array[pos_to_change[0]][pos_to_change[1]][wall_index] = counter
            #Move into the new cell
            pos_to_change = [pos_to_change[0]+displacement[0],pos_to_change[1]+displacement[1]]
        counter += 1
        #Fail state check
        if pos_to_change[0] > width and pos_to_change[1] > height:
            circling = False
    weight_group_array[center_of_maze[0]][center_of_maze[1]] = [0,0,0,0,0] #Remove all walls from center
    maze_array = kruskals_algorithim(weight_group_array,width,height,max_weight)
    return maze_array
```

"Generate Diamond Maze" is a more complicated **weight_group_array** generator used to create a maze with an actual texture. It does this by circling from cells from the maze center changing the weights so that the corridors are created in a certain way leading to a pyramid/diamond pattern. This method could also be used to create a circular maze, however, that type of maze is significatly less fun to play.

16 Window.py

Uses tkinter, NumPy and pillow (a fork of PIL (Python Imaging Library)) to create layered editable images on screen. Using tkinter it also handles input, unfortunately the window needs to be clicked on for input to be registered.

```
class Window():
    pixel_scale = 1
    last_key_pressed = None

    def __init__(self, height, width, default_colour, title):   #Creates the intial image and sets intial
        values
        self.height = int(height)
        self.width = int(width)
        self.title = title
        self.default_colour = default_colour
        self.window = create_tkinter_window(self.height, self.width, self.title)
        self.screen = create_canvas(self.window)
        self.layers = []
        self.layers.append(self.Layer(self, self.height, self.width, self.default_colour)) #Create the
            background layer
```

Above is the "Window" class and its "__init__" function. A "Window" instance has a tkinter window (with a canvas called .screen) upon which layers can be placed. In the "__init__" function only a background/default layer is created. Each layer is also an instance of a class called "Layer", which is a sub-class of "Window". However, it being a sub-class doesn't actually mean anything (other than making it easier to understand what "Layer" is meant for) so .layers is needed in "Window" to store that given window's layers. The code for "Layer" is shown below:

```
    class Layer():  #Layer Objects

        def __init__(self, window, height, width, default_colour):
            self.height = height
            self.width = width
            self.default_colour = default_colour
            self.layer_num = len(window.layers)
            self.array = create_image_array(height, width, default_colour)
            self.generated_image = ImageTk.PhotoImage(master = window.screen, image=Image.fromarray(self.
                array))
            self.image = window.screen.create_image(width, height, image=self.generated_image)
```

Layers are used as a form of optimisation so that when we update the screen, to move the player for example, we only need to update a very small image rather than the whole maze image.

```
    def move_layer(self, new_coords, layer_num = 0):  #Moves a layer to a given position
        #Get Current Top Left of layer Coords
        old_coords = self.screen.coords(self.layers[layer_num].image)
        old_coords[0] = old_coords[0] - (self.layers[layer_num].height/2)
        old_coords[1] = old_coords[1] - (self.layers[layer_num].width/2)
        #Move to new position
        self.screen.move(self.layers[layer_num].image, new_coords[0] - old_coords[0], new_coords[1] -
            old_coords[1])
```

"Move Layer" is moves any given layer to entered coordinates. While there is a standard move function for image objects on tkinter canvases, it moves objects by a 2D Vector rather than being coordinate based.

```
    def delete_layer(self, layer):
        self.screen.delete(self.layers[layer].image)
        self.layers.pop(layer)
```

"Delete Layer" deletes a layer by first removing its image from the canvas and then poping it from the .layers list. Unlike other functions that interact with layers this one requires a layer number to be entered (whereas others have a default of the background layer) so that the background layer isn't deleted by mistake.

```
    def reset(self, layer_num = 0):    #Resets the entered layer, used so the line below doesn't need to
        be typed everytime
        self.layers[layer_num].array = create_image_array(self.layers[layer_num].height, self.layers[
            layer_num].width, self.layers[layer_num].default_colour)
```

There is also "Reset" which will just reset a layer (based of the "Window" object .default_colour) rather than deleting it.

```python
    def set_pixel(self, coords, colour, layer_num=0): #Change a pixel in the image array
        coords[0] = (coords[0] * self.pixel_scale) - (self.pixel_scale - 1)
        coords[1] = (coords[1] * self.pixel_scale) - (self.pixel_scale - 1)
        for x in range(coords[0],coords[0]+self.pixel_scale):
            for y in range(coords[1],coords[1]+self.pixel_scale):
                try:
                    self.layers[layer_num].array[y,x] = colour
                except IndexError:
                    pass
```

"Set Pixel" allows any pixel on the entered layer to be altered based off the coordinates entered, a range of pixels can also be affected if the pixel scale isn't one. It does this by altering the coresponding index in a numpy array, this numpy array is then converted into an image using Pillow (PIL) and then subsequently turned into an image tkinter will accept, also using PIL. The image conversion is all done in the "Update" function, alongside updating the tkinter window itself.

```python
    def update(self, layer_num = 0):   #Updates an entered layer
        try:
            self.layers[layer_num].generated_image = ImageTk.PhotoImage(master = self.screen,image=Image.
                fromarray(self.layers[layer_num].array)) #Generate a updated image from the image array
            self.screen.itemconfig(self.layers[layer_num].image, image = self.layers[layer_num].
                generated_image)    #Applies the generated image
        except IndexError:
            print("Invalid Layer")
        self.window.update()
```

```python
    def init_input(self):                        #Input created using tkinter, last key pressed = key pressed
        that frame
        def on_key_press(event):
            self.last_key_pressed = event.char
            if self.last_key_pressed == '\boxempty':
                self.last_key_pressed = 'esc'
        def on_key_up(event):
            self.last_key_pressed = None
        self.window.bind('<KeyPress>', on_key_press)
        self.window.bind('<KeyRelease>', on_key_up)
```

The "Window" class also handles input, utilizing tkinter's event system. "Init Input" must be run to start input and within the function two other functions are also defined. "On Key Press" sets .last_key_pressed to the current key being pressed when a key is being pressed (as indicated by tkinter), while "On Key Up" sets .last_key_pressed back to None.

```python
    def set_fullscreen(self, boolean):  #Turns fullscreen on and off based on boolean
        self.window.overrideredirect(True)
        self.window.overrideredirect(False)
        self.window.attributes('-fullscreen',boolean)
        self.screen.pack(fill="both", expand=True)

    def set_pixel_scale(self, num): #Used to change the pixel scale
        self.pixel_scale = num

    def quit(self):                              #Quits window
        for i in range(0,len(self.layers)):
            self.reset(i)
        self.window.destroy()
        del self
```

"Set Fullscreen", "Set Pixel Scale" and "Quit" are the three functions in the "Window" class that don't directly interact with a certain layer. "Set Fullscreen" allows for fullscreen to be toggled on and off based on the parameter "boolean", "Set Pixel Scale" allows for the pixel scale to be changed in a less akward manner and "Quit" simply deletes every layer, destroys the tkinter window and then does the same to the instance of the class.

```python
def create_tkinter_window(height, width, title):    #Creates a tkinter window
    window = tk.Tk()
    window.title(title)
    window.geometry(str(width) + "x" + str(height))
    #window.overrideredirect(1) #Removes the Titlebar
    return window
```

"Create Tkinter Window" and the two other final functions in "Window.py" aren't directly related to the "Window" class but are used within it. "Create Tkinter Window" simply creates a tkinter window based of the parameters entered and then returns said window.

```python
def create_canvas(tkinter_window):  #Creates a tkinter canvas
    canvas = tk.Canvas(tkinter_window, bg="black")
    canvas.pack(fill="both",expand=True)
    return canvas
```

"Create Canvas" adds a canvas object to the passed tkinter window, the canvas is then made to fill the entire window. The canvas object it also returned.

```python
def create_image_array(height,width,colour): #Creates the intial image array
    image_array = np.zeros([height+1,width+1,3],dtype=np.uint8)
    image_array.fill(colour)
    return image_array
```

"Create Image Array" makes a numpy array and then fills it with the desired greyscale colour, entered as any value between 0 and 255, finnally the new image array is returned.

17 MazeRendererNew.py

Used when actually playing a maze, mainly used to implement the Window.py script to correctly draw the maze but also handles collision detection and a check to see if the player has won.

"Play Maze" is the longest function in my entire NEA totaling around 130 lines of code, hence I'll explain it section by section rather than all at once.

```
def play_maze(width, height, title, cube_size, win_pos_x, win_pos_y, start_pos, maze_data):
    #A cube_size of two and below will cause the squares to be too small to be properly represented
        properly on any pixelated screen, hence, 3 is the lowest the function allows
    if cube_size < 3: cube_size = 3
    screen = Window.Window(height, width, 0, "Test Window")
    screen.set_fullscreen(True)
    screen.init_input()
    screen.update()
    temp = 0 #Temporary Variable to manage progress of stand-in progress bar
    delta_time = 0
    fps = 0
    time_to_close = 1.5
    add_to_y = 0
    add_to_x = 0
    loading = True
    first_frame = True
    running = True
    position_set_to = [1,0]
    move_dir = ""
    player_pos = start_pos
    active_last_frame = True
    check_walls = True
    to_return = False
    ending = True
    drawing_per_frame = False
    input_confirmed = False
    input_delay = 0
```

18 External Libraries installation guide

To install all required packages the following commands must be run in command line

```
python -m pip install --upgrade pip
python -m pip install --upgrade Pillow
python -m pip install --upgrade numpy
```

Pillow Website: `https://pillow.readthedocs.io/en/stable/installation.html`