Chess game animation in blender

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Contents

1 Introduction

1.1 Project aims

This project aims to demonstrate a sufficient knowledge of computer graphics techniques and implementations through the creation of a visually appealing chess game animation tool. This was accomplished using Blender, and its python scripting API.
This project utilises two tools to create the chess animation

- Blender
  Blender had a large appeal due to is its extensibility through `Python` for this project The exposed API allows its users to script typical actions, and develop add-ons in a familiar and standard environment. Part of this scripting API allows the user to add and remove objects, insert key-frames, and change the properties of an object, anything a user can do with a mouse and keyboard, is able to be configured programmatically. This allows Blender to be used a front end to any `Python` or `C++` program.

- `python-chess` library
  The `python-chess` library is a chess library for python with move validation, generation, and `PGN` (Portable Game Notation, the most common file format for chess games) parsing. This library is designed to be able to function as back-end, making it perfect to use in conjunction with Blender.

2 The plan

During the proposal the plan was to create an interactive, real time chess board, however this was changed as the techniques and concepts would be severely limited. Blender with python scripting was a perfect compromise.

3 Blender implementation

3.1 Modelling, textures, and shading

The scaling of the models was deliberately chosen to be unrealistic in order to simplify the translation from position with the back to front end (See Python side - Array index to world space)

3.1.1 Nodes

Blender nodes allow for the creation of textures and shaders through a pipeline of simple operations to create complex procedural results. Its simple to understand visual workflow is a popular alternative to layer based compositing. [1]
Throughout this project, procedural texture and shading generation using nodes was used instead of the traditional texture wrapping using UV mapping in order to give objects consistent and appealing surfaces. This provides two relevant benefits;

- Tweaking textures and shading doesn't require an any more work than changing values on the respective node.

- Textures can be applied to any model without fitting issues, i.e. repetition and resolution.

3.1.2 Shaders

A shader is a program, typically run on the GPU, to computer the colour of a group or individual pixel. These shaders describe the lighting interactions of objects or surfaces, such as reflection, refractions, and absorption.

3.1.2.1 Principled BSDF

A `BSDF` (Bidirectional Scattering Distribution Function) describes how light scatters on a surface. In computer graphics, computing a highly detailed microsurface is not feasible, instead it is replaced with a simplified macrosurface (See Figure 1). As the surface no longer retains the detail it would in reality, light behaves differently on this new macrosurface. To compensate for this a `BSDF` is used that matches the aggregate direction scattering of the microsurface (at distance). [2]

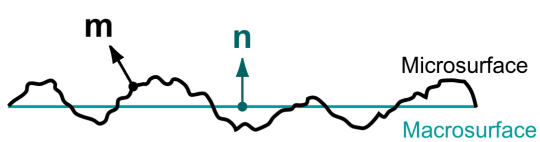


Figure 1: Micro vs macro surface (Source)

Blenders implementation breaks down this problem down into two separate functions by assuming that the microsurface can be adequately described using a microfacet distribution function and a shadowing-masking function.
Blender provides these options for the distribution and shadowing functions, and the subsurface methods.

- Distribution[1]
  - GGX
    `GGX` is a `BRDF` (bidirectional reflection distribution function) which aims to be a faster than its alternative `Multiple-scattering GGX` at the cost of physical accuracy. The `MDF` describes the distribution of microsurface normals **m** (Figure 1) while the shadow masking function describes what fraction of the microsurface normals **m** are visible. [2]

    In `GGX` the shadow masking function does not account for reflections or scattering. This can create excessive darkening and a loss in energy conservation in some areas [3].
  - Multiple-scattering GGX
    Almost all popular parametric `BSDF`'s only consider single reflection to account for self-shadowing but omit outgoing light that scatters multiple times between

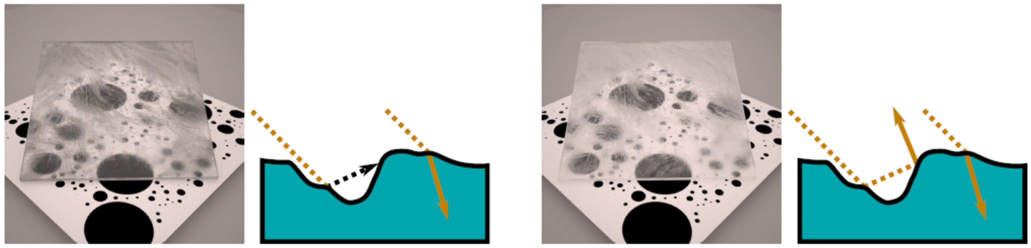


Figure 2: Single scattering (left), multiple scatters (right), (Source)

microfacets. Omitting outgoing light breaks conservation of energy and leads to dark patches within rough surfaces [4].

Blenders `Multiple-scattering GGX` BRDF allows for multiple light bounces within microfacets to achieve 100% energy conservation and provide a more physically accurate render [3], [4] . It accomplishes this by conducting a random walk on the microsurface until the ray escapes. Unlike `GGX` there is no known analytical expression for this model (Blender's specific implementation), it must instead be solved stochastically [5]. This comes at a performance cost, the original papers cites a 19% penalty using a Monte Carlo physically based renderer, Blenders development forums estimates the performance penalty to be approximately 3% at the time of implementation [5].

- Subsurface Scattering Method Subsurface scattering when light passes through an object that is normally opaque. Described by a `BSSRDF` (bidirectional subsurface scattering reflectance distribution function)
  - Christensen-Burley
    The `Chistensen-Burley` method is an approximation of a physically based volumetric scattering system with faster evaluation and efficiency [6]. TODO
  - Random walk
    ... This comes at a cost of rendering time (actually performance hit is largely dependent on the model itself), and increased noise. TODO

All renders within this report have `Multiple-scattering GGX` enabled as the benefit was need to outweigh the cost.
The `Principled BSDF` shader is a combination of multiple layers into a single node. This is done for ease of use.
This shader encapsulates bidirectional reflectance and transmittance distribution functions. Individually these functions determine how light behaves on the surface and inside a material.

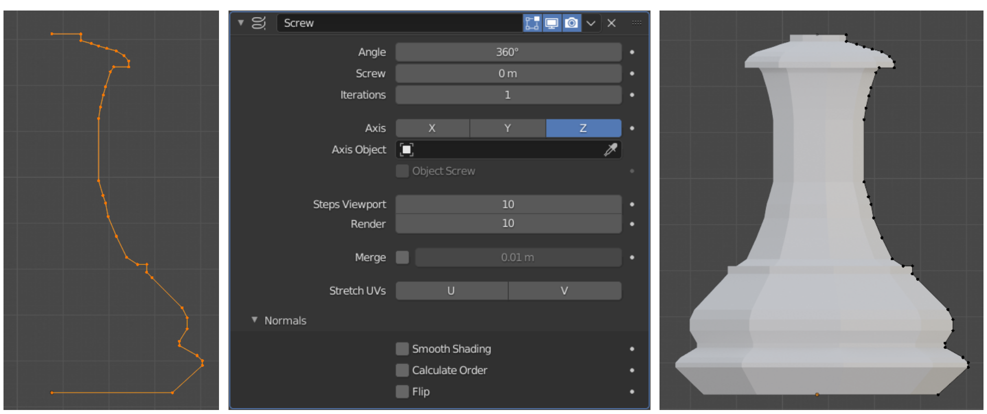
3.1.3 Pieces

Pieces were modelled after the reference image below Figure 3. From this image the pieces where traced using the `Add Vertex` tool, from the Add Mess Extra Objects add-on. To transform this line of vertices to a solid object a `Screw` modifier was applied.

[1] Note that the `Distrubution` option Blender gives is different from the `Microfacet Distrubution Function`, and includes both the `MDF` and the Shadow-masking function.

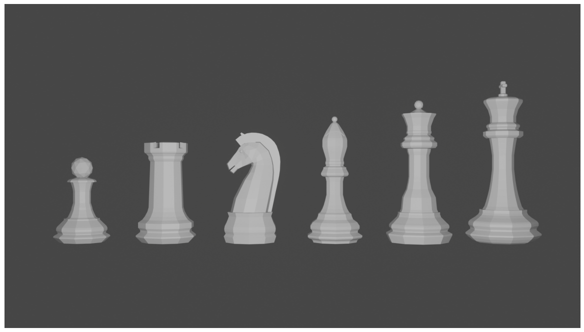
Figure 3: Reference image, Licensed under Pixabay License

Figure 4: Knight reference images, (Source)



The notable changes from the default settings is the lowering of the steps from 16 $\rightarrow$ 10 and disabling `Smooth Shading`. This was a stylistic choice as it was believed that the low polygon look would better demonstration reflections and the planned indirect lighting (See Lighting - Disco Ball).

To model the knight, 3 separate reference images where used. The base was constructed in a similar manner to the other pieces. The head was modelled manually (read painstakingly). Additionally ico-spheres where added to piece some pieces additional detail. The finally piece models appear as below.



3.1.4 Board

3.1.4.1 Chess board

The chess board model is a simple rectangular based prism with dimensions `8m x 8m x 0.4m`. The checker board texture comes from the `Checker Texture`, with `scale=8.0` and black and white colours. This texture output is then feed into the base colour input of a `Principled BSDF` shader node.

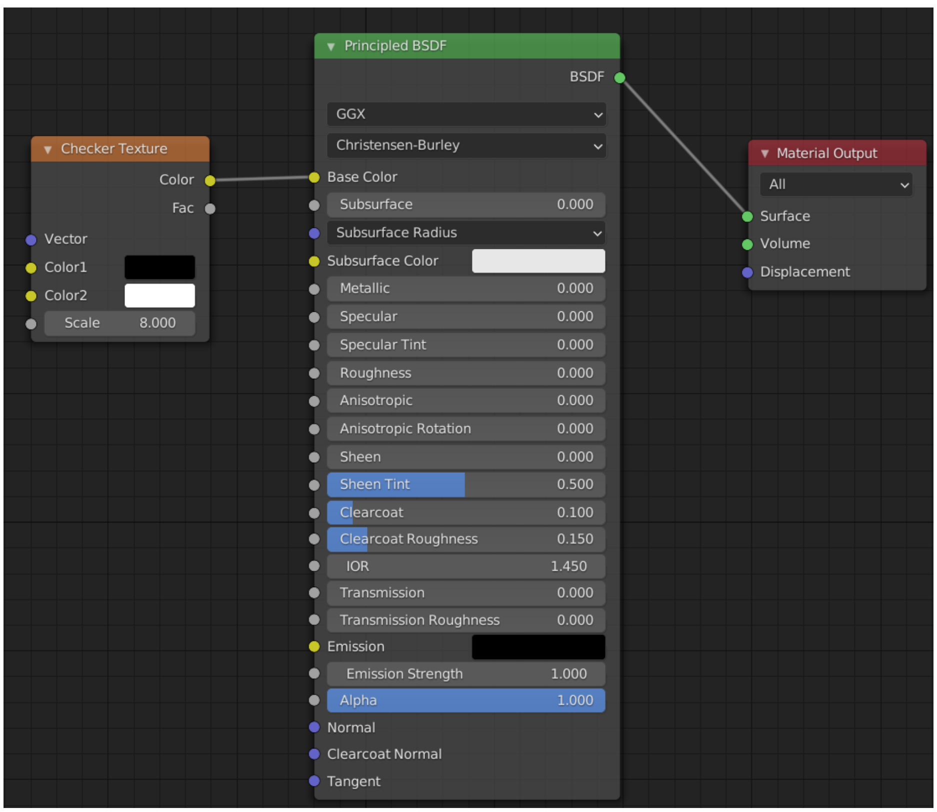


Figure 5: Complete checker board texture.

Within world space the board was positioned in the positive, positive quadrant such that the very bottom left handle corner of the board was at `0,0` with each squares dimensions as `1m x 1mx`. This positioning becomes important in Python implementation - Array index to world space.

3.1.4.2 Marble exterior

3.2 Particle effects

3.2.1 Explosions

3.2.2 Confetti

3.3 Lighting

3.3.1 Direct

3.3.2 Indirect

3.3.3 Disco ball

3.4 Render engine

3.4.1 Eevee

3.4.2 Cycles

3.4.2.1 Thank you to Jack

Due to significant hardware limitations for ray-tracing (`GTX 760, i5-4670`), a favour was called in with a good friend, Jack kindly lent their `RTX 2070` for a cycles render. See master/Videos/Marble$_{\text{cycles.mp4}}$.

3.4.3 Luxcore

3.4.4 Tragedy - 22:20, 01/June/2021

At 10:20pm on the first of June the PC that had been enslaved to rendering for more than 96 hours straight, died. It had been a good 8 years, but she finally gave out. Official cause of death is unknown but it suspected to be something to do with power delivery.
A successful data recovery was conducted the next morning.

4 Python implementation

4.1 Processing games

Reading and stepping through games is handled almost entirely by the chess library. No special considerations need to be made here. The minium working example below demonstrates all that is necessary to step through an entire game.

```python
import chess
with open(filename) as pgn:
    game = chess.pgn.read_game(pgn) # Parses pgn file
    board = game.board()

    for move in game.mainline_moves():
        board.push(move) # Pushs the move to the move stack, this "makes" the move
```

4.2 Pairing problem

During a game of chess there is nothing in between moves, simply one discrete board state after another. This is also how the chess library makes moves, by computing differences and tracking board states, while this is reliable and simple it does not play nice when games become continuous (animated).
Initially this script also tracked the board state using a dictionary, with the square as the key, and corresponding blender object as the value, pushing and pop at each move. However, this presented difficulties when implementing animations and special moves and animations. The code was generally cluttered and not up to an acceptable quality.

4.3 The solution

To remedy the mentioned problems a custom class was devised, and aptly name `CustomPiece`. This class acts as a generalised representation of a piece which is able to act upon itself and the Blender model it puppets. Stored within an unrolled 2d array with the index representing its position on the chess board (See Python implementation - Array Index to world space) the object is able to move itself within the array while handling move and capture animations. Special move handling is generalised into the main loop, (See Python implementation - Special moves).
This design approach has clear advantages such as

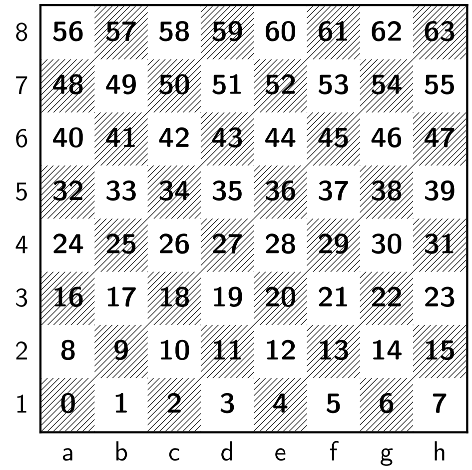
- Adheres to the `Model-View-Controller` design philosophy.
- Array and object manipulation is not handled at any higher level than required.
- Translation between the chess library interface and Blenders API is seamless.
- Creates a unique object that pairs a Blender model to a `python-chess` `PieceType`.

However, the self-referential nature of objects manipulating the array their are stored in adds significantly to the complexity. Luckily the implementation is simple.
An initial sketch of this class can be seen here 9.
Implementation can be see here 7.

4.4 Array index to world space

`python-chess` provides great functionality to retrieve what square a move is coming from, and going to. Internally this is stored as a `int` representing each square in 1d array notation.

```python
Square = int
SQUARES = [
    A1, B1, C1, D1, E1, F1, G1, H1,
    A2, B2, C2, D2, E2, F2, G2, H2,
    A3, B3, C3, D3, E3, F3, G3, H3,
    A4, B4, C4, D4, E4, F4, G4, H4,
    A5, B5, C5, D5, E5, F5, G5, H5,
    A6, B6, C6, D6, E6, F6, G6, H6,
    A7, B7, C7, D7, E7, F7, G7, H7,
    A8, B8, C8, D8, E8, F8, G8, H8,
] = range(64)
```



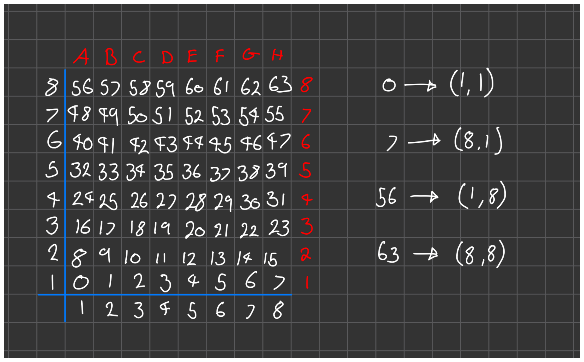


Figure 6: Array representation ((`tl`) Source code, (`tr`) Chess board, (`b`) Overlaid)

To convert form array indexing two simple expressions were used.

$$x = (\text{INDEX mod } 8) + 0.5$$

$$y = (\text{INDEX div } 8) + 0.5$$

[2] Note the addition of 0.5 is to centre the pieces on the board squares in world space and will be excluded from further examples.

4.4.1 Abuse of this functionality

While modulo will always produce a positive integer between $0 \rightarrow 7$, integer division can result negative numbers and is not bounded. Using this the mapping can be extended past the board it was designed for. This provides an easy method to place captured piece after their animation. By storing each pieces initial position, and adding or subtracting 16 depending on the colour, pieces can be placed 2 rows behind their initial position.

Two rows behind was preferable to the respective position on the other side of the board to avoid the inversion required so that the pawns would be in front of the back rank pieces.

72	73	74	75	76	77	78	79
64	65	66	67	68	69	70	71
56	57	58	59	60	61	62	63
48	49	50	51	52	53	54	55
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
8	9	10	11	12	13	14	15
0	1	2	3	4	5	6	7
-8	-7	-6	-5	-4	-3	-2	-1
-16	-15	-14	-13	-12	-11	-10	-9

Figure 7: Extended conversion

[2]Note `div` here is integer division.

4.5 Special moves

Figure 8 shows the main loop logic, used to move the correct pieces.

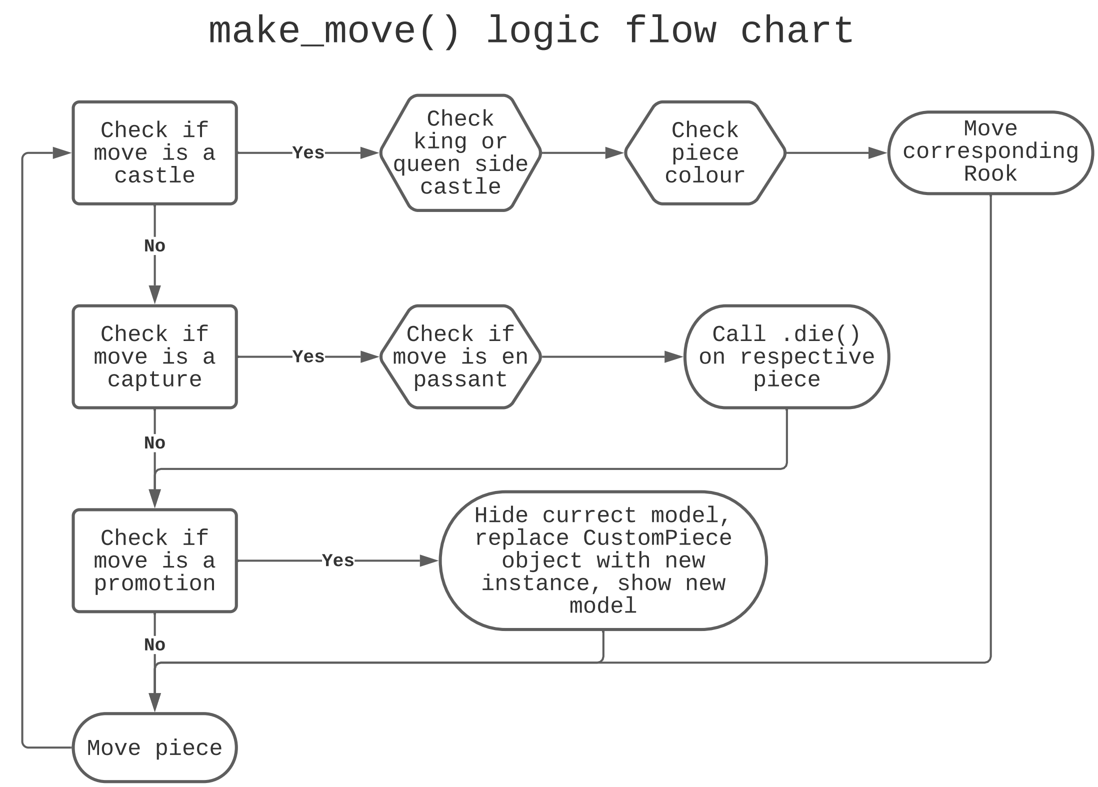


Figure 8: Main loop logic

4.5.1 Castling

Within standard chess there are only four castling possibilities, these are easy enough to check naively. This is the only section that limits this script to standard chess. To extend support to `chess960`, a bit-board mask of all the rooks with castling rights could be filtered to obtain the index of the rook that will be castled. See the documentation.

```
if board.is_castling(move):
    if board.turn: # White
        if board.is_kingside_castling(move):
            array[chess.H1].move(chess.F1)
        else: # queen side
            array[chess.A1].move(chess.D1)
    else: # Black
        if board.is_kingside_castling(move):
            array[chess.H8].move(chess.F8)
        else: # queen side
            array[chess.A8].move(chess.D8)
```

4.5.2 En passant

The `python-chess` library makes handling en passant a breeze. The move is checked if it is an en passant first, then as only one square is possible of an en passant on any move that position is retrieved.

```
else: # standard case
    if board.is_capture(move):# is en passant, great...
        if board.is_en_passant(move):
            array[board.ep_square].die() # NOTE, object is gc'ed
        else: # its a normal capture
            array[locTo].die() # NOTE, object is gc'ed
```

4.5.3 Promotion

Contained within a separate conditional is the promotion logic. This is handled separately from the rest of the logic as a move can be both a capture and a promotion.

```
array[locFrom].move(locTo) # NOTE, piece moves always

if move.promotion is not None:
    array[locTo].keyframe_insert(data_path="location", index=-1)
    array[locTo].hide_now() # hide_now unlinks within blender
    pieceType = move.promotion # piece type promoting to
    array[locTo] = CustomPiece(chess.Piece(pieceType, board.turn),\
                               SOURCE_PIECES[chess.piece_symbol(pieceType)],\
                               array, locTo) # shiny new object
    array[locTo].show_now()
```

A new key-frame is inserted initially as the piece that will promote has already been moved and that animation needs to finish before it can be hidden.
Within the Blender view port the pieces that will be promoted too already exist at the right position, they are just not rendered until needed.

4.6 Animation

4.6.1 Key frames

4.6.1.1 Timing

4.6.2 Interpolation

4.7 Reproducibility

This project was created used

- Blender `2.92` `https://www.blender.org/`
- Python `3.9.5` [3] `https://www.python.org/`
- python-chess `1.5.0` [4] `https://github.com/niklasf/python-chess`

[3] Blender comes bundled with this version. If the system python is used instead ensure it matches the version Blender was build with and is above `3.7` for the `__future__` module.

[4] This project requires the `Outcome` class released in `1.5.0`

4.7.1 Python environment

Blender is distributed with its own python installation for consistency, however this means that installed python modules are not present [7]. To mitigate this the `--target` flag for `pip install` can be used to install directly to the blender python environment [8].

```
pip install -t ~/.config/blender/2.92/scripts/modules chess
```

This ensures Blenders `Python` will has access to the required librarys for this script to function.

5 Results

6 Evaluation

7 Appendix

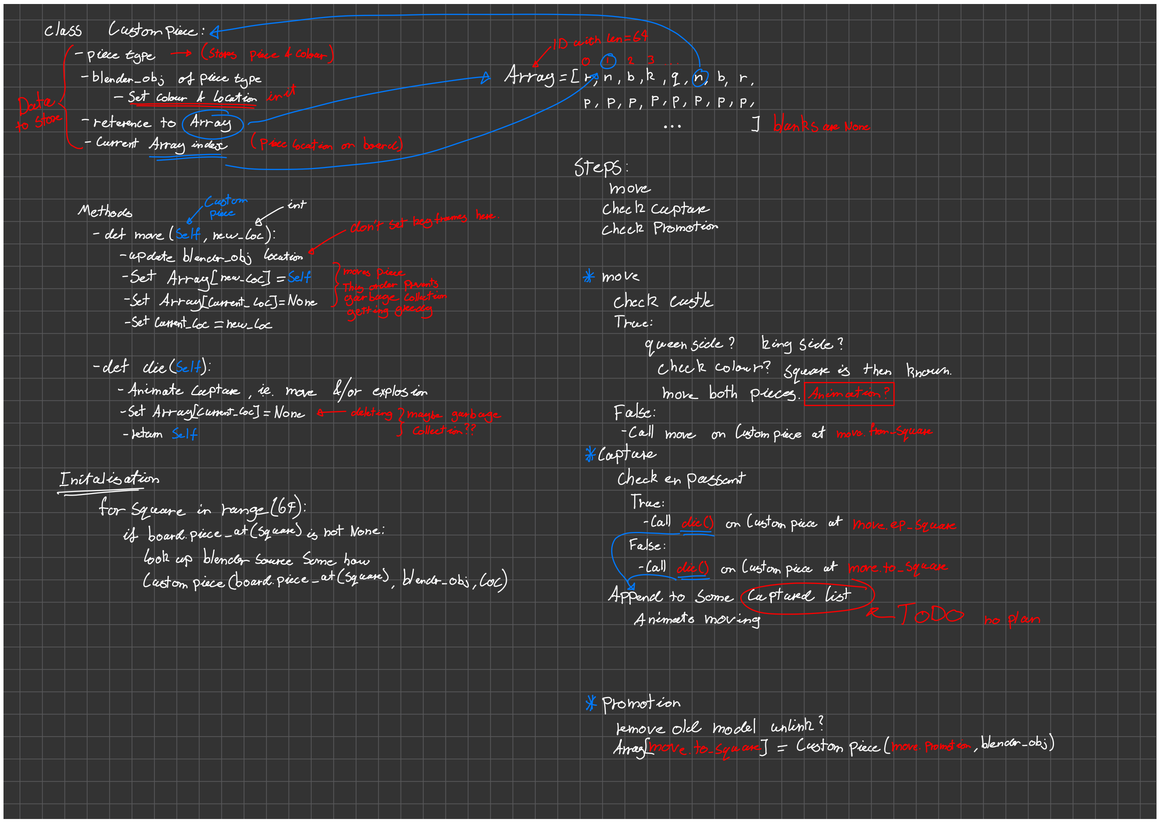


Figure 9: `CustomPiece` Initial sketch

```python
class CustomPiece():
    def __init__(self, pieceType: chess.Piece, blender_obj: bpy.types.Object,\
                 array: List[Optional[CustomPiece]], loc: int):
        self._pieceType = pieceType.piece_type # int
        self._colour = pieceType.color         # bool
        self._blender_obj = blender_obj.copy()
        self._array = array                    # reference to array containing self
        self._inital_loc = loc
        self._loc = loc                        # int (1d array index)

        x, y = square_to_world_space(self._loc)
        self._blender_obj.location = Vector((x, y, 0.3))

        # set material based on colour
        if self._colour:
            self._mat = bpy.data.materials["White pieces"]
        else:
            self._mat = bpy.data.materials["Black pieces"]
        self._blender_obj.active_material = self._mat
```

```
        if self._colour and self._pieceType == chess.KNIGHT:
            self._blender_obj.rotation_euler[2] = radians(180) #XYZ
        # add object to collection so its visable
        bpy.data.collections[['Black',
        ↪  'White'][self._colour]].objects.link(self._blender_obj)

    def move(self, new_loc: int, zTo: float = 0.3):
        xTo, yTo = square_to_world_space(new_loc)
        self._blender_obj.location = Vector((xTo, yTo, zTo))
        print("Moved to ", self._blender_obj.location)

        self._array[new_loc] = self
        self._array[self._loc] = None

        self._loc = new_loc

    def die(self) -> CustomPiece:
        self._array[self._loc] = None
        self.keyframe_insert(data_path="location", frame=FRAME_COUNT-6)

        xTo, yTo = square_to_world_space(self._loc)
        self._blender_obj.location = Vector((xTo, yTo, 2.1))
        self.keyframe_insert(data_path="location", frame=FRAME_COUNT+3)

        if self._colour:
            self._inital_loc += -16
        else:
            self._inital_loc += 16

        xTo, yTo = square_to_world_space(self._inital_loc)
        self._blender_obj.location = Vector((xTo, yTo, 2.1))
        self.keyframe_insert(data_path="location", frame=FRAME_COUNT+21)

        xTo, yTo = square_to_world_space(self._inital_loc)
        self._blender_obj.location = Vector((xTo, yTo, 0.1))
        self.keyframe_insert(data_path="location", frame=FRAME_COUNT+29)

        return self
```

References

[1] H. Hedin, "Comparison of node based versus layer based compositing," *Department of Industrial Development, IT and Land Management*, Jun. 2010. [Online]. Available: https://www.diva-portal.org/smash/get/diva2:327273/FULLTEXT02.pdf (cit. on p. 3).

[2] B. Walter, S. R.Marschner, H. Li, and K. E.Torrance, "Microfacet models for refraction through rough surfaces," 2007. [Online]. Available: https://www.cs.cornell.edu/~srm/publications/EGSR07-btdf.pdf (cit. on p. 4).

[3] B. Foundation. "Principled bsdf - blender documentation." (Feb. 25, 2020), [Online]. Available: https://docs.blender.org/manual/en/latest/render/shader_nodes/shader/principled.html (cit. on pp. 4, 5).

[4] E. Heitz, J. Hanika, E. d'Eon, and C. Dachsbacher, "Multiple-scattering microfacet bsdfs with the smith model," 2016. [Online]. Available: https://drive.google.com/file/d/0BzvWIdpUpRx_cFVlUkFhWXdleEU/view (cit. on p. 5).

[5] "Cycles: Add multi-scattering, energy-conserving ggx as an option to the glossy, anisotropic and glass bsdfs." (May 18, 2016), [Online]. Available: https://developer.blender.org/D2002 (cit. on p. 5).

[6] P. H. Christensen and B. Burley, "Approximate reflectance profiles for efficient subsurface scattering," *Pixar Technical Memo*, Jun. 2015. [Online]. Available: https://graphics.pixar.com/library/ApproxBSSRDF/ (cit. on p. 5).

[7] B. Foundation. "Tips and tricks - blender python api." (2021), [Online]. Available: https://docs.blender.org/api/current/info_tips_and_tricks.html#bundled-python-extensions (visited on 05/30/2021) (cit. on p. 14).

[8] pip developers, *Pip-install(1) linux man page*, 20.3, Jan. 26, 2021 (cit. on p. 14).