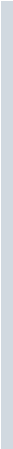


# **Course Project: Tetris 1 (Data Structure and Mapping)**

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- In this course project, we use the Tetris game as an example of improving software design.
  - From the prototype-level software, students refactor and redesign it into a high-quality, well-designed application ready to respond to users' requests.

# 1. Tetris Prototype

- When we build an application, we don't know exactly what we don't know yet.
- So, we start building a prototype to understand the application.
- We encounter many problems and solve them one by one.

## Prototype to know unknowns

- As a result, the prototype is barely working.
- But it is hard to add features or fix bugs with the software without a design.
- It is likely to add more bugs when we fix bugs.

## **Tetris as a prototype**

- In this course project, we mimic the situation of building a barely working Tetris prototype.
- It has no design, but simple data structures and algorithms to implement the game Tetris.

## Prototype to product through design

- At the end of the discussion, students are ready to refactor existing code into the designed code.
- The refactored code should easily add features to and fix bugs.

## Code smells

- When building a prototype, we sometimes make code that smells.
- After the prototype building, we should refactor the code to remove the code smells.

## The new age of coding

- LLM/AI is a great coder and smells bad code well.
- Discussing with LLM/AI to refactor the code is a good idea and fun.



## Vibe coding to make a prototype

- Don't forget that we are software engineers who solve problems by making software.
- When LLM/AI makes the code, there is no meaning in knowing what we didn't know.
- It is dangerous when you can't follow what LLM/AI generated.

- LLM/AI can be a great coding partner (only) when you know what you're doing.
- LLM/AI is a great coder and tester who can save you time by giving you more time to solve problems.

- As problem solvers, we must take the lead and use LLM/AI as a tool.
- It will open a whole new way of solving problems when you do the design/architecture, and LLM/AI does the rest.
- Otherwise, it is a disaster for software engineers who can only code.

## 2. Tetris: Data Structure

- Colors
- Figures
- Field

## Color representation

- Any color can be represented with RGB information.

BLACK = (0, 0, 0)

WHITE = (255, 255, 255)

GRAY = (128, 128, 128)

## A Series of Colors

- We can define a series of Colors.

```
Colors = [  
    (0, 0, 0), # We don't use this  
    (120, 37, 179),  
    (100, 179, 179),  
    (80, 34, 22),  
    (80, 134, 22),  
    (180, 34, 22),  
    (180, 34, 122),  
]
```

## Code smell

- When we use a list in a program, it implies that we will add more elements dynamically.
- However, the Colors array is constant, so this is a code smell: Use immutable objects whenever necessary.
- In Python, use the tuple `()` to efficient memory usage.

- When a value is constant, the name should be all capitalized.
- Using a number instead of a name is always a bad idea.

```
PRIMARY_PURPLE = (120, 37, 179)
ACCENT_TEAL = (100, 179, 179)

COLORS = (PRIMARY_PURPLE, ACCENT_TEAL)
```

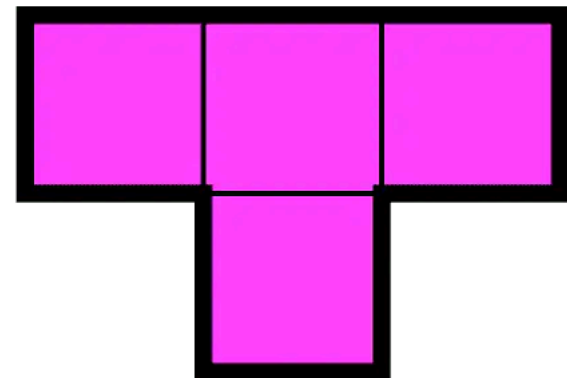
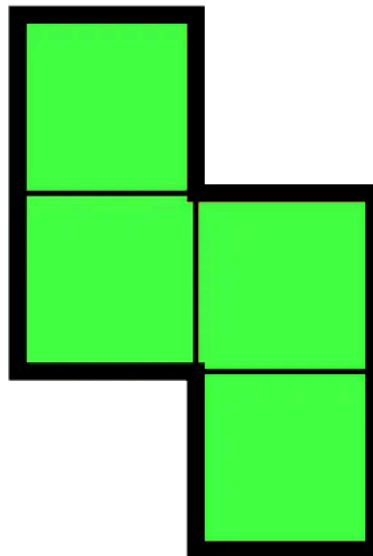
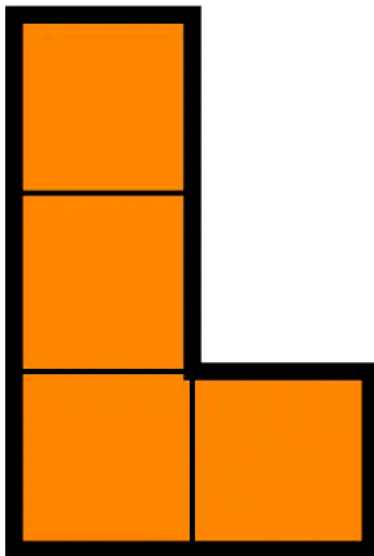
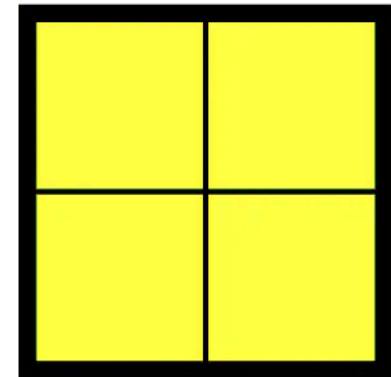
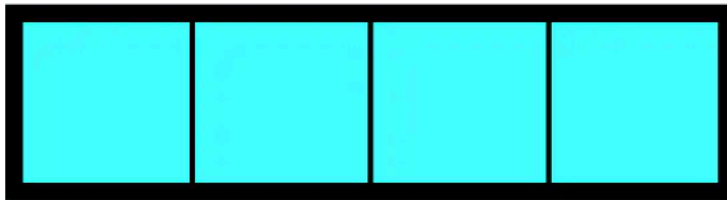


## Figure representation

- Five figures (tetrominos)
- Figure array

## Five figures (tetrominos)

- Tetris has five figures called tetrominos.



- However, we can use an array to represent the same information.
- For example,  $[1,5,9,3]$  represents a vertical figure, and  $[4,5,6,7]$  a horizontal one.

0	1	2	3
4	5	6	7
8	9	10	11
12	13	14	15

0	1	2	3
4	5	6	7
8	9	10	11
12	13	14	15

0	1	2	3
4	5	6	7
8	9	10	11
12	13	14	15

0	1	2	3
4	5	6	7
8	9	10	11
12	13	14	15

- We can use an array of arrays to represent a figure and its rotation.
- In this example, [4,5,6,7] is the rotation of [1,5,9,13].

```
[[1, 5, 9, 13], [4, 5, 6, 7]]
```

- We can have a figure array of arrays to store all the figures and their rotations.

```
Figures = [  
    [[1, 5, 9, 13], [4, 5, 6, 7]],  
    [[4, 5, 9, 10], [2, 6, 5, 9]],  
    [[6, 7, 9, 10], [1, 5, 6, 10]],  
    [[1, 2, 5, 9], [0, 4, 5, 6], [1, 5, 9, 8], [4, 5, 6, 10]],  
    [[1, 2, 6, 10], [5, 6, 7, 9], [2, 6, 10, 11], [3, 5, 6, 7]],  
    [[1, 4, 5, 6], [1, 4, 5, 9], [4, 5, 6, 9], [1, 5, 6, 9]],  
    [[1, 2, 5, 6]],  
]
```

## Code smell

- The code still uses a list when we have no plan to change its size.
- This violates the "Use immutable objects whenever necessary" rule.

```
((1, 5, 9, 13), (4, 5, 6, 7)) ...
```

## Selecting the Figure

- We can use two variables, Type and Rotation, to select the figure (tetromino) and its rotation.
  - For example, Figures[0] is the first figure, and Figures[1] is the second figure.

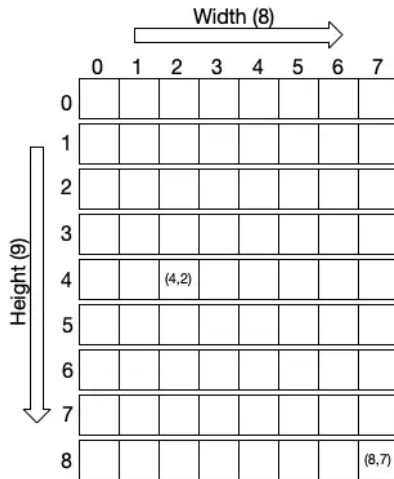
- `Figures[Type][0]` is the figure not rotated,  
`Figures[Type][1]` is the first rotation, and  
`Figures[Type][2]` is the next rotation.

```
1  Type = 0
2  Rotation = 0
3  Figures[Type][Rotation]
4  fig = Figures[0][1] # first figure rotated
```



# Field

- The Field contains the Width  $\times$  Height blocks.
  - In this example, we have an  $8 \times 9$  Field.



- To access the 2D list, we should specify the Y first, then X.
- For example, the last box in the 2D list is in `Field[8][7]` , which means  $9^{th}$  row and  $8^{th}$  column.
- We use two global variables Shift\_X and Shift\_Y to specify the location in the Field in this program.

- We need Width and Height variables to specify the x and y dimensions of the Field.
- Global variables, StartX and StartY, specify where the Field is drawn on the screen.
- If these values are (0, 0), the Field will be drawn on the left-upper side of the screen.

## Global variables

```
Type = 0
Color = 0
Rotation = 0
State = "start" # or "gameover"
Field = []
Height = 0 # Tetris block Height and Width
Width = 0
StartX = 100 # StartX/Y position in the screen
StartY= 60
# Block size
Tzoom = 20
ShiftX = 0 # Shift left/right or up/down
ShiftY = 0
```

## Code smell

- It's always a bad idea to use global variables.
- It is a direct violation of the OOP **Encapsulation** rule.
- Instead, use a class to abstract and encapsulate.

## Code smell

- Do not use a shortened name unless it is a well-known name.
- It is not easy to understand what **Tzoom** means.
- Use a more descriptive name for a variable.

Tzoom

## Initialization

- This is the way to make a list of N elements.
- We make a list of 5 elements (all 0).

```
[0] * 5 # [0, 0, 0, 0, 0]
```

- Then, we use the append method to add the generated 1D list to the Field list Height times.

```
for i in range(Height):  
    new_line = [0] * Width  
    Field.append(new_line)
```



## Python Pitfall

- As we can make a list using the \* operator, we may think we can make a list of a list with it; This is a bug that is hard to find in Python.
- Because it is a reference duplication, not a real value.

```
[0] * 5 # [0, 0, 0, 0, 0] OK  
[[0,0,0,0,0]] * Height # Bug! If you don't know what you are doing
```

- This is one of the reasons why we should know what we are doing.

```
# DANGEROUS – creates 3 references to the SAME list
matrix = [[0, 0, 0]] * 3 # [[0,0,0], [0,0,0], [0,0,0]]
print("Before:", matrix) # [[0,0,0], [0,0,0], [0,0,0]]

matrix[0][1] = 99
print("After:", matrix) # [[0,99,0], [0,99,0], [0,99,0]]
# ALL rows changed because they're the same object!
```

## Code smell

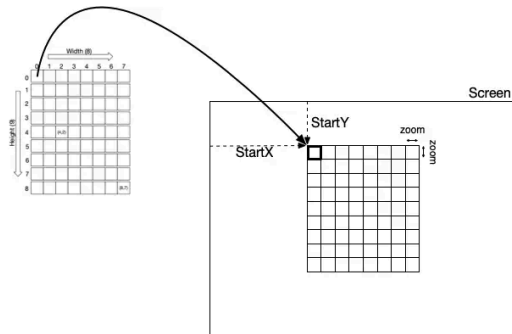
- We used a for loop to avoid this issue; However, the better solution is to use Python list comprehension.
- Use a simpler solution to solve the same problem.

```
for i in range(Height): # our solution
    new_line = [0] * Width
    matrix.append(new_line)

matrix = [[0] * Width for _ in range(Height)] # better
```

### 3. Tetris: Mapping

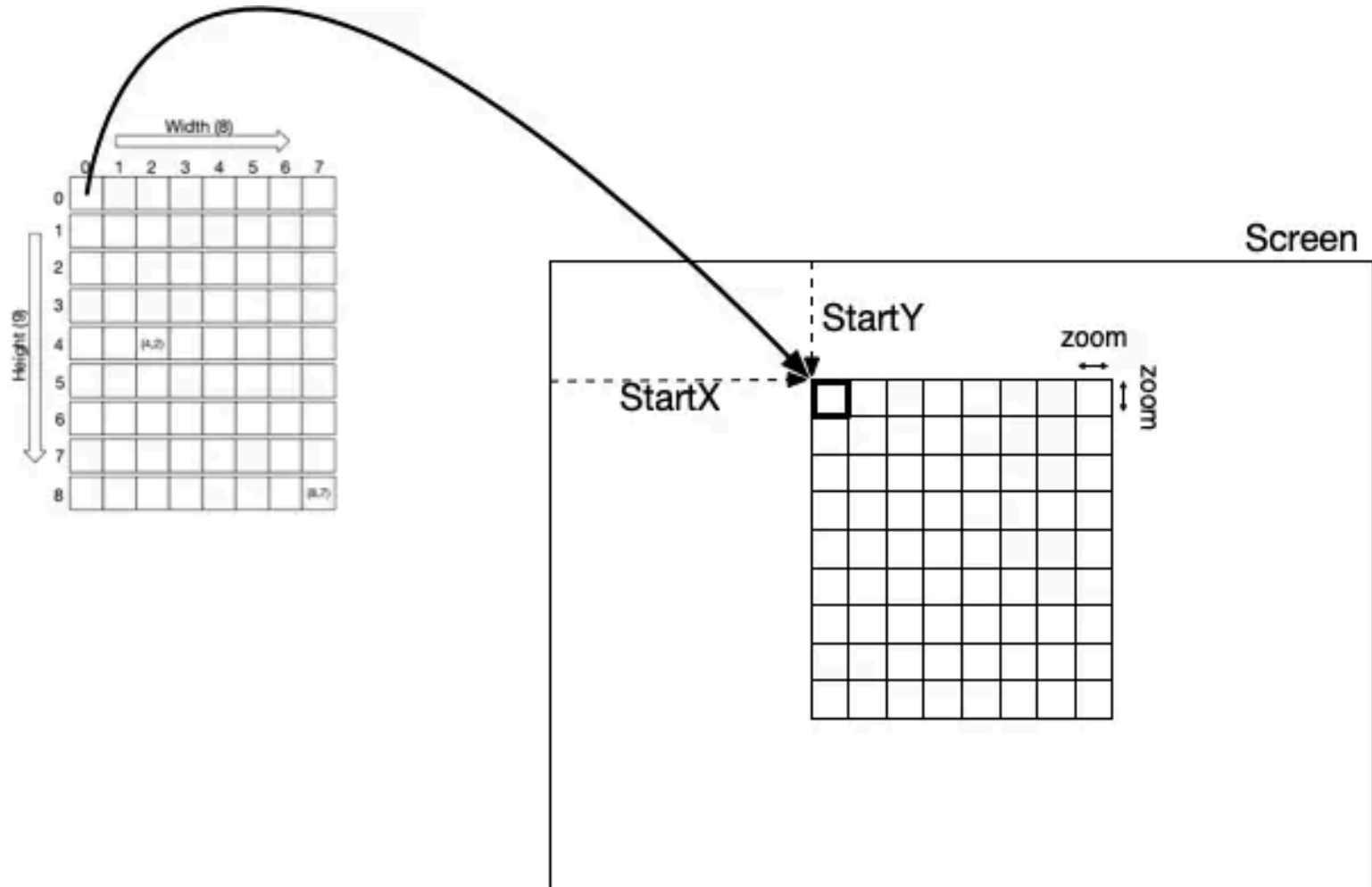
Mapping Logical Location to Physical Point



## Logical to Physical

- The Field 2D array is a logical concept that needs to be mapped to a screen.
- As an example, `Field[Y][X]` maps to the location at  $(\text{StartX}, \text{StartY}) : (\text{StartX} + \text{zoom } X, \text{StartY} + \text{zoom } Y)$ .

- Field[0][0] -> (StartX, StartY):(StartX + zoom 1, StartY + zoom 1).



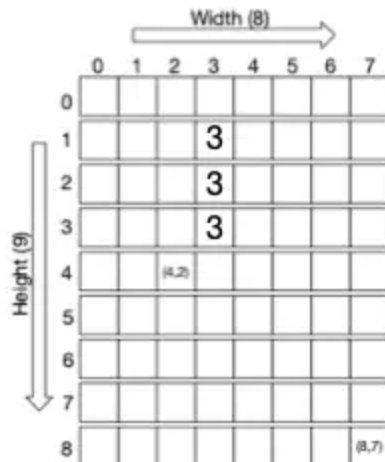
## Drawing a board

- We can use this mapping rule to draw a board on the screen.
- We use `pygame.draw.rect` to draw rectangles with the Gray color.

```
for i in range(Height): # i means Y direction
    for j in range(Width): # j means X direction
        pygame.draw.rect(screen, GRAY,
                        [x + zoom * j, y + zoom * i, zoom, zoom], 1)
```

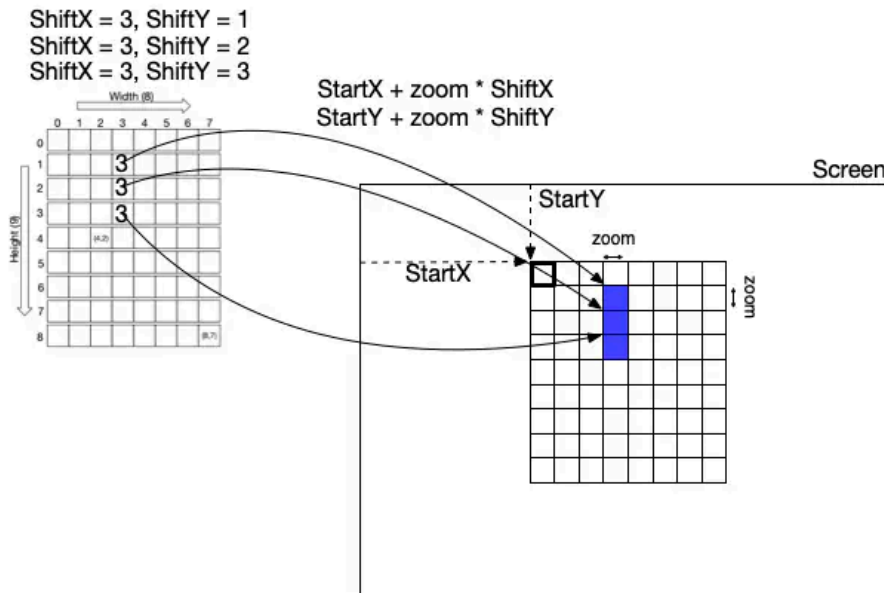
- The logical locations "i and j" in Field[i][j], where i matches the y (ShiftY) coordinate, and j matches the x (ShiftX) coordinate.
- For example, with Field[1][3], [2][3], and [3][3], the ShiftX and ShiftY can locate the position.

ShiftX = 3, ShiftY = 1  
 ShiftX = 3, ShiftY = 2  
 ShiftX = 3, ShiftY = 3





- The Field[1][3] is mapped to ( $\text{StartX} + \text{zoom} \cdot 3$ ,  $\text{StartY} + \text{zoom} \cdot 1$ , zoom, zoom) in the screen and on.



## Drawing a rectangle

- We can write the algorithm to draw a rectangle using this mapping rule.

```
if Field[i][j] > 0:
    pygame.draw.rect(screen, # screen
                     Colors[Field[i][j]], # color
                     [x + zoom * j + 1, #
                      y + zoom * i + 1, #
                      zoom - 2, #
                      zoom - 2]) #
```

## Visual borders

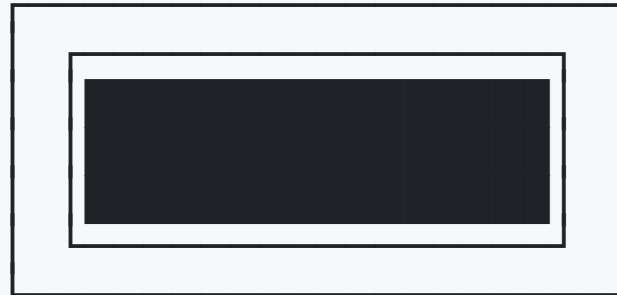
- In the code, we add +1 and -2; this is a common technique in pygame for creating **visual borders** between grid elements.

Without borders:



20×20 pixels

With +1 and -2 borders:



18×18 pixels + 1px border

## Drawing a figure

- Drawing a figure on the board is drawing rectangles with the color using the image list.
- It must use the `shift_x` and `shift_y` variables to shift the figure's location.

## Drawing a figure from an image

- We can draw the figure at (x, y) from the image.

```
image = [1, 5, 9, 13]
...
for i in range(4):
    for j in range(4):
        p = i * 4 + j
        if p in image:
            pygame.draw.rect(screen, Colors[Color],
                             [x + zoom * (j + shift_x) + 1, y + zoom * (i + shift_y) + 1,
                              zoom - 2, zoom - 2]
                             )
```