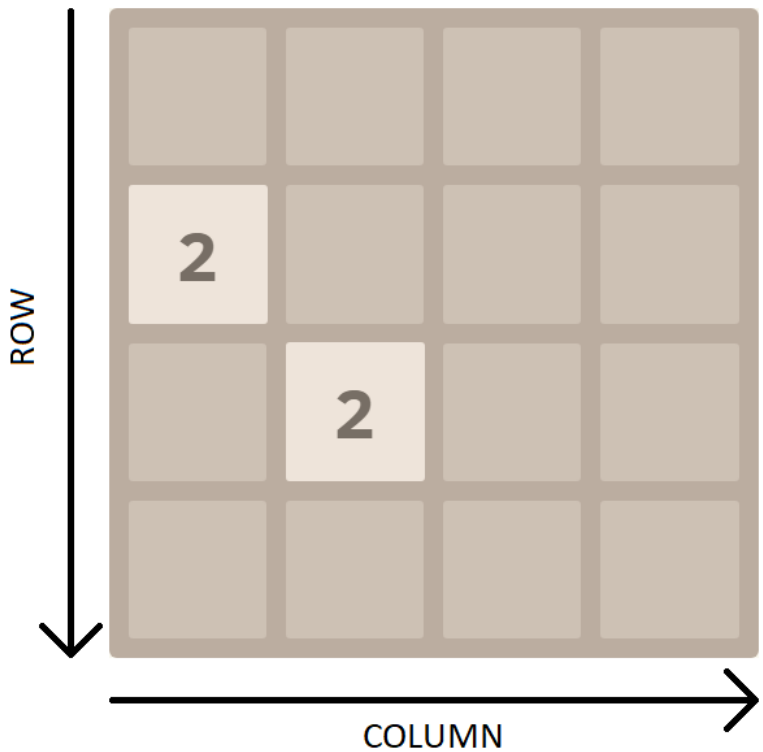
Assignment 4, Design Specification

COMP SCI 2ME3

April 12, 2021

This Module Interface Specificaiton (MIS) document contains the modules, types, and methods for implementing the game 2048. At the start of each game, 2 numbers are created in a random location on a 4x4 grid. The number created has 90% chance of being a 2, and a 10% chance of being a 4. The user must combine matching numbers together to eventually create the number 2048 in order to win. The numbers on the board can be shifted in the desired direction using the arrow keys, and if there is any matching numbers present in the direction being shifted, the numbers will combine. When shifting numbers, all numbers are shifted in the input direction as far as possible. For combining numbers, a number can only combine once for a given movement. For example, shifting [2,2,2,2] to the right will not from [_,_,_,8], but [_,_,4,4]. Which can be then shifted right one more time to form [_,_,_,8]. On the gameboard, the Row numbers increase top to bottom, and column number increases left to right. The game requires a GUI to be played, and can be launched by running `Demo.java` in the desired IDE.



The above board visualization is from https://www.play2048.co/

1 Overview of the design

This design applies the Model View design pattern. The Model View design pattern components are *GameBoard* (model Module) and *Game* (view and controller Module).

The Module View design pattern is implemented in the following way: the *GameBoard* module stores the state of the game board and the status of the game. As well as the main methods required for checking for win/lose conditions and adding/movement of the board. The *Game* module is responsible for the main UI and the inputs to the game. It displays the game board and decides the actions that should be taken on a certain key press.

Likely Changes my design considers:

- Change in UI Design (such as tile color).
- Addition of key inputs (such as w,a,s,d).

Game Board Module

Template Module

GameBoard

Uses

N/A

Syntax

Exported Constants

None

Exported Types

GameBoard = ?

Exported Access Programs

Routine name	In	Out	Notes	Exceptions
new GameBoard		GameBoard		
new GameBoard	seq [4] of (seq [4] of $\mathbb{N}$)	GameBoard	For testing purposes	
addNewNum				
addNewNum	$\mathbb{N}, \mathbb{N}, \mathbb{N}$		For testing purposes	
getScore		$\mathbb{N}$		
getHighestNum		$\mathbb{N}$		
getBoard		seq [4] of (seq [4] of $\mathbb{N}$)		
getCount		$\mathbb{N}$		
moveUp				
moveDown				
moveLeft				
moveRight				
gameOver		$\mathbb{B}$		

Semantics

State Variables

board: seq of [4] (seq of [4] $\mathbb{N}$)
score: $\mathbb{N}$
highestNum: $\mathbb{N}$

State Invariant

None

Assumptions

- Arugments given to the methods created for testing purposes will be of the correct type.
- Assume there is a function *random* that generates a random value between 0 and 1.
- Assume final results are rounded to the nearest integer.

Access Routine Semantics

new GameBoard():

- output: out := self
- transition:
  - board := ⟨ [[0,0,0,0], [0,0,0,0], [0,0,0,0], [0,0,0,0]] ⟩
    $\langle random() * 9 \equiv 0 \Rightarrow board[i][j] := 4|2$ where $i = random() * 3 \wedge j = random() * 3 \wedge \exists(board[i][j] \equiv 0)\rangle$
    $\langle random() * 9 \equiv 0 \Rightarrow board[i][j] := 4|2$ where $i = random() * 3 \wedge j = random() * 3 \wedge \exists(board[i][j] \equiv 0)\rangle$
    // Initializes a gameboard of 0's, and adds either a 2 (90% chance) or a 4(10% chance) into a random location twice.
  - score := 0
  - highestNum := $(i, j : \mathbb{N}|i, j \in [0..3] : board[i][j] > highestNum \Rightarrow highestNum := board[i][j])$
- exception: none

new GameBoard($layout$):

- output: out := self
- transition:
  - board := $layout$
  - score := 0
  - highestNum := $(i : \mathbb{N} | i \in [0..3] : (j : \mathbb{N} | j \in [0..3] : board[i][j] > highestNum \Rightarrow highestNum := board[i][j]))$
- exception: none

addNewNum():

- transition: board := $random() * 9 \equiv 0 \Rightarrow board[i][j] = 4|2$ where $i = random() * 3 \wedge j = random() * 3 \wedge \exists(board[i][j] \equiv 0)$
  // adds either a 2 (90% chance) or a 4(10% chance) into a random location that currently has a 0.
- exception: none

addNewNum($value, row, col$):

- transition: board[row][col] := $value$
- exception: none

getScore():

- output: out := $score$
- exception: none

getHighestNum():

- output: out := $highestNum$
- exception: none

getBoard():

- output: out := $board$
- exception: none

getCount():

- output: out := $count$ where $count \equiv (i : \mathbb{N}|i \in [0..3] : (j : \mathbb{N}|j \in [0..3] : \neg(board[i][j] = 0) \Rightarrow count := count + 1|count))$
  // Returns the number of elements on the board that are not 0.

- exception: none

moveUp():

- transition: board := shiftUp() ∧ combineUp() ∧ shiftUp()
  // Shifts all the numbers up, combines matching numbers, and shifts up again.

- exception: none

moveDown():

- transition: board := shiftDown() ∧ combineDown() ∧ shiftDown()
  // Shifts all the numbers down, combines matching numbers, and shifts down again.

- exception: none

moveLeft():

- transition: board := shiftLeft() ∧ combineLeft() ∧ shiftLeft()
  // Shifts all the numbers left, combines matching numbers, and shifts left again.

- exception: none

moveRight():

- transition: board := shiftRight() ∧ combineRight() ∧ shiftRight()
  // Shifts all the numbers right, combines matching numbers, and shifts right again.

- exception: none

gameOver():

- output := $\neg(getCount() = 16) \Rightarrow False|(\exists((row : \mathbb{N}|row \in [0..3] : col : \mathbb{N}|col \in [0..2] : board[row][col] \equiv board[row][col + 1]) \wedge (col : \mathbb{N}|col \in [0..3] : row : \mathbb{N}|row \in [0..2] : board[row][col] \equiv board[row + 1][col])) \Rightarrow False|True)$
  //returns false if getCount() is not 16. Otherwise checks every column to see if any adjacent numbers are matching, and then checks ever row ot see if any adjacent number are matching. If no adjacent matching number, returns true.

- exception: none

Local Functions

shiftUp()

- transition: $(col : \mathbb{N}|col \in [0..3] : (row : \mathbb{N}|row \in [1..3] : board[X][col] \equiv 0 \Rightarrow board[X][col] := value \wedge board[row][col] := 0))$
  where $X : \mathbb{N}|X \in [row..0] \wedge value = board[row][col]$
  // Goes through each column and beginning from the top shifts each number up continuously until the number above is not a 0, end result being all number are shifted and compressed to the top replacing any 0's.

- exception: none

combineUp()

- transition: $(col : \mathbb{N}|col \in [0..3] : (row : \mathbb{N}|row \in [1..3] : board[row-1][col] \equiv value \Rightarrow board[row-1][col] := value * 2 \wedge board[row][col] := 0 \wedge score := score + value * 2))$
  where $value \equiv board[row][col]$
  Combine numbers that are equal and adjacent vertically and of the two nubmers, the number that is north on the grid is replaced with the result, with the number below being replaced with a 0.

- exception: none

shiftDown()

- transition: $(col : \mathbb{N}|col \in [0..3] : (row : \mathbb{N}|row \in [2..0] : board[X][col] \equiv 0 \Rightarrow board[X][col] := value \wedge board[row][col] := 0))$
  where $X : \mathbb{N}|X \in [row..3] \wedge value = board[row][col]$
  // Goes through each column and beginning from the bottom shifts each number down continuously until the number below is not a 0, end result being all number are shifted and compressed to the bottom replacing any 0's.

- exception: none

combineDown()

- transition: $(col : \mathbb{N}|col \in [0..3] : (row : \mathbb{N}|row \in [2..0] : board[row+1][col] \equiv value \Rightarrow board[row+1][col] := value * 2 \wedge board[row][col] := 0 \wedge score := score + value * 2))$
  where $value \equiv board[row][col]$
  Combine numbers that are equal and adjacent vertically and of the two nubmers, the number that is south on the grid is replaced with the result, with the number above being replaced with a 0.

- exception: none

shiftLeft()

- transition: $(row : \mathbb{N}|row \in [0..3] : (col : \mathbb{N}|col \in [1..3] : board[row][Y] \equiv 0 \Rightarrow board[row][Y] := value \wedge board[row][col] := 0))$
  where $Y : \mathbb{N}|Y \in [col..0] \wedge value = board[row][col]$
  // Goes through each row and beginning from the left shifts each number to the left continuously until the number to the left is not a 0, end result being all number are shifted and compressed to the left replacing any 0's.

- exception: none

combineLeft()

- transition: $(row : \mathbb{N}|row \in [0..3] : (col : \mathbb{N}|col \in [1..3] : board[row][col-1] \equiv value \Rightarrow board[row][col-1] := value * 2 \wedge board[row][col] := 0 \wedge score := score + value * 2))$
  where $value \equiv board[row][col]$
  Combine numbers that are equal and adjacent horizontally and of the two nubmers, the number that is further left on the grid is replaced with the result, with the number to the right being replaced with a 0.

- exception: none

shiftRight()

- transition: $(row : \mathbb{N}|row \in [0..3] : (col : \mathbb{N}|col \in [2..0] : board[row][Y] \equiv 0 \Rightarrow board[row][Y] := value \wedge board[row][col] := 0))$
  where $Y : \mathbb{N}|Y \in [col..3] \wedge value = board[row][col]$
  // Goes through each row and beginning from the right shifts each number to the right continuously until the number to the right is not a 0, end result being all number are shifted and compressed to the right replacing any 0's.

- exception: none

combineRight()

- transition: $(row : \mathbb{N}|row \in [0..3] : (col : \mathbb{N}|col \in [2..0] : board[row][col+1] \equiv value \Rightarrow board[row][col+1] := value * 2 \wedge board[row][col] := 0 \wedge score := score + value * 2))$
  where $value \equiv board[row][col]$
  Combine numbers that are equal and adjacent horizontally and of the two nubmers, the number that is further right on the grid is replaced with the result, with the number to the left being replaced with a 0.

- exception: none

View and Controller Module

Module inherits JPanel, KeyListener

Game

Uses

JFrame, JPanel, KeyListener

Syntax

Exported Constants

None

Exported Types

None

Exported Access Programs

Routine name	In	Out	Exceptions
GUI			
KeyPressed	KeyEvent		
KeyReleased	KeyEvent		
KeyTyped	KeyEvent		
paint	Graphics		
drawTiles	Grahpics, $\mathbb{N}, \mathbb{N}, \mathbb{N}$		

Access Routine Semantics

Semantics

Envrionment Variables

window: A portion of the computer screen to display the game.

State Variables

gb : GameBoard
$game$: Game
$frame$: JFrame

State InVariant

None

Access Routine Semantics

GUI:

- transition: window is intialized to the correct dimensions.
- exception: none

KeyPressed(e):

- Not Implemented.
- exception: none

KeyReleased(e):

- transition: $(e \equiv KeyEvent.UP \Rightarrow gb.moveUp()) \vee (e \equiv KeyEvent.DOWN \Rightarrow gb.moveDown()) \vee (e \equiv KeyEvent.LEFT \Rightarrow gb.moveLeft()) \vee (e \equiv KeyEvent.RIGHT \Rightarrow gb.moveRIGHT())$
  // Calls the corresponding movement function on the game board on the given key press.
- exception: none

KeyTyped(e):

- Not implemented.
- exception: none

paint(g):

- transition: window := Prints the game board on a 4x4 grid and displays the number in the location on the grid with row 0 beginning at the top of the grid, and column 0 beginning at the left of the grid. So row 0, column 0 would be the top left corner, and row 3, column 3 would be the bottom right corner. Score is displayed above the grid. If gb.GameOver() becomes true, then prints "GAME OVER" message. If gb.getHighestNum() equals 2048, then "YOU WIN" message is printed below the game board, and the game is allowed to continue.
- exception: none

drawTiles(g, $value, x, y$):

- transition: window := prints the given value in the specified location on the grid given the x and y coordinates (which correspond to the column and row number). If the value is 0, then nothing is displayed.
- exception: none

JPanel Module

Generic Template Module

JPanel

Considerations

Implemented as part of Java, as described in the Oracle Documentation

KeyListener Module

Interface Module

KeyListener

Considerations

Implemented as part of Java, as described in the Oracle Documentation

Critique of Design

- I designed the GameBoard module as an ADT opposed to an abstract object as it is easier to create a new instance of the game board when the game is restarted. This also enables me to initalize multiple game boards for testing the methods implemented, as I can observe how the same method functions on different game boads simultaneously.

- One problem with my design is that it could have more encapsulation. The movement logic could have been seperated into another module specifically for movement, and another ADT could have been created for each value (for example a Tile module which would hold the value and relevant information such as color to display).

- The GUI method in *Game* was created as a static method to ensure only one window is created at a time, and to prevent overlap of resources.

- In terms of generality, my design could be better. Currently it only creates a 4x4 board, but an option to create boards of different sizes would be useful.

- The $getCount()$ method is not essential, as it is only as a condition in $gameOver()$, however $gameOver()$ already goes through the entire board, so a count could be mainted in that method as well. However, this was implemented more for testing purposes to check if $addNewNum()$ was successful.

- In terms of consistency, I believe my design is fairly consistent. All the logic for shifting and combining numbers is fairly intuitive, with just a change in the directions the rows/columns are being processed.

- Another method for implementing the movement would have been to implement a single method for shifting and combining, and add a method for rotating the board. For example, just having a method for shifting and combining up, however if left key is pressed, the board is rotated 90°counter clockwise before calling the movement method, and rotated back clockwise 90°afterwards. This would increase minimality, essentiality, and generality. As it would reduce a lot of similar method, and implement new method such as Rotate.

- My design has low coupling as the modules are fairly independent of each other. It also has fairly high cohesion as all the methods for manipulating the game board is contained in the GameBoard module, and the methods responsible for the UI and the controller are housed in the Game module.

- I believe my design also implements information hiding fairly well. For example users do not have direct acces to the board and are not able to manipulate the board state once the game has started. They are able to generate a board with the wanted layout, however that was made mostly for testing purposes.

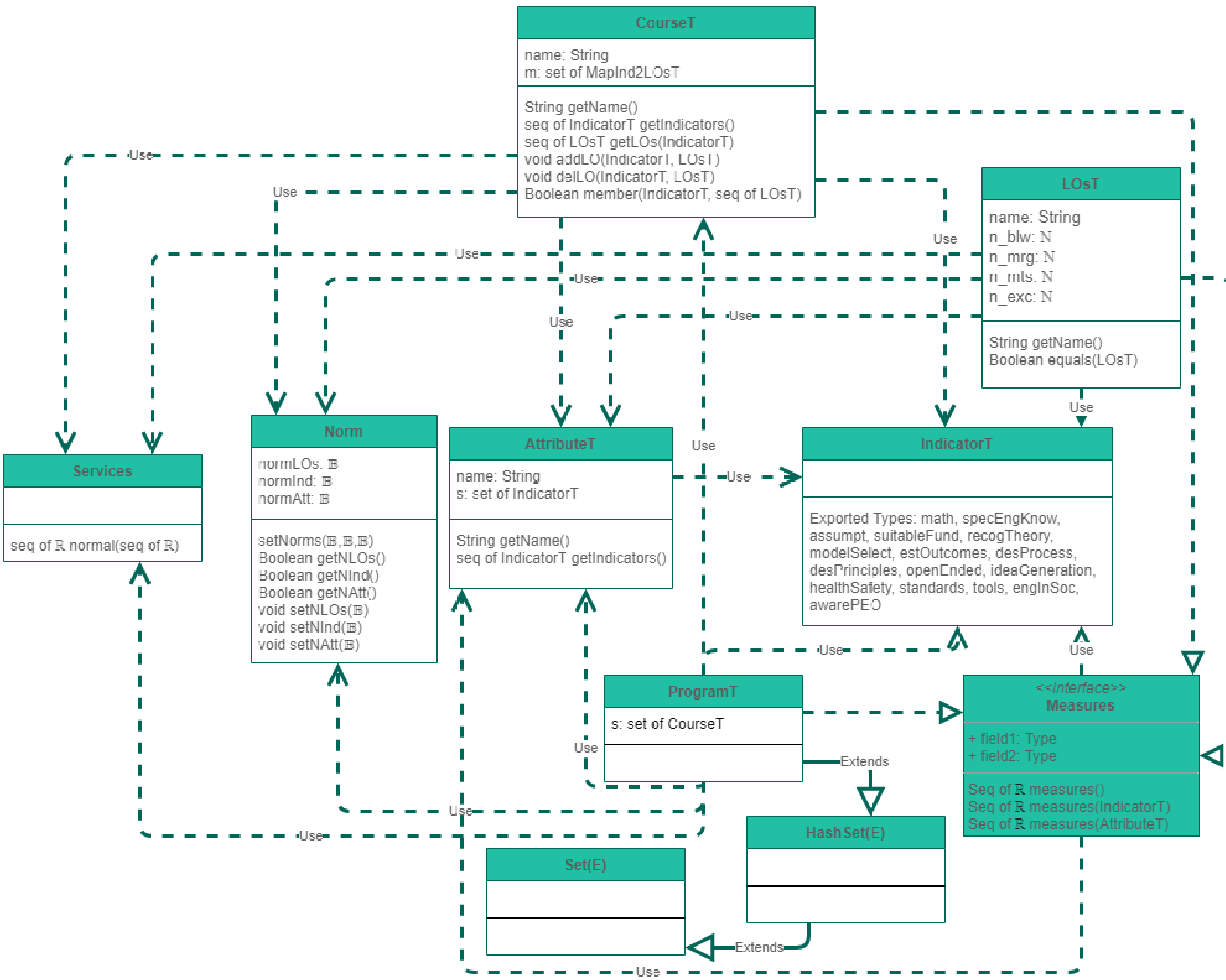
- The methods for creating a new board with the desired layout as well as the methods for adding a number into a desired location, both should have constraints (such as only being able to insert numbers that are a power of 2), however this was not implemented because those methods were made only to be used for testing.

- Test cases were designed to validate the correctness of the program. However, testing for $AddNewNum()$ was done by checking if the number of elements in the grid increased by one.

- No test cases were implemented fo the controller and the viewer. But the viewer was tested using repeated observation.

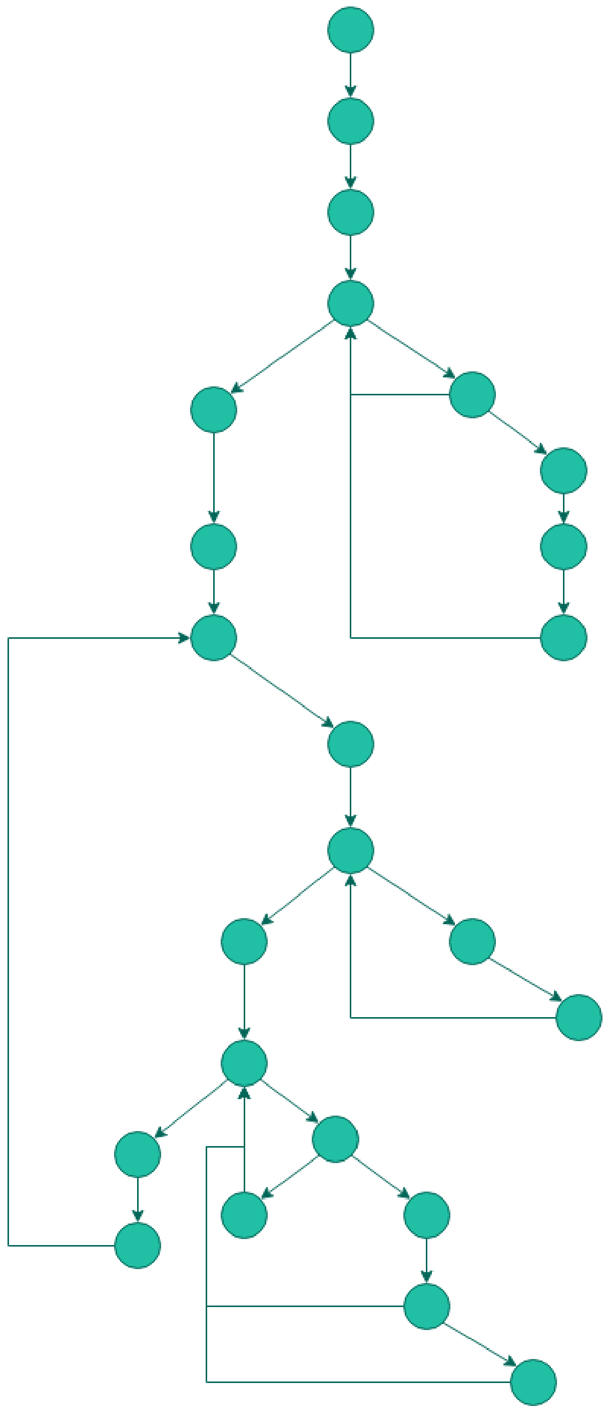
Answers to Questions:

Q1: Draw a UML diagram for the modules in A3.



The UML is constructed using https://app.diagrams.net/

Q2: Draw a control flow graph for the convex hull algorithm.



The control flow graph is constructed using https://app.diagrams.net/