Gamification Using Alpha-Beta Algorithm

Contents

Development of the Game

System component

1- Game board

As shown in figure, to display the board of the game, we need an array to store its values and also we need to store the position of the tile. In our implementation, we used class ***game_board*** to store the needed information and the needed operations of the board.

game_board class has the following attributes:

1	-1	0
1	0	1
0	1	-1

Figure 1 - Game Board

1. board: 2D array that store all numbers in the board.
2. tile_position: integer value used to store the current position of the tile.
3. prev_tile_position: integer value used to store the previous position of the tile in the previous move, it helps in generating the number by the min user.

Operations in ***game_board***:-

1- **Constructor:** Initialize the information of the board using a 2d array (board), tile position and by default the previous tile position = 6.

```
def __init__(self, arr,tile):
    self.prev_tile_position = 6
    self.board = arr
    self.tile_position = tile
    self.row_index = self.tile_position//3
    self.col_index = self.tile_position%3
```

2- **print_game_board :** used to print all information of the board.

```
def print_game_board(self):
    for row in self.board:
        print(row)
    print("tile position = " , self.tile_position)
```

3- **can_move_up, can_move_down, can_move_right and can_move_left** : check if the tile can move to a specific direction using its position.
For example: if the tile at upper corner so its position will be equals to 0 so it can't move up or left. Figure 4 shows how we represent the tile_position in the board.

0	1	2
3	4	5
6	7	8

Figure 2: Indexes used to represent the tile position

```
# if tile position != 0,1,2
def can_move_up(self):
    if (self.tile_position != 0
        and self.tile_position!=1
        and self.tile_position!=2):
        return True
    else:
        return False

# if tile position != 6,7,8
def can_move_down(self):
    if (self.tile_position != 6
        and self.tile_position!=7
        and self.tile_position!=8):
        return True
    else:
        return False

# if tile position != 2,5,8
def can_move_right(self):
    if (self.tile_position % 3 != 2
        and self.tile_position % 3 != 5
        and self.tile_position % 3 != 8):
        return True
    else:
        return False

# if tile position != 0,3,6
def can_move_left(self):
    if (self.tile_position != 0
        and self.tile_position != 3
        and self.tile_position != 6):
        return True
    else:
        return False
```

4- **move_up, move_down, move_right, move_left:**
Used to update the board info after moving, by update the tile position and change the value at the previous tile position to "?" to represent the position where the Min player will put (1, 0 or -1). In the following two figures an example of moving right.

0	1	2
3	4	5
6	7	8

Figure 3: Before any move, tile_position = 6

0	1	2
3	4	5
?	7	8

Figure 4: after moving right, tile_position = 7

```
    #tile_position -= 3
    def move_up(self):
        self.prev_tile_position = self.tile_position
        self.row_index = self.tile_position//3
        self.col_index = self.tile_position%3
        self.tile_position -= 3
        self.board[self.row_index-1][self.col_index] +=
self.board[self.row_index][self.col_index]
        self.board[self.row_index][self.col_index] = '?'

    def move_down(self):
        self.prev_tile_position = self.tile_position
        self.row_index = self.tile_position//3
        self.col_index = self.tile_position%3
        self.tile_position += 3
        self.board[self.row_index+1][self.col_index] +=
self.board[self.row_index][self.col_index]
        self.board[self.row_index][self.col_index] = '?'

    def move_right(self):
        self.prev_tile_position = self.tile_position
        self.row_index = self.tile_position//3
        self.col_index = self.tile_position%3
        self.tile_position += 1
        self.board[self.row_index][self.col_index+1] +=
self.board[self.row_index][self.col_index]
        self.board[self.row_index][self.col_index] = '?'

    def move_left(self):
        self.prev_tile_position = self.tile_position
        self.row_index = self.tile_position//3
        self.col_index = self.tile_position%3
        self.tile_position -= 1
        self.board[self.row_index][self.col_index-1] +=
self.board[self.row_index][self.col_index]
        self.board[self.row_index][self.col_index] = '?'
```

5- **set_at_prev_tile(num:int), get_value_at_tile():int:** 2 functions just to change the value at tile position and the previous position.

```
    def set_at_prev_tile(self,num):
        row = self.prev_tile_position//3
        col = self.prev_tile_position%3
        self.board[row][col] = num

    def get_value_at_tile(self):
        self.row_index = self.tile_position//3
        self.col_index = self.tile_position%3
        curr_score = self.board[self.row_index][self.col_index]
        return curr_score
```

2- <u>Game state:</u>

After each move from the Max or Min player a new state created for the game that shows the current board (data and tile) and the current score. We represent this state using ***game_state*** class.

game_state class has the following attributes:

1. max_score: integer value used to represent minimum level goal of the game.
2. max_depth: integer value used to represent maximum number of movements in the game.
3. current_score: integer value used to represent the score that the max user get till the current game state.
4. board: game_board object that store the info of the board at the current state.
5. parent_state: game_state object used to represent the previous game state.

Operations in ***game_state*** class:

1. **Constructor**: used to initialize all attributes of game_state object

```
    def __init__(self, board , max_depth , max_score ,  curr_score):
        self.parent_state = None
        self.board = copy.deepcopy(board)
        self.max_depth = max_depth
        self.max_score = max_score
        self.current_score = curr_score
```

2. **print_game_state():** print the board info and the current score at this state

```
def print_game_state(self):
        self.board.print_game_board()
        print("current_score = " , self.current_score)
        print("-------------------------------------")
```

3. **Isleaf:** check if the current state of the game is a leaf or not using the max depth and max score.
   Leaf state: is a state when the Max player exceeded the level goal or when the current depth (number of moves done till this state) is greater than or equal to the maximum number of movements.

```
def isleaf(self,current_depth):
        if self.current_score >= self.max_score or current_depth >=
self.max_depth:
            return True
        else:
            return False
```

4. **get_max_children ()**: get all possible moves that max player can move, and store them in a list then return this list.
   Figure 6 displays a children of one game state when max player move.
   In the Current state the tile position equals to 7 so the tile can only move up, right and left. So for the current state there are 3 children have different score and different board but same parent.
   NOTE: Score at child state equals to [score at the parent state + the value at new tile position after moving], for example score at *child_up* in *figure 6* equals to [score at parent + 1] while in *child_right equals to* [score at parent + 0].

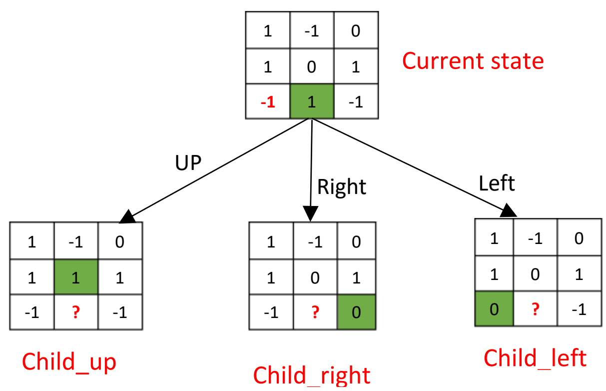


Figure 4: children Tree that represent all possible moves that max player can move

```
def get_max_children(self):
        parent = copy.deepcopy(self)

        children = []
        current_board = copy.deepcopy(self.board)

        if current_board.can_move_down():
            self.board.move_down()
            new_score = self.current_score +
self.board.get_value_at_tile()
            child_down = create_game_state(self.board
,self.max_depth,self.max_score,new_score)
            child_down.parent_state = copy.deepcopy(parent)
            children.append(child_down)
        self.board = copy.deepcopy(current_board)
```

```
        if current_board.can_move_right():
            self.board.move_right()
            new_score = self.current_score + self.board.get_value_at_tile()
            child_right = create_game_state(self.board
,self.max_depth,self.max_score,new_score)
            child_right.parent_state = copy.deepcopy(parent)
            children.append(child_right)
        self.board = copy.deepcopy(current_board)

        if current_board.can_move_left():
            self.board.move_left()
            new_score = self.current_score + self.board.get_value_at_tile()
            child_left = create_game_state(self.board
,self.max_depth,self.max_score,new_score)
            child_left.parent_state = copy.deepcopy(parent)
            children.append(child_left)
        self.board = copy.deepcopy(current_board)

        if current_board.can_move_up():
            self.board.move_up()
            new_score = self.current_score + self.board.get_value_at_tile()
            child_up =
create_game_state(self.board,self.max_depth,self.max_score,new_score)
            child_up.parent_state = copy.deepcopy(parent)
            children.append(child_up)
        self.board = copy.deepcopy(current_board)

        return children
```

5. **get_min_children() :** get all possible moves that min player generate a random number, store them in a list and return this list. The following figure displays a children of one game state when min player set a number from (0,1,-1).
Note: there is no change at score for min children.

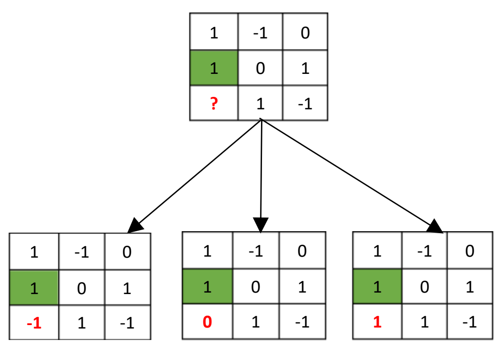


Figure 5: children Tree that represent all possible numbers that min player can generate in the previous tile position

```
def get_min_children(self):

        parent = copy.deepcopy(self)
        children = []
        current_board = copy.deepcopy(self.board)

        self.board.set_at_prev_tile(1)
        child1 =
create_game_state(self.board,self.max_depth,self.max_score,self.current_sco
re)
```

```
        child1.parent_state = copy.deepcopy(parent)
        children.append(child1)
        self.board = copy.deepcopy(current_board)

        self.board.set_at_prev_tile(0)
        child2 = 
create_game_state(self.board,self.max_depth,self.max_score,self.current_sco
re)
        child2.parent_state = copy.deepcopy(parent)
        children.append(child2)
        self.board = copy.deepcopy(current_board)

        self.board.set_at_prev_tile(-1)
        child3 = 
create_game_state(self.board,self.max_depth,self.max_score,self.current_sco
re)
        child3.parent_state = copy.deepcopy(parent)
        children.append(child3)
        self.board = copy.deepcopy(current_board)

        return children
```

6. **move_to_random_min_child() :** generate a random number in range of [-1,1] then use this number to create a new game state as a min state.

```
def move_to_random_min_child(self):
        value = random.randint(-1,1)
        parent = copy.deepcopy(self)
        self.board.set_at_prev_tile(value)
        self.parent_state = copy.deepcopy(parent)
```

7. **less_than_or_equal():** compare between the score at each state then return true if the current state less than or equal to state2 at the parameters

```
def less_than_or_equal(self,state2):
        score2 = state2.get_current_score()
        if self.current_score <= score2:
            return True
        else:
            return False
```

8. **get_original_state_from_leaf():** using the parent_state attribute, this function returns the first parent of a state (first move done to reach the current state). It is implemented as getting second node in a linked list from the last node.

```
def get_original_state_from_leaf(self):
        curr_state = copy.deepcopy(self)

        while curr_state.parent_state.parent_state != None:
            curr_state = copy.deepcopy(curr_state.parent_state)

        return curr_state
```

3- Alpha-beta Algorithm

Alpha beta burning algorithm, is a search technique that used to enhance the minimax algorithm be decreasing the expanded nodes in search tree.

Alpha-beta pseudocode:

```
Minimax (current_state, current_depth,isMaximizingPlayer, alpha , beta ):
    if current state is a leaf state:
       return current_state
    if isMaximizingPlayer:
       best_value = -INF
       for each child in children of current state:
          next_state = minimax(child,current_depth+1,False ,alpha ,beta))
           best_value = max (best_value, next_state)
           alpha = max (alpha, best_value)
           if beta<=(alpha):
               break
        return best_value
    else:
       best_value = INF
       for each child in children of current state:
           next_state =minimax(child, current_depth+1, True, alpha, beta)
           best_value = min (best_value,next_state)
           beta = min (beta,best_value))
           if beta <= (alpha):
              break
        return best_value
```

In our project we use alpha-beta algorithm to make the max player is an optimal player by using the algorithm to select the best moves while the min player selects the numbers in its turn randomly. The algorithm is implemented in the ***alpha_beta*** class.

alpha_beta class has no attributes, but it has three operations:

1. **minimax(current_state: game_state ,current_depth: int , isMaximizingPlayer: Boolean , alpha: game_state , beta: game_state) : game_state**

In this function we apply alpha-beta algorithm each time max player should move. It implements using DFS to traverse the searching tree. It returns the best final score the max player can gain. Then using (**get_original_state_from_leaf ()**) function in *game_state* class to get the current step max player should do –which is the first parent for final state-.

```
def minimax(self,current_state,current_depth,isMaximizingPlayer,alpha,beta ):
        if(current_state.isleaf(current_depth)):
            return current_state
        if isMaximizingPlayer:
            best_value = copy.deepcopy(create_inf_state(current_state ,
NEG_INF))
            children = copy.deepcopy(current_state.get_max_children())
            for child in children:
                next_state = copy.deepcopy(self.minimax(child,
current_depth+1, False , alpha , beta))
                best_value = copy.deepcopy(self.max_state(best_value ,
next_state))
                alpha = copy.deepcopy(self.max_state(alpha , best_value))
                if beta.less_than_or_equal(alpha):
                    break
            return best_value
        else:
            best_value = copy.deepcopy(create_inf_state(current_state , INF))
            children = copy.deepcopy(current_state.get_min_children())
            for child in children:
                next_state = copy.deepcopy(self.minimax(child,
current_depth,True , alpha , beta))
                best_value =
copy.deepcopy(self.min_state(best_value,next_state))
                beta = copy.deepcopy(self.min_state(beta,best_value))
                if beta.less_than_or_equal(alpha):
                    break
            return best_value
```

2. **max_state(state1:game_state , state2:game_state):game_state.** In this function we compare between two game_state objects using the current_score attribute and return the state that has the maximum score.

```
def max_state(self,state1 , state2):
       score1 = state1.get_current_score()
       score2 = state2.get_current_score()
       if score1 > score2:
           return state1
       else:
           return state2
```

3. **min_state(state1:game_state , state2:game_state):game_state** In this function we compare between two game_state objects using the current_score attribute and return the state that has the minimum score.

```
def min_state(self,state1 , state2):
        score1 = state1.get_current_score()
        score2 = state2.get_current_score()
        if score1 < score2:
            return state1
        else:
            return state2
```

4- Run the game

Rand_vs_ia_agent.py and GUI_game.py these two files used to run the game.

1. **rand_vs_ai_agent.py:**

Play (depth: int, score: int, player: win_player): game_state [] .This function used to alternate between min and max player turns. In max player turn we use **create_inf_state (current_state: game_state, INF: int): game_state** to create alpha and beta game states that have INF and –INF score. Then we use them to apply alpha-beta algorithm returning the best score can max player win with, then using **get_original_state_from_leaf ()** function in *game_state* class to get the new current state. In min player turn, current_state call move_to_random_min_child () to generate a random next state.

```
def play(depth,score,player):

    max_depth = depth
    max_score = score
    random_min = True
    state = intialize_game(max_depth,max_score)

    current_depth = 0
    MAX_PLAYER = True
    INF = 2147483648
    NEG_INF = -2147483648
    current_score = 0
    game = alpha_beta()  # constructor do nothig

    all_states = []
    all_states.append(copy.deepcopy(state))
    while True:
        current_score = state.get_current_score()

        max_player_win =
is_max_win(max_depth,max_score,current_depth,current_score)
```

```
        max_player_loss =
is_max_loss(max_depth,max_score,current_depth,current_score)
        if max_player_win:
            player.name = "MAX Player"
            break
        if  max_player_loss:
            player.name = "MIN Player"
            break
        if MAX_PLAYER:
            alpha = create_inf_state(state,NEG_INF)
            beta = create_inf_state(state,INF)
            state.set_parent(None) # root of the alpha beta tree
            best_state = game.minimax(state, 1, True, alpha, beta)
            state = best_state.get_original_state_from_leaf()
            all_states.append(copy.deepcopy(state))
            current_depth += 1
            MAX_PLAYER = False
        else:
            if random_min:
                state.move_to_random_min_child()
            else:
                alpha = create_inf_state(state,NEG_INF)
                beta = create_inf_state(state,INF)
                state.set_parent(None) # root of the alpha beta tree
                best_state = game.minimax(state, 1, False, alpha, beta)
                state = best_state.get_original_state_from_leaf()
            MAX_PLAYER = True
    return all_states
```

5- User Interface:

User Interface of the project implemented in file **GUI_game.py** using standard GUI Library called **Tkinter.** UI of our project has two frames one for control and read inputs of the game, the other is for showing game states one by one.

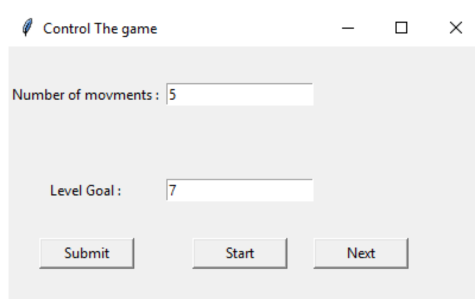


Figure 6: This Form to control the game and read inputs

When we run **GUI_game.py** file, the control form in figure 6 appears so you can write your inputs in textboxes and press submit button. After pressing "submit", play() function called and returns all states result from your inputs in an array – This may take time due to recursion implementation in alpha beta algorithm and its high complexity.
After that you can start showing the states of the game using start and next buttons.

Test cases (output of the game play)

To run the game you need to follow these steps:

1- Put all files in same folder
2- Run “GUI_game.py” file
3- UI appears so you can write your inputs
4- Submit the inputs via “Submit button” then press “Start button” to see the game states one by one using “Next button”.

NOTE: after pressing submit it may take time to be able to press “start button” because of the high complexity of alpha-beta and it also depends on ‘max number of movements’ you entered in the game.

<u>Test case #1:</u>

Input:

1- Minimal Level Goal (score) = 7
2- Maximum number of moves = 5

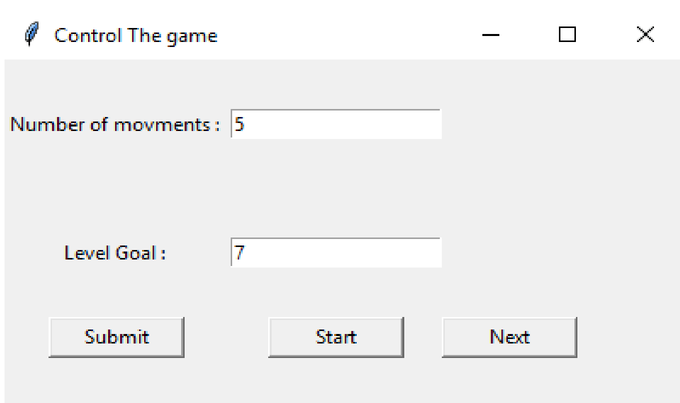


Figure 8: Inputs in GUI form

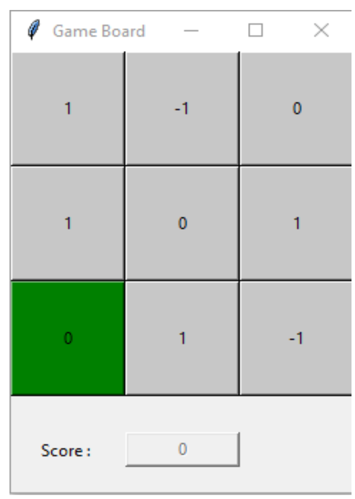


Figure 7 : Initial state of the game

Output:

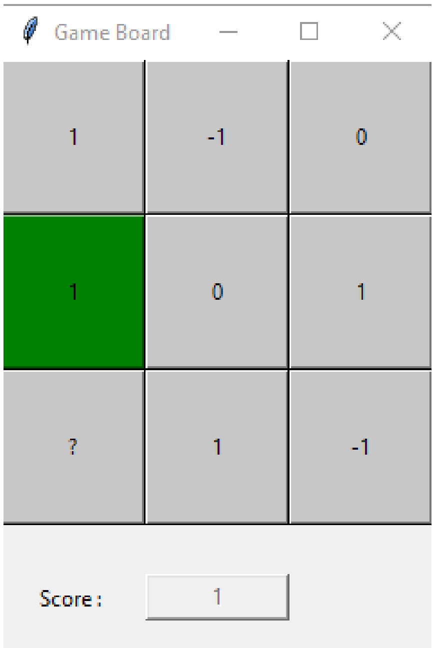


Figure 1: max user moved up with score =1

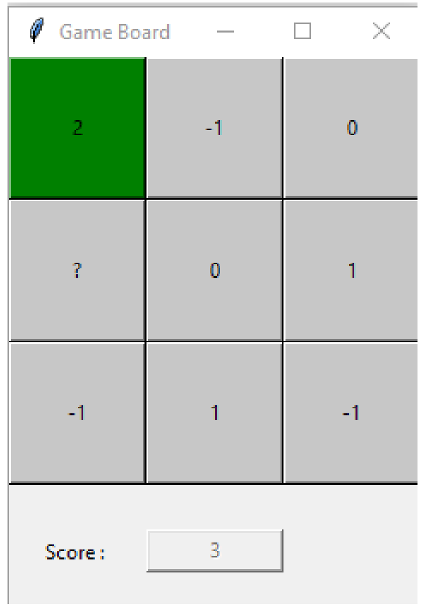


Figure 2 Min player generate -1 at previous tile position and max player moved up again. Score

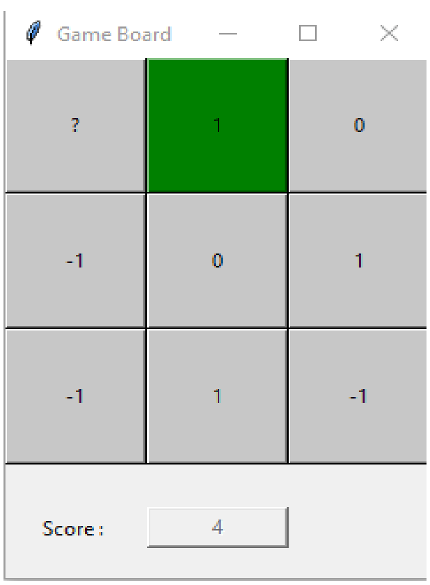


Figure3: Min player generated -1 at previous tile position and max player moved right.

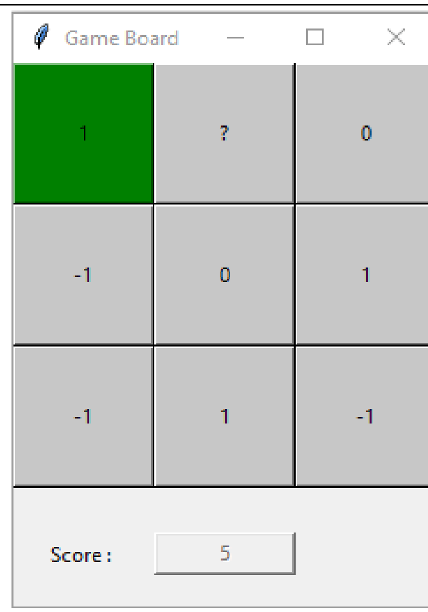


Figure 4 Min Player generated 1 at previous tile position, then Max Player moved left

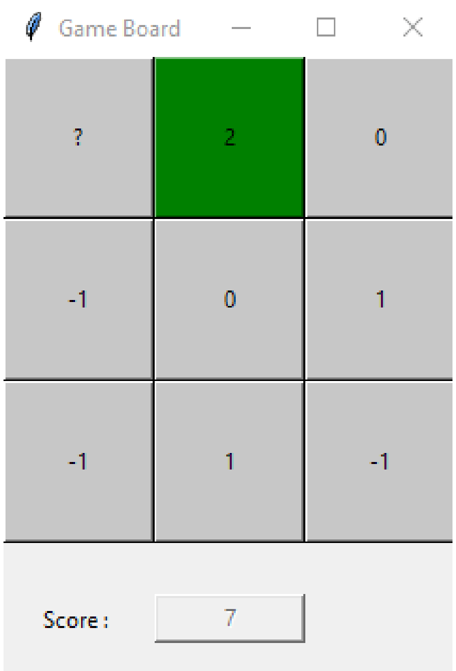


Figure 5: Min player generated 1 at previous tile position, then Max Player moved up.

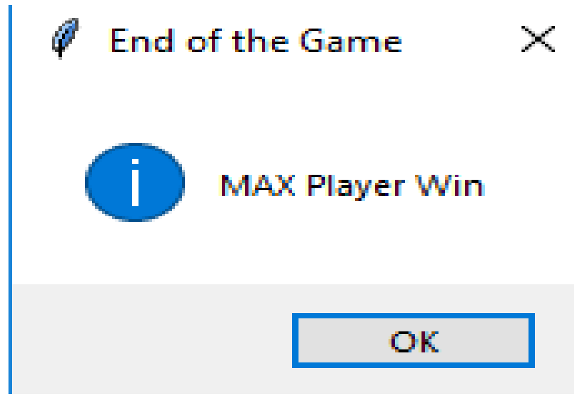


Figure 6: Max Player get Score equal 7 in 5 steps.

Test Case #2

Input:

1- Minimal Level Goal (score) = 10
2- Maximum number of moves = 3

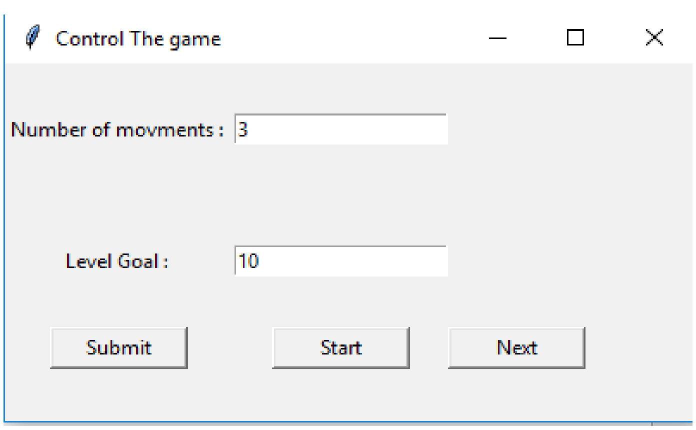


Figure 8: Inputs in GUI

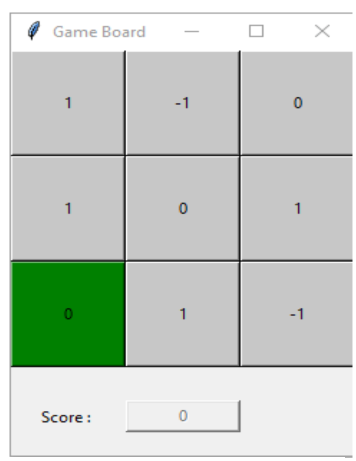
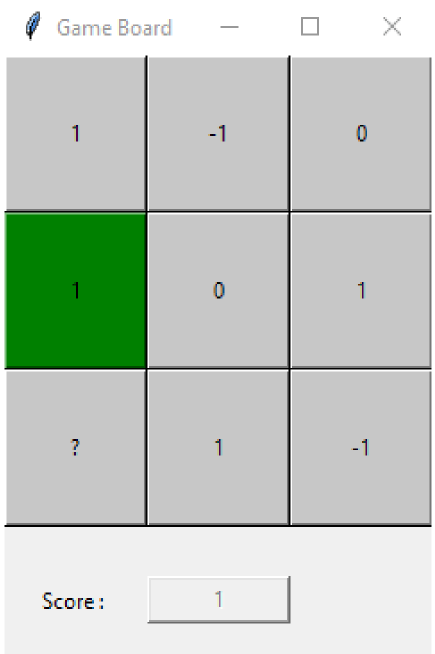
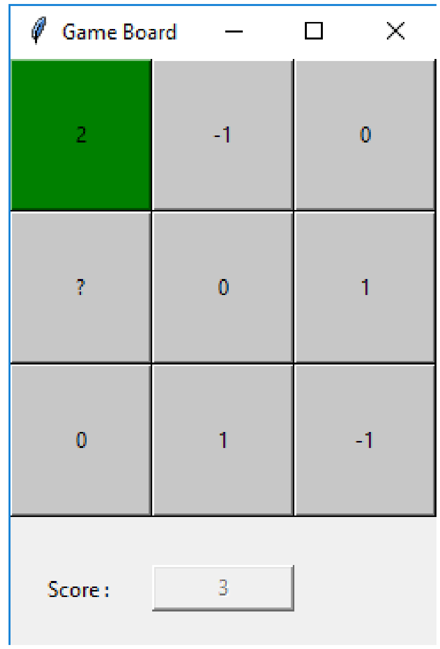


Figure 9: Initial state of the game

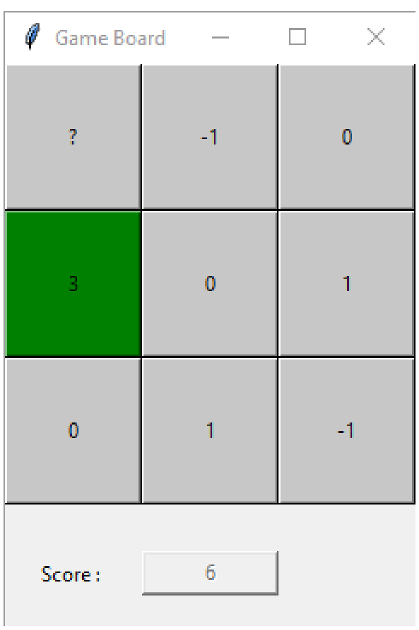
Output



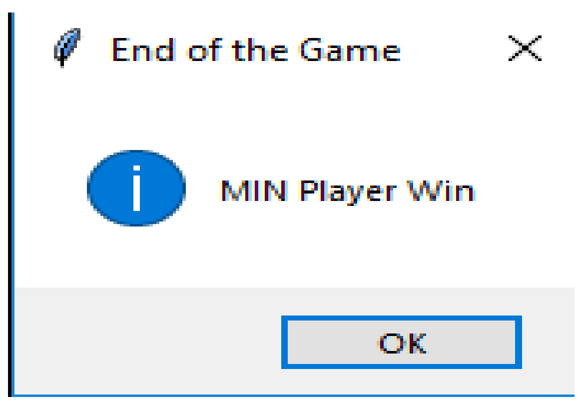
Max Player Move up



Min player generate 1 at previous tile position, then max player moved up again.



Min player generated 1 at previous tile position, then max player moved down.



Max Player cannot get score 10 in 3 steps, so Min player win

Test Case #3

Input:

1- Minimal Level Goal (score) = 7
2- Maximum number of moves = 5

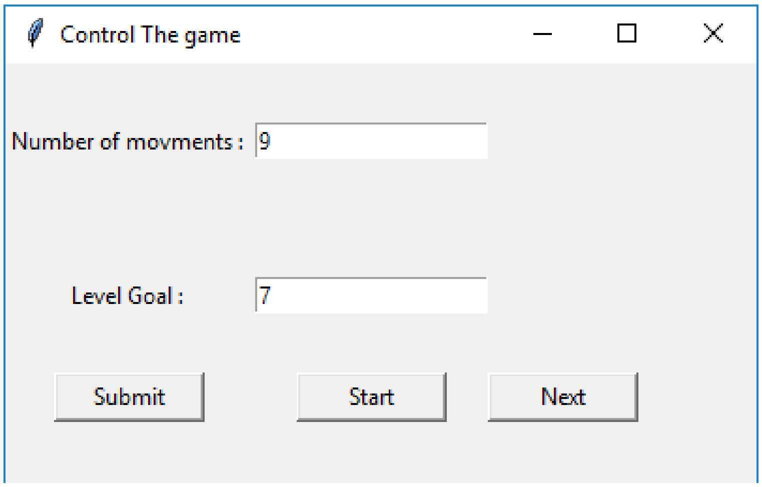


Figure 11: Inputs in GUI form

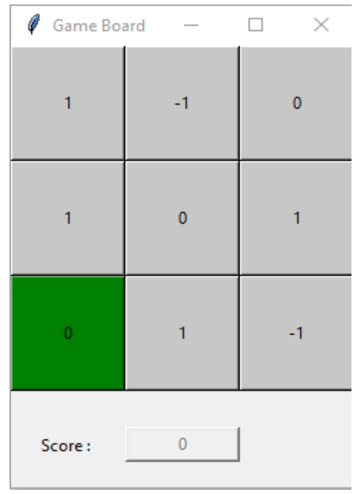
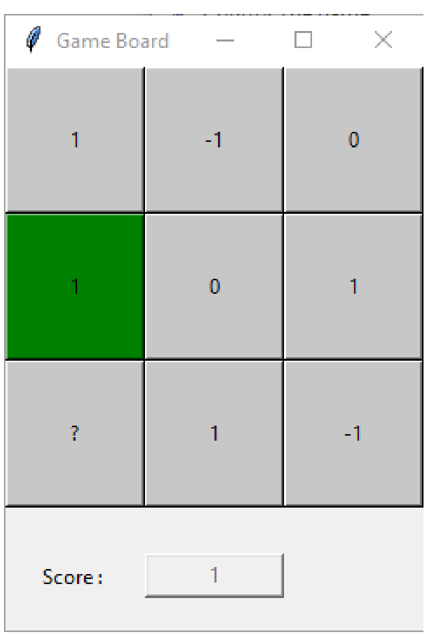
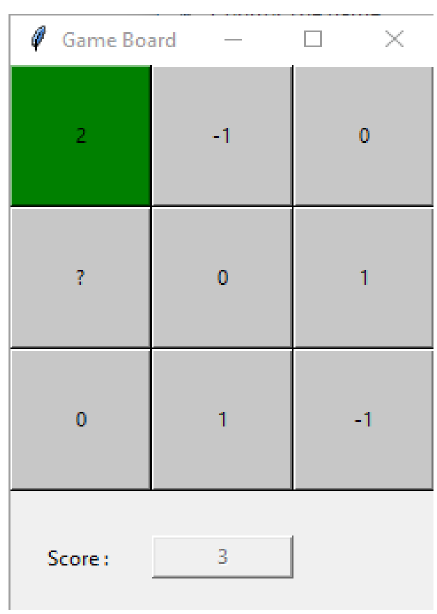


Figure 11 : Initial state of the game

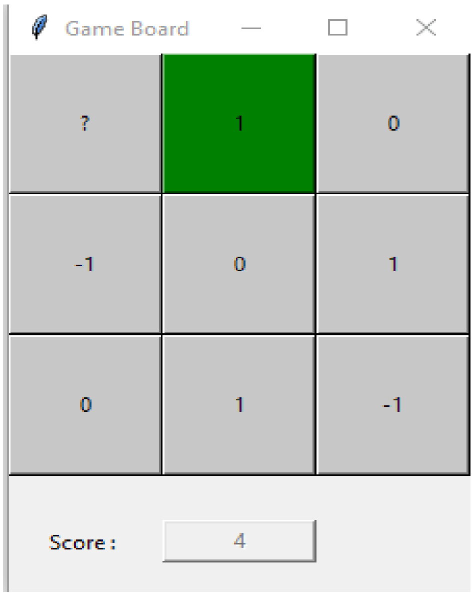
Output



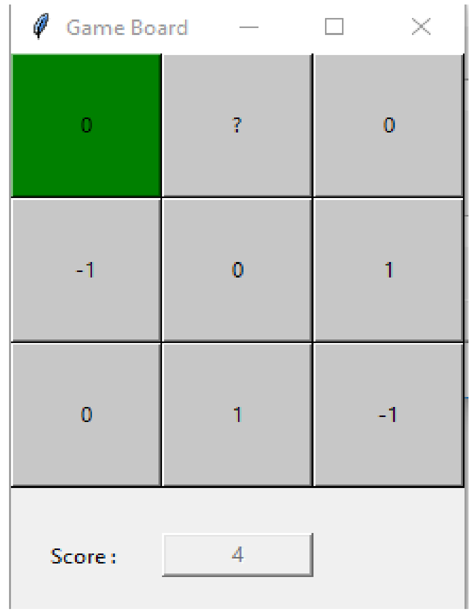
Max Player Move up



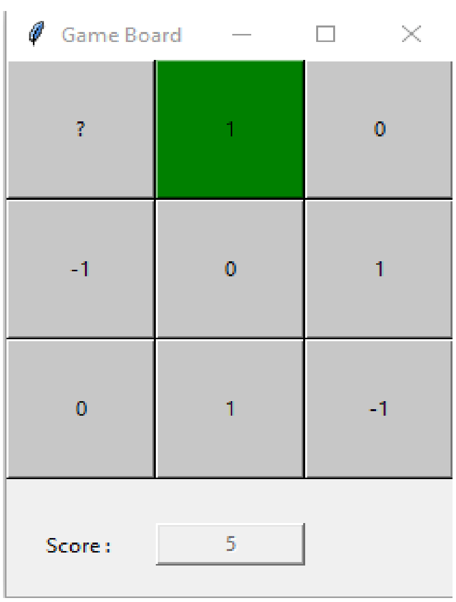
Min player generate 0 at previous tile position, then max player moved up again.



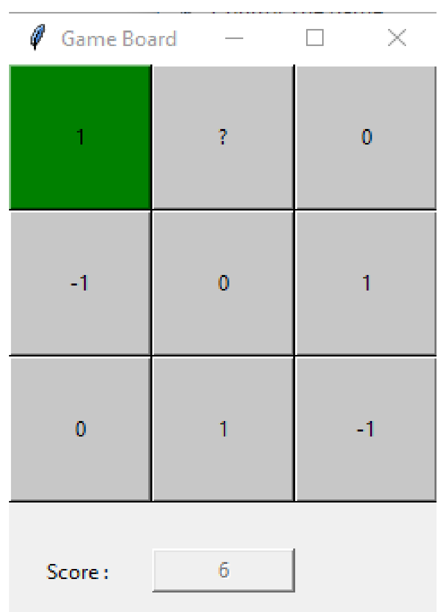
Min player generate -1 at previous tile position, then max player moved right.



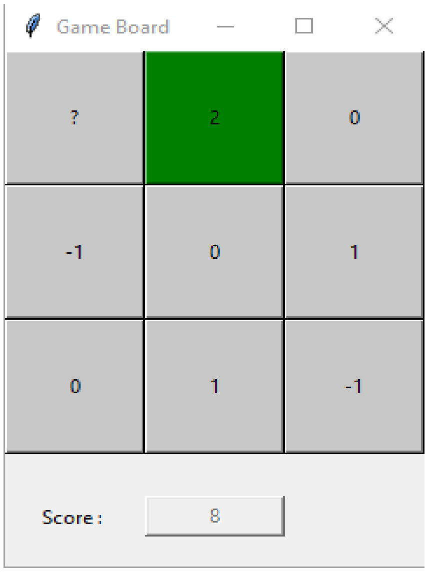
Min player generate -1 at previous tile position, then max player moved left



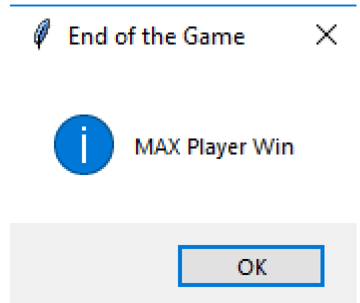
Min player generate 1 at previous tile position, then max player moved right



Min player generate 0 at previous tile position, then max player moved left



Min player generate 1 at previous tile position, then max player moved right.



Max Player get Score equals 8 in 7 steps.

Test Case #4

Input:

1- Minimal Level Goal (score) = 7
2- Maximum number of moves = 5

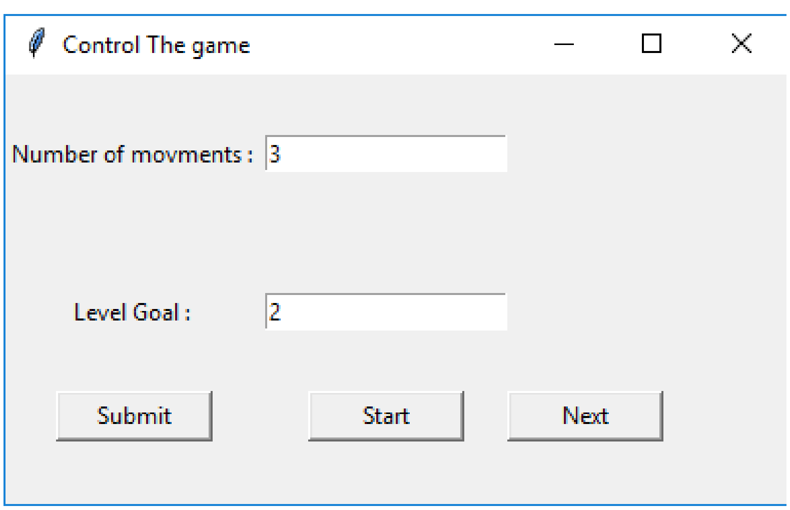


Figure 13: Inputs in GUI form

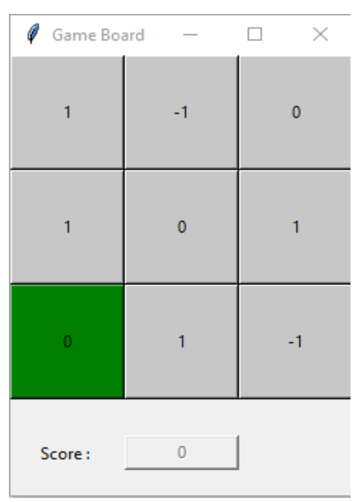
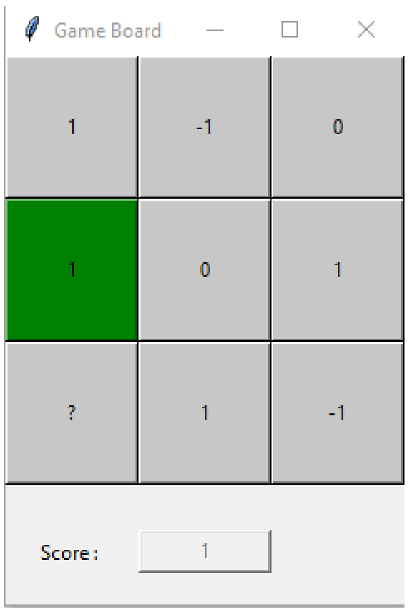
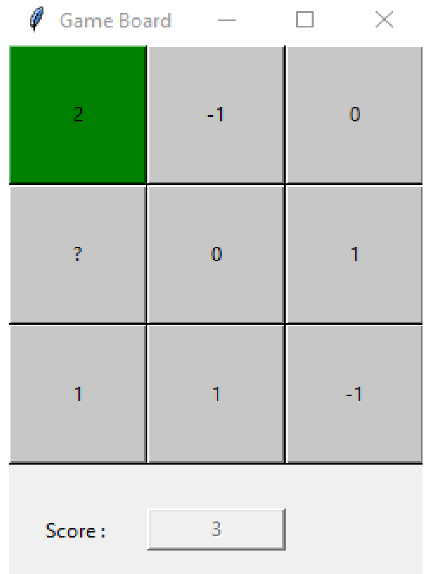


Figure 13 : Initial state of the game

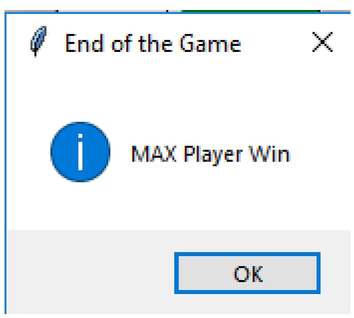
Output



Max Player Move up



Min player generate 1 at previous tile position, then max player moved up again.



Max Player get Score equal 3 in 2 steps.