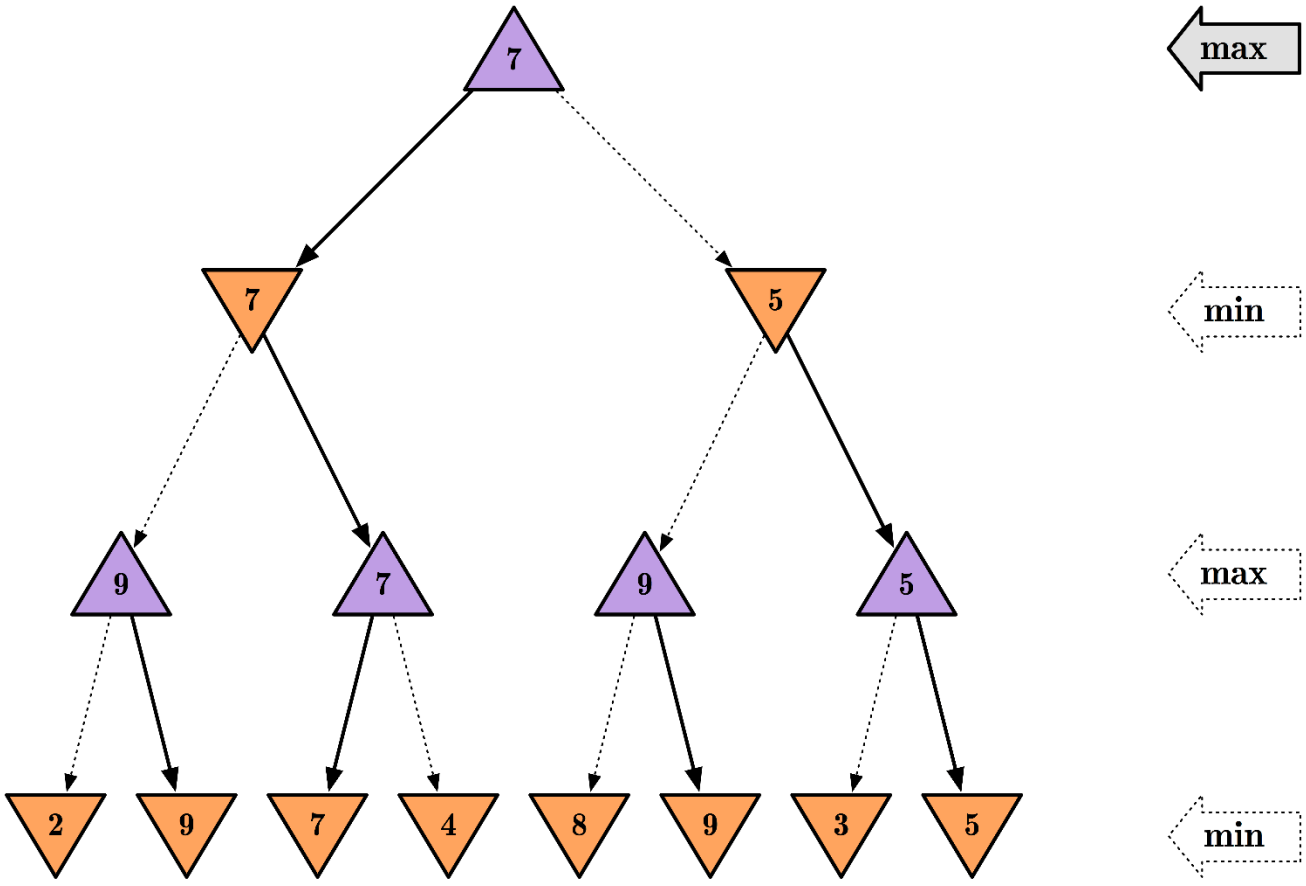
Tic-Tac-Toe

Algorithms Review

Before you begin, review the lecture slides and the book on **adversarial search**. Is this a zero-sum game? What is the minimax principle? We will create a "Player AI" to play **as if** the computer is completely adversarial. In particular, we will employ the **minimax algorithm** in this assignment.

Remember, in game-playing we generally pick a **strategy** to employ. With the minimax algorithm, the strategy assumes that the computer opponent is perfect in minimizing the player's outcome. Whether or not the opponent is actually perfect in doing so is another question. As a general principle, how far the actual opponent's actual behavior deviates from the assumption certainly affects how well the AI performs [**1**]. However, you will see that this strategy works well in this game. In this assignment, we will implement and optimize the minimax algorithm.



[**1**] In the case of a simple game of tic-tac-toe, it is useful to employ the minimax algorithm, which assumes that the opponent is a perfect "minimizing" agent. In practice, however, we may encounter a **sub-par opponent** that makes silly moves. When this happens, the algorithm's assumption deviates from the actual opponent's behavior. In this case, it still leads to the desired outcome of never losing. However, if the deviation

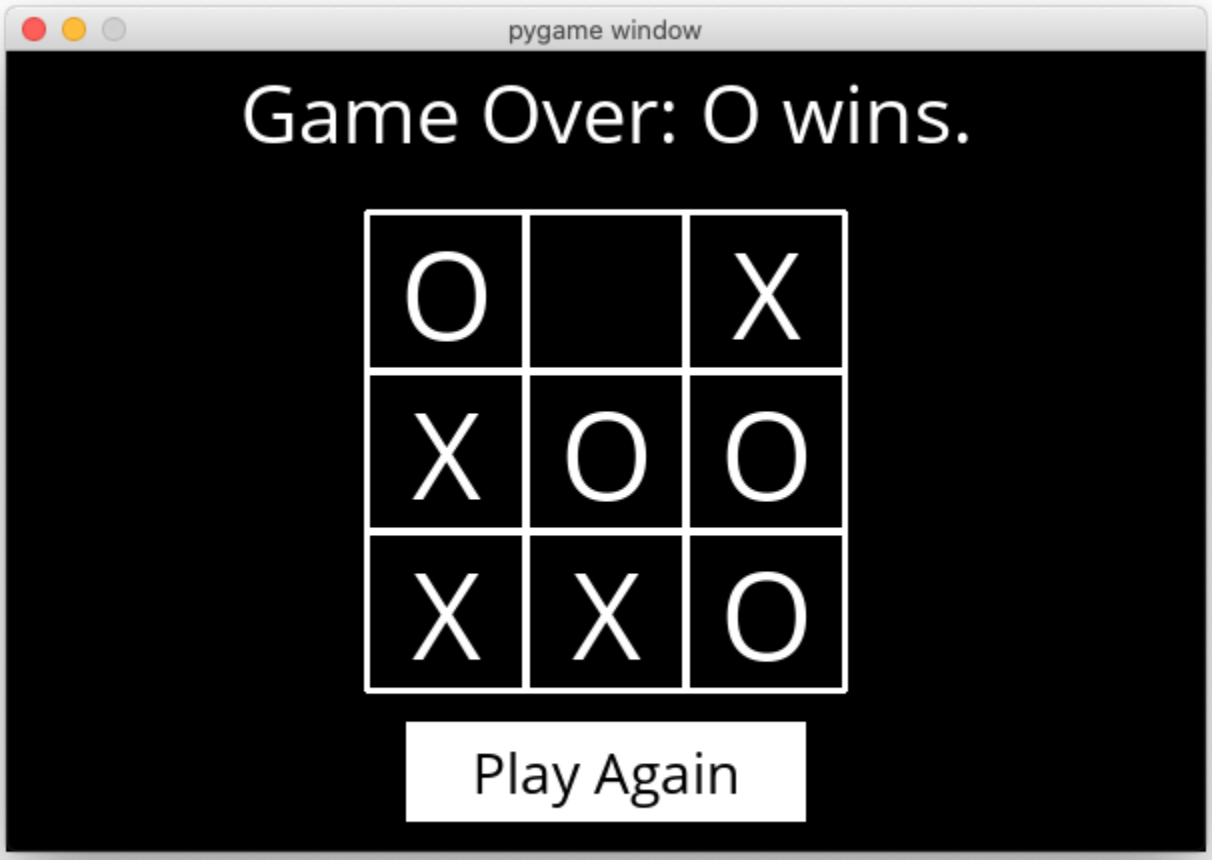
goes the other way (e.g. suppose we employ a "maximax" algorithm that assumes that the opponent wants us to win), then the outcome would certainly be different.

Description

Using Minimax, implement an AI to play Tic-Tac-Toe optimally.

Introduction

In the directory for the project, run `pip3 install -r requirements.txt` to install the required Python package (`pygame`) for this project.



Understanding the Environment

There are two main files in this project:

- runner.py **(implemented for you):** contains all of the code to run the graphical interface for the game.
- tictactoe.py **(your task):** contains all of the logic for playing the game, and for making optimal moves.

Once you've completed all the required functions in **tictactoe.py**, you should be able to run python runner.py to play against your AI!

In **tictactoe.py** we define three variables: X, O, and EMPTY, to represent possible moves of the board.

The function **initial_state** returns the starting state of the board. For this problem, we've chosen to represent the board as a list of three lists (representing the three rows of the board), where each internal list contains three values that are either X, O, or EMPTY. What follows are functions that we've left up to you to implement!

Task Specification

Complete the implementations of player, actions, result, winner, terminal, utility, and minimax.

- The player function should take a board state as input, and return which player's turn it is (either X or O).
  - In the initial game state, X gets the first move. Subsequently, the player alternates with each additional move.
  - Any return value is acceptable if a terminal board is provided as input (i.e., the game is already over).
- The actions function should return a set of all of the possible actions that can be taken on a given board.
  - Each action should be represented as a tuple (i, j) where i corresponds to the row of the move (0, 1, or 2) and j corresponds to which cell in the row corresponds to the move (also 0, 1, or 2).
  - Possible moves are any cells on the board that do not already have an X or an O in them.
  - Any return value is acceptable if a terminal board is provided as input.
- The result function takes a board and an action as input, and should return a new board state, without modifying the original board.
  - If action is not a valid action for the board, your program should raise an exception.
  - The returned board state should be the board that would result from taking the original input board, and letting the player whose turn it is make their move at the cell indicated by the input action.
  - Importantly, the original board should be left unmodified: since Minimax will ultimately require considering many different board states during its computation. This means that simply updating a cell in board itself is not a correct implementation of the result function. You'll likely want to make a deep copy of the board first before making any changes.
- The winner function should accept a board as input, and return the winner of the board if there is one.
  - If the X player has won the game, your function should return X. If the O player has won the game, your function should return O.
  - One can win the game with three of their moves in a row horizontally, vertically, or diagonally.
  - You may assume that there will be at most one winner (that is, no board will ever have both players with three-in-a-row, since that would be an invalid board state).

    - If there is no winner of the game (either because the game is in progress, or because it ended in a tie), the function should return `None`.
- The `terminal` function should accept a `board` as input, and return a boolean value indicating whether the game is over.
    - If the game is over, either because someone has won the game or because all cells have been filled without anyone winning, the function should return `True`.
    - Otherwise, the function should return `False` if the game is still in progress.
- The `utility` function should accept a terminal `board` as input and output the utility of the board.
    - If X has won the game, the utility is `1`. If O has won the game, the utility is `-1`. If the game has ended in a tie, the utility is `0`.
    - You may assume `utility` will only be called on a `board` if `terminal(board)` is `True`.
- The `minimax` function should take a `board` as input, and return the optimal move for the player to move on that board.
    - The move returned should be the optimal action `(i, j)` that is one of the allowable actions on the board. If multiple moves are equally optimal, any of those moves is acceptable.
    - If the `board` is a terminal board, the `minimax` function should return `None`.

For all functions that accept a `board` as input, you may assume that it is a valid board (namely, that it is a list that contains three rows, each with three values of either `X`, `O`, or `EMPTY`). You should not modify the function declarations (the order or number of arguments to each function) provided.

Once all functions are implemented correctly, you should be able to run `python runner.py` and play against your AI. And, since Tic-Tac-Toe is a tie given optimal play by both sides, you should never be able to beat the AI (though if you don't play optimally as well, it may beat you!)

Implementation Hints

- If you'd like to test your functions in a different Python file, you can import them with lines like **`from tictactoe import initial_state`**.
- You're welcome to add additional helper functions to **`tictactoe.py`**, provided that their names do not collide with function or variable names already in the module.
- Alpha-beta pruning is optional, but may make your AI run more efficiently!

Peer-grading Guidelines

Run `python runner.py` and play around **5** games against the AI of your peer student. Try to play to beat the AI:

1- If all of the games resulted in a draw or if the AI beat you on all of them, give full points.
2- If you were able to beat the AI on some games but not others, give half points.
3- If you won all games, give zero points.

Note: consider playing against your peer student's AI with output produced by your own AI.