COMPSCI 383 – Fall 2022

Homework 2 Coding

Due Wednesday, October 19th at 11:59pm ET

You are encouraged to discuss the assignment in general with your classmates, and may optionally collaborate with one other student. If you choose to do so, you must indicate with whom you worked. Multiple teams (or non-partnered students) submitting the same code will be considered plagiarism.

Code must be written in a reasonably current version of Python (>3.8), and be executable from a Unix command line. You are free to use Python's standard modules for data structures and utilities, as well as the pandas, scipy, and numpy modules. Do not use any modules or libraries that implement Minimax or Alpha-Beta pruning.

Greetings, Professor Falken. Shall we play a game?

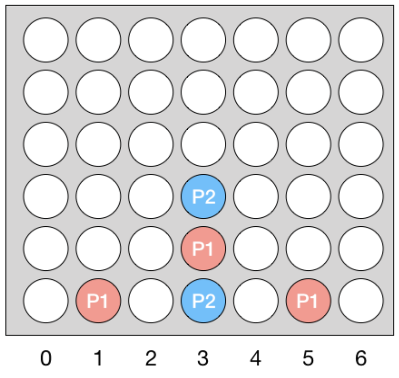
For this assignment, you will implement a game playing agent for a ***modified*** version of "Connect 4", a vertical tic-tac-toe-like game. Your agent will be able to play against humans or other automated agents, and we will pit them against each other in a class-wide tournament.

Classic Connect 4

In the basic game, the board is made up of six rows and seven columns, which are filled with tokens. Players take turns dropping tokens into vertical columns until one player has 4-in-a-row (vertically, horizontally, or diagonally) or the board is full.

The board shown on the right illustrates a game in progress after the following five moves have been made:

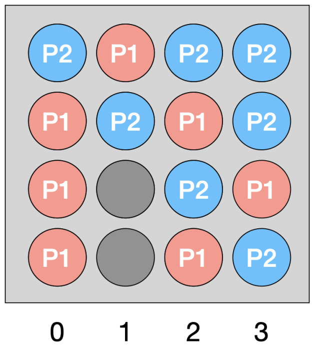
Player 1 to column 1
Player 2 to column 3
Player 1 to column 3
Player 2 to column 3
Player 1 to column 5



You can play an online version here.

Connect 383

Our variant, Connect 383, will have three main differences from the basic game. First, we will not be limited to 6x7 boards. Secondly, games may start with one or more "obstacle" pieces already on the board which do not belong to either player. Lastly, play will always continue until the board is completely full (even after a player has achieved 4-in-a-row), at which point scores for each player will be calculated.



Points are awarded as follows: for each run of length three or greater, the player will receive points equal to the square of the length of that run. For example, 3-in-a-row is worth 9 points, 4-in-a-row 16, 5-in-a-row 25, etc.

For the 4x4 board on the left, Player 1 scores 18 points (one vertical and one diagonal 3-in-a-row), while Player 2 receives 16 points (one diagonal 4-in-a-row). The two obstacles (gray) don't contribute to either player's score.

When calculating the value of different moves, your game-playing agent will use the scores as utility values for the terminal games states, and seek to maximize the delta between its score and that of its opponent using the Minimax algorithm.

Implementing Adversarial Search for Connect 383

Step 0: Running the Game

We've created a Python module that will handle representing the game state and manage play called `connect383.py`. *You do not need to change any of the code in this file*, but will need to understand how it works to program your game playing agent.

To play a game, you run `connect383.py` from a command line (or within an IDE) and supply it with arguments that determine the parameters of the game and which type of agents are playing. The required arguments are, in order: `play1`, `play2`, and `brd`.

The first two arguments specify the agent type for Player 1 and Player 2, respectively. Their value should be one of { *random*, *human*, *mini*, *prune*, *lookN*, or *altN* }, where *N* is an integer specifying the depth limit for lookahead agents.

The third argument specifies the board type to play on. Its value can be a tag associated with a a predefined board in `boards.py`, or can take the form *RxC* where *R* and *C* are integers defining the number of rows and columns, respectively.

For example, to play against a random computer agent on a 4x5 board, you would type:

```
> python connect383.py random human 4x5
```

To pit a Minimax agent against a depth-limited heuristic agent (with a lookahead limit of 3) on a the board labeled “tournament” you would enter:

```
> python connect383.py mini look3 tournament
```

Try playing against a partner or random opponent to make sure you understand the game. Later, you’ll be programming a bot that will probably beat you.

Step 1: Implement Minimax

Once you’re comfortable running the game, it’s time to implement your computer agent. The `agents.py` file contains code for different agent types, each defined by its own class. Your task at this step is to implement the `minimax()` method for the `MinimaxAgent` class. Given a game state, `minimax()` should recursively traverse the game tree, eventually determining the value of that state for use in the `get_move()` method. The utility of the *terminal* states is calculated using the `GameState.utility()` method, with positive numbers corresponding to Player 1 outscoring Player 2, and negative numbers for Player 2 winning.

Step 2. Testing Your Minimax Code

To facilitate debugging and allow you to test your code for correctness, you should create some game states in `boards.py` with most of the pieces already in place and compare the Minimax values calculated in your code with values that you calculate by hand. To do this, you’ll need to instrument your code with `print()` statements or use a debugger.

N.B.: Assuming you don’t have a quantum supercomputer at your disposal, you will not be able to run Minimax on a full-sized (6x7) or larger board, as the game tree will be much too big (over 13 decillion game states). Instead, you should test your Minimax on much smaller boards, where you can easily calculate the value of the states by hand and verify correctness.

Step 3: Create an Evaluation Heuristic

In order to be able to play on larger boards, your computer agent must be able to invoke a heuristic evaluation function when Minimax reaches a certain depth limit. The code for this should be put in `MinimaxLookaheadAgent.evaluation()` and get called by `MinimaxLookaheadAgent.minimax()` in accordance with the `depth_limit` parameter given to the constructor. Note that if the depth is larger than the number of total moves for a game, this agent should behave identically to the `MinimaxAgent`.

The evaluation will contain the “brains” of your Connect 383 bot, and the quality of your utility estimation is what will differentiate your agent from others. Your method must compute a utility based on static features of the game state, and should not generate new states in its calculations (we will check for this!).

The evaluation function should return an estimated utility value (positive or negative) for any game state based on features that you construct. For example, you might count all the open-ended 2-in-a-rows for each player for a given state, and return the difference. To make your life easier, we've added some convenience accessors to the GameState class (`get_rows()`, `get_cols()`, and `get_diags()`). Note that you cannot simply duplicate the `score()` method found in `connect383.py` for use as an evaluation function.

To run your heuristic code using the evaluation function, you must supply a depth limit as part of the agent tag:

```
> python connect383.py random look4 6x7
```

Step 4: Alpha-Beta Pruning

Finally, you will create a computer agent that uses alpha-beta pruning within the Minimax traversal by implementing `MinimaxPruneAgent.minimax()` in `agents.py`. Whenever possible, this implementation of Minimax should ignore parts of the tree that don't need to be traversed (see the AIMA Sec. 5.3 and the slides and videos from class for examples). Once again, you should instrument your code to communicate which branches of the search are being pruned and test on simple examples.

The Tournament

We will be pitting all of the submitted computer agent bots against each other in a round-robin tournament, and will be publishing a top-twenty ranking. Note that since Minimax is optimal, your agents can only be differentiated when using a depth limit – your "secret sauce" will be in your implementation of the `evaluation()` method. For the tournament, agents will play on a 6x7 board with a lookahead depth limit of 3. Agents that come in the top 3 will receive extra credit, a can of Moxie, and unimaginable prestige.

Additional Notes

See the comments in the code for more details. Make sure that you *do not change the API* (number of arguments or return values) for any of the above methods, as we'll be calling them directly to evaluate your code.

There is a stub for an additional class `AltMinimaxLookaheadAgent` in `agents.py`. You are not required to implement this class, but may find it useful for testing and improving your heuristic agent's evaluation function. This class will be used if you specify player type *alt* on the command line. For example, once you get a lookahead agent working with a simple evaluation function, you might try adding improvements to the alternate class, and then testing them against each other:

```
> python connect383.py look3 alt3 5x6
```

Additionally, the `connect383.GameState` class does some bookkeeping to help you test your pruning code. Specifically, it counts the number states generated by each player (see the code for more details). Pay attention to this output when testing your lookahead limit and pruning code.

You should test your agent on a variety of boards to ensure that it's functioning correctly, and add test cases to `boards.py`.

We will be checking your individual method implementations, as well as verifying that your agent can successfully beat some simple agents. Note that your solutions will only be tested on well-formed boards – we are not going to feed your program incorrectly formatted game states.

What to Submit

You should submit your versions of `agents.py` and `boards.py`, along with a `readme.txt` that contains:

- Your name(s)
- The name of your tournament bot
- A short description of your thinking and the design behind your `evaluation()` function, along with some thoughts on its effectiveness
- Short descriptions of the cases that any states in `boards.py` are meant to test
- Any noteworthy resources you consulted in doing your project
- Notes or warnings about what you got working, what is partially working, and what is broken