Assignment 4: Game-Playing Agents

CSE 415: Introduction to Artificial Intelligence
The University of Washington, Seattle, Winter 2019

This continues the search theme of Assignments 2 and 3 and has the same associated reading: Chapter 5 (Search) of *Introduction to Artificial Intelligence Using Python*.

Due Monday, February 11 via Catalyst CollectIt at 11:59 PM.

Overview

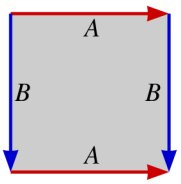
In this assignment we explore two-person, zero-sum game playing using a family of games called "Toro-Tile Straight". Here we put our agents into competition, adding lookahead (with the Minimax technique) and pruning (with the alpha-beta method) to the search. The assignment has two parts: creating your agent and engaging your agent in a first round of competitive play.

PART I: Creating a Game-Playing Agent (80 points).

Create a program implementing an agent that can participate in a game of Toro-Tile Straight (defined below). Your program should consist of a single file, with a name of the form [UWNetID]_TTS_agent.py, where [UWNetID] is your own UWNetID. For example, my file would have tanimoto_TTS_agent.py for its name.

Although you create one Python file for this assignment, it will contain a collection of specific functions for playing games of "Toro-Tile Straight". We define a Toro-Tile Straight game as a kind of generalized K-in-a-Row with the following features:

- (a) Just as in a game like Othello, there are two players: one plays White and the other plays Black;
- (b) the board is rectangular, but is not necessarily 3 by 3; it is mRows by nColumns, where these dimensions are chosen by the Game Master (referee) at the beginning of the game;
- (c) a player wins by getting K in a row, where K is not necessarily 3; K can be any integer greater than 1;
- (d) the topology of the board is *toroidal*. This means that the left edge and right edge of the board can be considered equivalent, and the top and bottom edges can be considered equivalent. If a piece is placed in the left column of the array, then moving one unit in the West direction is defined to "wrap around" to the rightmost column (but same row). Similarly, moving South from the bottom row, wraps around to the top of the same column.



The toroidal topology is illustrated above, with line segments A unified, as well as line

segments B unified. These are at the outer boundaries of the array.

- (e) there can be "forbidden squares" on the board; these are chosen at the beginning of the game by the Game Master; a square on the board that is available is represented by a blank, whereas a forbidden square is represented by a dash "-" ;
- (f) there can be "handicaps" in the initial state, meaning that some White and/or Black tiles can be set up on the board by the Game Master in order either to influence the succeeding play or to change the balance of advantage and disadvantage to the players.

You can see a full transcript of a sample game here. The two agents that played this game are very dumb, but they followed the rules. The code for each of these agents is part of the starter code. You can use this code to organize the required functions, adding to them to create a good player.

It will be essential that your program use the provided representation of a game state, so that it is compatible with all the other A4 game agents developed in the class.

Your program should be designed to anticipate time limits on moves. There are two aspects to this: (1) use iterative deepening search, and (2) poll a clock frequently in order to return a move before time runs out.

In addition to being able to play the game, your program should make an utterance --- that is, a comment in each move, as if participating in a dialog. Ideally, your program would have a well-defined "personality". Some examples of possible personalities are these: friendly; harmless joker; blunt joker; paranoid; wisecracker; sage; geek; wimp; competitive freak; fortune-teller (based on the state of the game). The personality will be revealed during games via the "utterances" made by the program. (For more details, see the description of the take_a_turn function below.)

Your program must include the following functions. You can have helper functions if you like. Please keep all the functions required by your player in just one Python file that follows the naming convention mentioned earlier. For example, my player would be in a file tanimoto_TTS_agent.py. This will facilitate your player's being part of the class tournament.

1. **get_ready(initial_state, k, what_side_i_play, opponent_moniker).** This function takes four arguments and it should "remember" these values for the game that is about to be played. (However, if your agent is in a match with itself say for testing purposes, this get_ready method will be called twice. In this case, be careful not to let the agent assume it is playing 'B' on both turns.)

   The first parameter, **initial_state**, allows your agent to figure out any needed properties of the game board before the playing begins. It is a legal game state that can be used by your player, for example, to determine the dimensions of the board, the locations of forbidden squares, and even the locations of any handicap items.

   The second parameter, **k**, is the number of pieces in a row (or column or diagonal) needed to win the game.

   The parameter **what_side_i_play** is 'W' if your agent will play as White; it is 'B' if your agent will play Black.

   The parameter **opponent_moniker** allows your utterance-generation mechanism to refer to the opponent by name, from time to time, if desired.

Note that your program does not really have to do much at all when its get_ready method is called. The main thing it should do is return "OK". However, the **get_ready** function offers your agent an opportunity to do any initialization of tables or other structures without the "clock running." This could be used to do any preprocessing related to, say, speeding up move generation, e.g., finding out which of the four directions a win can occur from a particular square -- a list of all the squares on the board where such a winning line could actually start. Having these lists can save time in your static evaluation function.

2. **who_am_i()**. This function will return a multiline string that introduces your player, giving its full name (you get to make that up), the name and UWNetID of its creator (you), and some words to describe its character.

3. **moniker()**. This function should return a short version of the playing agent's name (16 characters or fewer). This name will be used to identify the player's moves in game transcripts.

4. **take_turn(current_state, opponents_utterance, time_limit=10)**. This is probably your most important function. Unlike the parameterized_minimax function described below, this method should always use your most advanced search techniques (while still respecting the time limit) to make your agent as competitive as possible. It should return a list of the form [[move, new_state], new_utterance].

   The move is a data item describing the chosen move.
   The new_state is the result of making the move from the given current_state. It must be a complete state and not just a board.
   The opponents_utterance argument is a string representing a remark from the opponent on its last move.
   The time_limit represents the number of seconds available for computing and returning the move.

   The new_utterance to be returned must be a string. During a game, the strings from your agent and its opponent comprise a dialog. Your agent must make "interesting" utterances, described in more detail in the feature section.

5. **parameterized_minimax(**keywordargs)**. This method will let both you and the graders execute a search under a specific set of conditions without having to set up a full TTS game. You can assume this function will be called after get_ready(), though not during the course of a normal game. This method accepts a set of parameters that determine how the minimax search will run. The possible fields and their default values are listed below:

   - **current_state**=None: This field will be assigned a valid TTS state that should be used as the root node for minimax search that will occur in this method function call.
   - **use_iterative_deepening_and_time**=False: This field is a boolean value that determines if the minimax search should use elastic search methods, namely iterative deepening minimax search and a strict time limit. If this field is true, your search should run until either you run out of time or if your search reaches the max allowed ply (see the next field).
   - **max_ply**=2: This field determines the maximim allowed depth of your minimax search. This should limit the search regardless if iterative deepening is enabled or not.
   - **use_default_move_ordering**=False: If this field is true, you should use a standard move generation method. That method is to list available spots on the board from **left-**

to-right, top-to-bottom. That is, if your board is an empty 2x2 grid, the move generation method should return [upper-left, upper-right, lower-left, lower-right] in that order. This is necessary for us to consistently test your pruning algorithm. If this is set to False then you are free to use whatever move generation method you like to maximize pruning potential.

- **alpha_beta**=False: This field determines if the search should use alpha-beta pruning or not.
- **time_limit**=1.0: This field specifies the time limit (in seconds) your search is under. If timing is not enabled from the use_iterative_deepening_and_time field you can ignore this.
- **use_custom_static_eval_function**=False: This field determines if you should use the basic eval (described below) or your own custom eval function during the search.

When this method ends its search it should return a list of data related to how it executed the search.

a. The static eval value of the current_state as determined by your minimax search
b. The number of states expanded as part of your minimax search
c. The number of static evals performed as part of your minimax search
d. The maximum depth reached as part of the minimax search
e. The number of cutoffs that occurred during the minimax search (0 if alpha-beta was not enabled)

It is important that you implement this function in a manner consistent with the options you are handling, particularly the more advanced features such as alpha-beta pruning. Certain basic features of your code may also be tested using this function, and so you'll want to handle this well, both for testing your own code as you go and to allow any autograder system to award you as many points as possible.

6. **static_eval(state)**. This function will perform a static evaluation of the given state. The value returned should be a number that is high if the state is good for White and low if the state is good for Black. See the MY_TTS_State class provided in the starter code in PlayerSkeleton.py for where to invoke the two required versions of this. Here is a description of these two versions:

   a. basic_static_eval(self): This is probably the very first function you should implement. It must compute the following value accurately (whereas with your custom function, you'll get to design the function to be computed). Depending on the game type, there will be a particular value of K, the number of tiles a player must place in a straight line in order to win. Based on the initial state of the game, there is some number T of possible instances of a line of K tiles that do not involve any forbidden squares. Your function should return C(White, 2) - C(Black, 2). Here C is a count of the number of these lines that have **exactly** this number (here 2) of the specified color of tiles and are otherwise vacant (not blocked). Note that if a line of K tiles has exactly 3 White tiles, it should NOT count in C(White, 2).

Keep in mind that each vacant square on the board is potentially the beginning of 4 different lines of K tiles each, going in 4 of the 8 allowed directions. (We don't want to consider all 8 directions because then we would double count lines, once at the beginning of the line and once at the end.) As stated elsewhere, the lines can wrap around, according to the toroidal topology of the board space. If the game type happened to be K = 3 on a 3x3 board with no forbidden squares, then we would have T=36, because of the nine possible starting squares and the four possible directions, and your basic_static_eval function would potentially examine each of three squares (because K=3) 36 times to see how many of them had exactly 2 Whites, and then do all this again to find out how many of them had exactly 2 Blacks.

(Note: You do not have to implement the function C described above for values that aren't 2, but your basic eval method should work for general values of K. You can assume K ≥ 2. ~~(Note: You do not have to implement the function C described above, e.g., for general K. It was only used above to explain what your basic_static_eval function needs to compute.)~~

An autograder will be checking to make sure your function comes up with the right numbers for various given states.

b. custom_static_eval(self): You get to design this function. You'll want it to perform "better" than the basic function above. Here better could mean any of the following: (a) more accurate assessment of the value of the board, to better inform the choice of the best move, (b) faster to compute, or (c) achieving a better combination of accuracy and efficiency than the basic function. (It might be less efficient, but a lot more accurate, for example.)

   Two motivations for putting some thought into this function are: (i) your agent's ability to play well depends on this function, and (ii) an autograder will likely try comparing your function's values on various states, looking for reasonable changes in value as a function of how good the states are, in terms of likelihood of a win.

Potentially Useful Python Technique

When one of the game master programs calls your take_turn function or a testing program calls your tryout function, you may convert the current_state object into your own derived subclass object as follows, assuming you are using the My_TTS_State class:

```
current_state.__class__ = My_TTS_State
```

Then you will be able to invoke your own methods on it, such as static_eval.

Required Features

The following features must be implemented as part of the functions described above.

1. Minimax search (required). The number of ply to use should either be a parameter (if part of parameterized_minmax) or determined by you according to preference or time limit requirements.

2. Iterative deepening (required). You should start your time-limited algorithm by finding a legal move quickly, and then as time permits, finding better and better moves. When there is no longer enough time to safely compute a better move, then the best move found so far should be returned. You will do this by running your minimax search to deeper and deeper levels. However, note that in the parameterized_minimax function, you'll need to be able to turn the iterative deepening technique on or off, to support discovering the differences it leads to. Also note that the autograder may test for times lower than the default 10 seconds, though you can assume the time limit will never be below 1 second.

3. "Interesting" utterances (required). Although this is required, you may choose either of two options or, for 5 points of extra credit, do both, creating utterances each of which contributes both to the distinctive character of the agent (as in option a) and sensible observations about the game (as in option b). If you are doing both options for the extra credit, then add a comment line near the top of your agent's file such as:

   ```
   # I have implemented both options under Interesting utterances, for the extra credit.
   ```

   - **Option (a)**: program your agent in such a way that it reveals a personality through its utterances. The utterances should not repeat often. Let us say 10 is the minimum number of turns, before one of these utterances can be repeated. Here is an example of this type of utterance: "Although I hate waiting in lines, I'm going to make a nice long one!" (The personality here is one of a joker.)

   - **Option (b)**: Each utterance should report on an actual feature of the state of the game, and you should have either two or three features. Any one remark would only have to use one (or two) of these features. The features should be worked into a reasonably natural-sounding English remark. The feature could be the static value of the new state, or its backed-up (via minimax) value. Or it could the length of the longest line of Ws or Bs on the board and who has it. You are encouraged to make up your own measurable feature of the board that, when reported in the utterance, would be an interesting observation about the state of the game. Here is an example utterance of this type: "This is not going well for me, since the minimax value of this new state is -4.7. Furthermore, I see you have a line of 4, whereas my longest line has only 3."

4. Alpha-beta pruning. Alpha-beta pruning should be implemented as part of your minimax search that happens during take_turn and also as a search option in parameterized_minimax according the algorithm described in lecture.

   This feature will be autograded, in which case the move-generation order will need to be consistent. Your pruning should work with minimax search using the basic eval function and the simple move generation order described above.

PART II: Game Transcript (20 points).

Follow the directions below to produce a transcript of a match between your agent and another student's agent.

Using the timed_tts_game_master.py program to run a Gold Rush match, create a transcript of a game between your agent and the agent of another student in the class. Set up the match so that your agent plays White and your opponent plays Black. Use the following game instance for your

match. For this run, you should set a time limit of 1.00 seconds per move. This can be specified on the command line when you run timed_tts_game_master.py.

Here is the starter code for this assignment

The following is the representation of the initial board in a TTS game we are calling "Gold Rush" in which the objective is to get a (connected) line segment of five tiles. The line may go horizontally, vertically, or diagonally.

```
[[['-',' ',' ','-',' ',' ','-'],
  [' ',' ',' ',' ',' ',' ',' '],
  [' ',' ',' ',' ',' ',' ',' '],
  ['-',' ',' ','-',' ',' ','-'],
  [' ',' ',' ',' ',' ',' ',' '],
  [' ',' ',' ',' ',' ',' ',' '],
  ['-',' ',' ','-',' ',' ','-']], "W"]
```

Note that in the following state, White has just won, because there is a diagonal line of Ws that starts near the lower left corner of the space, and continues up and to the right, wrapping around twice in the toroidal space (once from right to left, and once from top to bottom). With the upper-left square (which happens to be forbidden in this game) at row 0, column 0, we can describe White's winning line as this sequence of locations: [(3,5), (2,6), (1,0), (0, 1), (6, 2)]

```
[[['-','W',' ','-',' ',' ','-'],
  ['W',' ',' ',' ',' ',' ','B'],
  [' ',' ',' ',' ','B','B','W'],
  ['-',' ',' ','-',' ','W','-'],
  [' ',' ',' ',' ',' ',' ',' '],
  [' ',' ','B',' ',' ',' ',' '],
  ['-',' ','W','-',' ',' ','-']], "B"]
```

It is not required that the line of tiles involve the toroidal wraparound. Five in a line somewhere near the middle of the board could also win, for example. However, the wraparound feature can often help to open up many more possibilities for winning.

The timed_tts_game_master program will automatically generate an HTML file containing a formatted game transcript of your game. Turn in that HTML file.

Competition Option

You can earn extra credit by having your agent participate in a competition. To enter the competition, first your agent must qualify, and then you submit your evidence of qualification. For your agent to qualify, you must submit game transcripts for two games that meet the following criteria.

1. Each game must be between your agent and a different opponent.
2. Your agent must be the winner of each of these two games.
3. The games must involve a version of Toro-Tile Straight in which (a) K is at least 5 and the board is at least 7 by 7, but it can be bigger if you wish. (I.e., you may use the Whites_Challenge_Game_Type or the Gold_Rush_Game_Type).

   If you submit two game transcript files, then we will assume that you are saying that your agent has won both games, and it therefore qualifies for the competition.

If you enter your agent and it does qualify, you will automatically get 5 more points of extra credit, even if your agent doesn't win any more games. If your agent is a finalist (one of the top 20 percent

of the qualifying contestants), you'll get 5 more points of extra credit. Finally, if your agent is the overall winner, you'll receive five additional points for a total of 15 points for participating in and winning the competition.

What to Turn In

Turn in at least one Python file (the one for your agent). If you have created one or two new Python files that your agent needs to import, include those as well (named properly). Do not turn in any of the starter code files. Turn in either one or two game files (Two if your agent has qualified and you are entering it in the competition.) The game files are the HTML files that are automatically created when you match up your player with the opponent.

Updates and Corrections:

Feb. 4 at 2:38 PM: the requirement for function C was modified (see changes to the spec in red). If necessary, additional updates and corrections will be posted here and/or mentioned in class, or Piazza.