Artificial Intelligence Nanodegree
Project 3: Build an Adversarial Game Playing Agent
By Taimur Zahid

Variables:

1. Total Rounds = 10
2. Depth = 1, 3, 7, 10
3. Fair Match = True, False
4. Time limit = 150, 300, 600, and 900 milliseconds
5. Opponent = Random, Greedy, Mini-max, Self

Greedy Agent:

Fair Match with a Greedy Opponent and Time Limit 150 milliseconds:

python run_match.py -f -r 10 -o GREEDY -t 150

Depth = 1:

Running 20 games:

+---++---++--+----+-

Running 20 games:

---+-+-+-++--+----+-

Your agent won 35.0% of matches against Greedy Agent

Depth = 3:

Running 20 games:

++----++++-+--+++-+-

Running 20 games:

-+-+--+-++-++-++--++

Your agent won 55.0% of matches against Greedy Agent

Depth = 7:

Running 20 games:

-++---+-++++-++-++-+

Running 20 games:

-++---+++++++++--+-+

Your agent won 62.5% of matches against Greedy Agent

Depth = 10:

Running 20 games:

-+---++++++-+--+++++

Running 20 games:

-+-+-+++-++++--+-+++

Your agent won 65.0% of matches against Greedy Agent

Fair Match with a Greedy Opponent and Time Limit 300 milliseconds:

python run_match.py -f -r 10 -o GREEDY -t 300

Depth = 1:

Running 20 games:

+++-+++-+----+++++--

Running 20 games:

+++++++-----++++++-+

Your agent won 65.0% of matches against Greedy Agent

Depth = 3:
Running 20 games:
+++----+++--++-+++-+
Running 20 games:
++++---+++-+++--++-+
Your agent won 62.5% of matches against Greedy Agent

Depth = 7:
Running 20 games:
---+++++---+++---+--
Running 20 games:
+----++-+----+--++--
Your agent won 40.0% of matches against Greedy Agent

Depth = 10:
Running 20 games:
-++++----+----+-+-++
Running 20 games:
++++-----+--+-+-+-++
Your agent won 47.5% of matches against Greedy Agent

Fair Match with a Greedy Opponent and Time Limit 600 milliseconds:
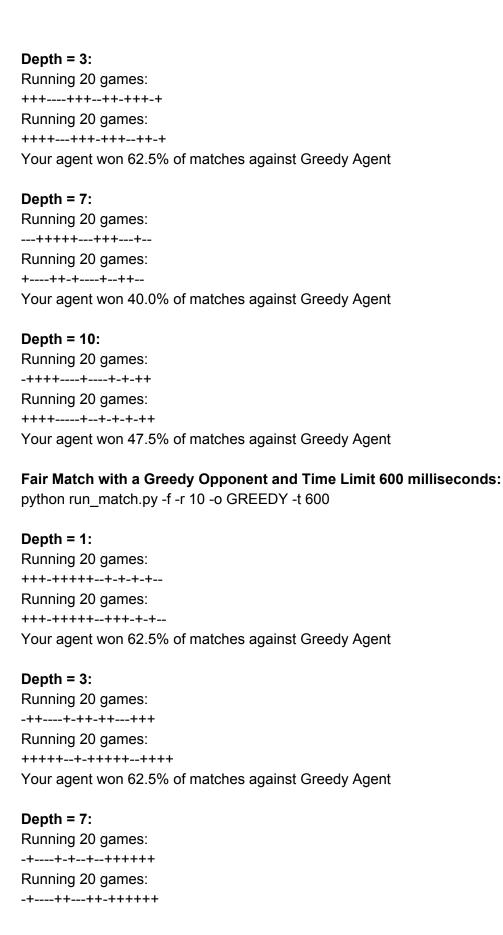python run_match.py -f -r 10 -o GREEDY -t 600

Depth = 1:
Running 20 games:
+++-+++++--+-+-+-+--
Running 20 games:
+++-+++++--+++-+-+--
Your agent won 62.5% of matches against Greedy Agent

Depth = 3:
Running 20 games:
-++----+-++-++---+++
Running 20 games:
+++++--+-+++++--++++
Your agent won 62.5% of matches against Greedy Agent

Depth = 7:
Running 20 games:
-+----+-+--+--++++++
Running 20 games:
-+----++---++-++++++

Your agent won 52.5% of matches against Greedy Agent

Depth = 10:
Running 20 games:
-++---+--+--++--+-++
Running 20 games:
++++--+--+-+++-+--+-
Your agent won 50.0% of matches against Greedy Agent

Fair Match with a Greedy Opponent and Time Limit 900 milliseconds:
python run_match.py -f -r 10 -o GREEDY -t 900

Depth = 1:
Running 20 games:
+----++-+----++++-++
Running 20 games:
---++++-+--++++---+-
Your agent won 50.0% of matches against Greedy Agent

Depth = 3:
Running 20 games:
+--+-++++-+++----+-
Running 20 games:
+---++++--+++--+--+-
Your agent won 50.0% of matches against Greedy Agent

Depth = 7:
Running 20 games:
++---+-++-+-+++-++-+
Running 20 games:
-+-+++-+--+--+++++-+
Your agent won 60.0% of matches against Greedy Agent

Depth = 10:
Running 20 games:
-++++-+-+-++---++---
Running 20 games:
+++++-+++-+-----+---
Your agent won 50.0% of matches against Greedy Agent

Unfair Match with a Greedy Opponent and Time Limit 150 milliseconds:
python run_match.py -r 10 -o GREEDY -t 150

Depth = 1:
Running 20 games:
-+++-+--+++++++-+++
Your agent won 75.0% of matches against Greedy Agent

Depth = 3:
Running 20 games:
--++++--++-+-++-+-++
Your agent won 60.0% of matches against Greedy Agent

Depth = 7:
Running 20 games:
-++------+++--++-+++
Your agent won 50.0% of matches against Greedy Agent

Depth = 10:
Running 20 games:
+++++-+-++---+--+---
Your agent won 50.0% of matches against Greedy Agent

Unfair Match with a Greedy Opponent and Time Limit 300 milliseconds:
python run_match.py -r 10 -o GREEDY -t 300

Depth = 1:
Running 20 games:
+++-+-++-++++-++++-+
Your agent won 75.0% of matches against Greedy Agent

Depth = 3:
Running 20 games:
++-+++-+----++-+-+++
Your agent won 60.0% of matches against Greedy Agent

Depth = 7:
Running 20 games:
-++-++---+--+--+-+--
Your agent won 40.0% of matches against Greedy Agent

Depth = 10:
Running 20 games:
+--++-+-+--++-+--+--
Your agent won 45.0% of matches against Greedy Agent

Unfair Match with a Greedy Opponent and Time Limit 600 milliseconds:
python run_match.py -r 10 -o GREEDY -t 600

Depth = 1:
Running 20 games:
--++-+--+-+++++++++-
Your agent won 65.0% of matches against Greedy Agent

Depth = 3:
Running 20 games:
--+-++-+-+-+--++-+-+
Your agent won 50.0% of matches against Greedy Agent

Depth = 7:
Running 20 games:
+++-----+++++-+-+-+-
Your agent won 55.0% of matches against Greedy Agent

Depth = 10:
Running 20 games:
++---++-++-+----++++
Your agent won 55.0% of matches against Greedy Agent

Unfair Match with a Greedy Opponent and Time Limit 150 milliseconds:
python run_match.py -r 10 -o GREEDY -t 900

Depth = 1:
Running 20 games:
+--++--+++-+----+-++
Your agent won 50.0% of matches against Greedy Agent

Depth = 3:
Running 20 games:
-+++-+--+++-+----+-+
Your agent won 50.0% of matches against Greedy Agent

Depth = 7:
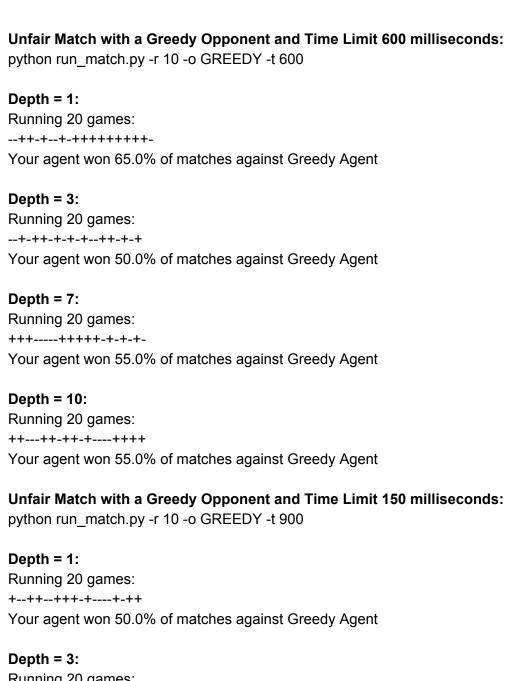Running 20 games:
++-++-++-++-+-+++---
Your agent won 60.0% of matches against Greedy Agent

Depth = 10:
Running 20 games:

+++----+-+-++++---+-
Your agent won 50.0% of matches against Greedy Agent

Mini-Max Agent:

Fair Match with a Minimax Opponent and Time Limit 150 milliseconds:
python run_match.py -f -r 10 -o MINIMAX -t 150

Depth = 1:
Running 20 games:
++--+-++---++--+-+++
Running 20 games:
-+----++---++--++++-
Your agent won 50.0% of matches against Minimax Agent

Depth = 3:
Running 20 games:
------------+-+-----
Running 20 games:
----+------++-+-+---
Your agent won 17.5% of matches against Minimax Agent

Depth = 7:
Running 20 games:
++++++++++++++++++++
Running 20 games:
++++++++++++++++++++
Your agent won 100.0% of matches against Minimax Agent

Depth = 10:
Running 20 games:
++++++++++++++++++++
Running 20 games:
++++++++++++++++++++
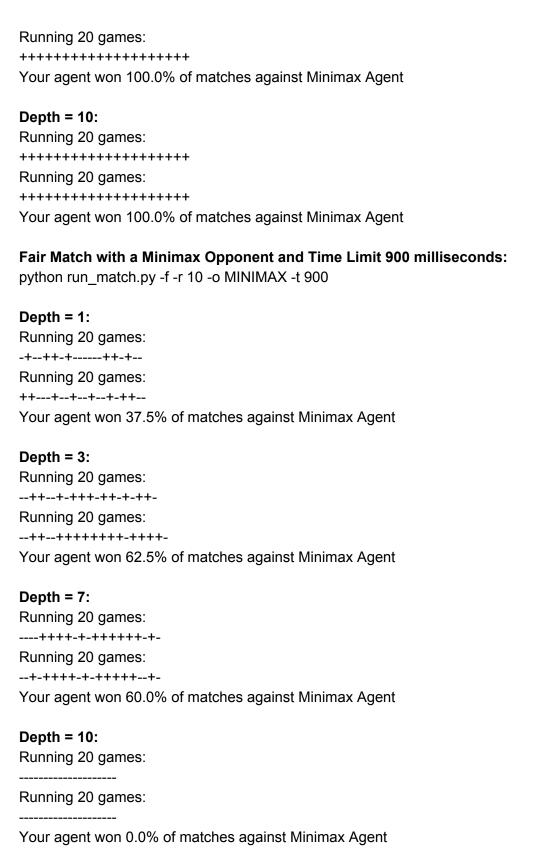Your agent won 100.0% of matches against Minimax Agent

Fair Match with a Minimax Opponent and Time Limit 300 milliseconds:
python run_match.py -f -r 10 -o MINIMAX -t 300

Depth = 1:
Running 20 games:
+-+---++--+----++-+-
Running 20 games:
+-+++-+++-+++--++-+-

Your agent won 52.5% of matches against Minimax Agent

Depth = 3:
Running 20 games:

Running 20 games:
+--+--------------+
Your agent won 7.5% of matches against Minimax Agent

Depth = 7:
Running 20 games:
++++++++++++++++++++
Running 20 games:
++++++++++++++++++++
Your agent won 100.0% of matches against Minimax Agent

Depth = 10:
Running 20 games:
++++++++++++++++++++
Running 20 games:
++++++++++++++++++++
Your agent won 100.0% of matches against Minimax Agent

Fair Match with a Minimax Opponent and Time Limit 600 milliseconds:
python run_match.py -f -r 10 -o MINIMAX -t 600

Depth = 1:
Running 20 games:
-----+---+-++-+--++-
Running 20 games:
+---++-+-+----+--++-
Your agent won 37.5% of matches against Minimax Agent

Depth = 3:
Running 20 games:
-----++-+-----++----
Running 20 games:
+--+-++-------+-+--+
Your agent won 30.0% of matches against Minimax Agent

Depth = 7:
Running 20 games:
++++++++++++++++++++

Running 20 games:

++++++++++++++++++++

Your agent won 100.0% of matches against Minimax Agent

Depth = 10:

Running 20 games:

++++++++++++++++++++

Running 20 games:

++++++++++++++++++++

Your agent won 100.0% of matches against Minimax Agent

Fair Match with a Minimax Opponent and Time Limit 900 milliseconds:

python run_match.py -f -r 10 -o MINIMAX -t 900

Depth = 1:

Running 20 games:

-+--++-+------++-+--

Running 20 games:

++---+--+--+--+-++--

Your agent won 37.5% of matches against Minimax Agent

Depth = 3:

Running 20 games:

--++--+-+++-++-+-++-

Running 20 games:

--++--++++++++-++++-

Your agent won 62.5% of matches against Minimax Agent

Depth = 7:

Running 20 games:

----++++-+-++++++-+-

Running 20 games:

--+-++++-+-+++++--+-

Your agent won 60.0% of matches against Minimax Agent

Depth = 10:

Running 20 games:

Running 20 games:

Your agent won 0.0% of matches against Minimax Agent

Unfair Match with a Minimax Opponent and Time Limit 150 milliseconds:

python run_match.py -r 10 -o MINIMAX -t 150

Depth = 1:
Running 20 games:
-+----------+-++--+-
Your agent won 25.0% of matches against Minimax Agent

Depth = 3:
Running 20 games:
-++--+++-++-+--++---
Your agent won 50.0% of matches against Minimax Agent

Depth = 7:
Running 20 games:

Your agent won 0.0% of matches against Minimax Agent

Depth = 10:
Running 20 games:

Your agent won 0.0% of matches against Minimax Agent

Unfair Match with a Minimax Opponent and Time Limit 300 milliseconds:
python run_match.py -r 10 -o MINIMAX -t 300

Depth = 1:
Running 20 games:
+----------+---+----
Your agent won 15.0% of matches against Minimax Agent

Depth = 3:
Running 20 games:
--++-+-+--++-----++-
Your agent won 40.0% of matches against Minimax Agent

Depth = 7:
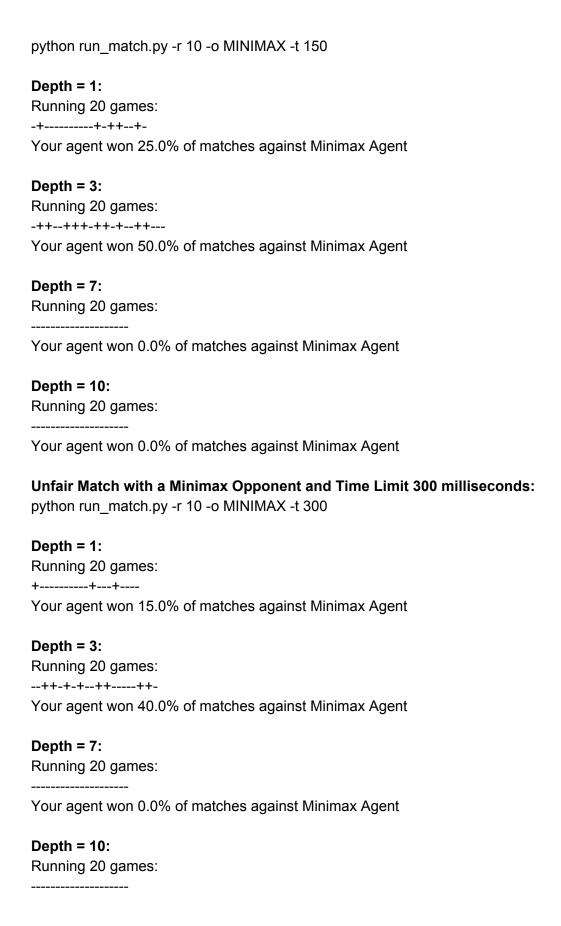Running 20 games:

Your agent won 0.0% of matches against Minimax Agent

Depth = 10:
Running 20 games:

Your agent won 0.0% of matches against Minimax Agent

Unfair Match with a Minimax Opponent and Time Limit 600 milliseconds:
python run_match.py -r 10 -o MINIMAX -t 600

Depth = 1:
Running 20 games:
--++---------++----+
Your agent won 25.0% of matches against Minimax Agent
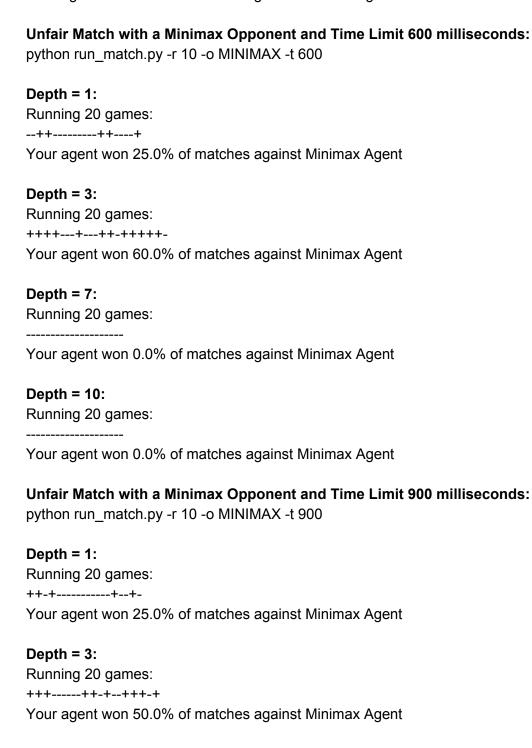
Depth = 3:
Running 20 games:
++++---+---++-+++++-
Your agent won 60.0% of matches against Minimax Agent

Depth = 7:
Running 20 games:

Your agent won 0.0% of matches against Minimax Agent

Depth = 10:
Running 20 games:

Your agent won 0.0% of matches against Minimax Agent

Unfair Match with a Minimax Opponent and Time Limit 900 milliseconds:
python run_match.py -r 10 -o MINIMAX -t 900

Depth = 1:
Running 20 games:
++-+-----------+--+-
Your agent won 25.0% of matches against Minimax Agent

Depth = 3:
Running 20 games:
+++------++-+--+++-+
Your agent won 50.0% of matches against Minimax Agent

Depth = 7:
Running 20 games:
--------+++-+++-+---
Your agent won 35.0% of matches against Minimax Agent

Depth = 10:
Running 20 games:

Your agent won 0.0% of matches against Minimax Agent

Random Agent:

Fair Match with a Random Opponent and Time Limit 150 milliseconds:
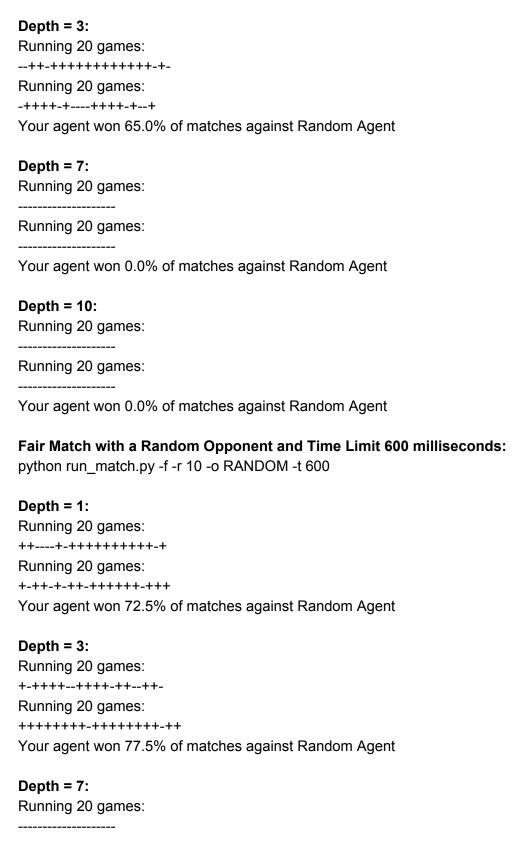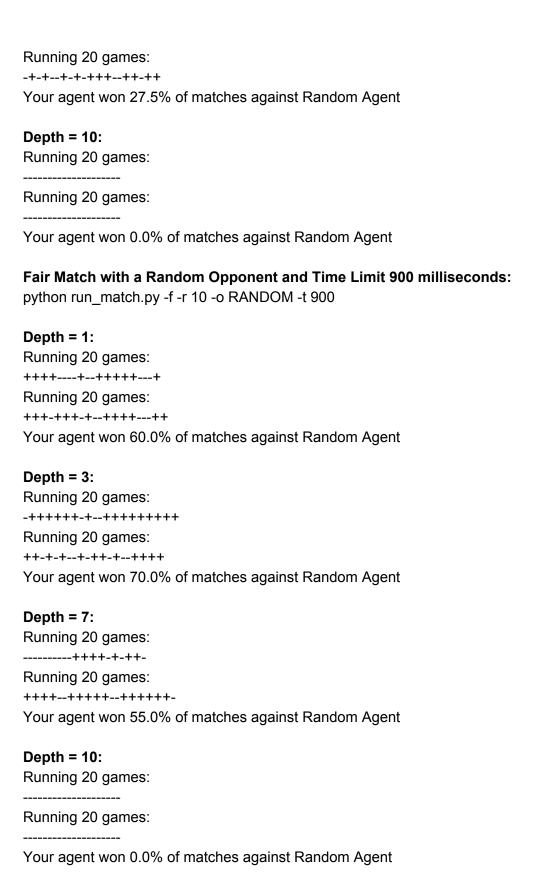python run_match.py -f -r 10 -o RANDOM -t 150

Depth = 1:
Running 20 games:
----+-+-+--++-+--++-
Running 20 games:
+--+++--+-+++--++-++
Your agent won 50.0% of matches against Random Agent

Depth = 3:
Running 20 games:
--++++-+++-+++++-+-+
Running 20 games:
++++-+-+--++-++++-++
Your agent won 70.0% of matches against Random Agent

Depth = 7:
Running 20 games:

Running 20 games:

Your agent won 0.0% of matches against Random Agent

Depth = 10:
Running 20 games:

Running 20 games:

Your agent won 0.0% of matches against Random Agent

Fair Match with a Random Opponent and Time Limit 300 milliseconds:
python run_match.py -f -r 10 -o RANDOM -t 300

Depth = 1:
Running 20 games:
++-+--+++-----++-+--
Running 20 games:
++++++--+-++++++++++

Your agent won 65.0% of matches against Random Agent

Depth = 3:
Running 20 games:
--++-++++++++++++-+-
Running 20 games:
-++++-+----++++-+--+
Your agent won 65.0% of matches against Random Agent

Depth = 7:
Running 20 games:

Running 20 games:

Your agent won 0.0% of matches against Random Agent

Depth = 10:
Running 20 games:

Running 20 games:

Your agent won 0.0% of matches against Random Agent

Fair Match with a Random Opponent and Time Limit 600 milliseconds:
python run_match.py -f -r 10 -o RANDOM -t 600
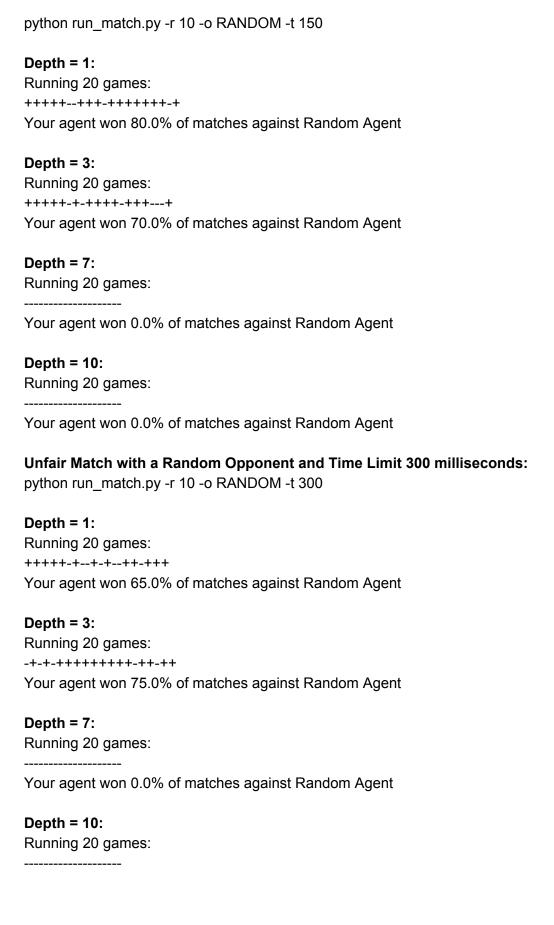
Depth = 1:
Running 20 games:
++----+-+++++++++++-+
Running 20 games:
+-++-+-++-++++++-+++
Your agent won 72.5% of matches against Random Agent

Depth = 3:
Running 20 games:
+-++++--++++-++--++-
Running 20 games:
++++++++-+++++++++-++
Your agent won 77.5% of matches against Random Agent

Depth = 7:
Running 20 games:

Running 20 games:

-+-+--+-+-+++--++-++

Your agent won 27.5% of matches against Random Agent

Depth = 10:
Running 20 games:

Running 20 games:

Your agent won 0.0% of matches against Random Agent

Fair Match with a Random Opponent and Time Limit 900 milliseconds:
python run_match.py -f -r 10 -o RANDOM -t 900

Depth = 1:
Running 20 games:

++++----+--+++++---+

Running 20 games:

+++-+++-+--++++---++

Your agent won 60.0% of matches against Random Agent

Depth = 3:
Running 20 games:

-++++++-+--+++++++++

Running 20 games:

++-+-+--+-++-+--++++

Your agent won 70.0% of matches against Random Agent

Depth = 7:
Running 20 games:

----------++++-+-++-

Running 20 games:

++++--+++++--++++++-

Your agent won 55.0% of matches against Random Agent

Depth = 10:
Running 20 games:

Running 20 games:

Your agent won 0.0% of matches against Random Agent

Unfair Match with a Random Opponent and Time Limit 150 milliseconds:

python run_match.py -r 10 -o RANDOM -t 150

Depth = 1:
Running 20 games:
+++++--+++-+++++++-+
Your agent won 80.0% of matches against Random Agent

Depth = 3:
Running 20 games:
+++++-+-++++-+++---+
Your agent won 70.0% of matches against Random Agent

Depth = 7:
Running 20 games:

Your agent won 0.0% of matches against Random Agent

Depth = 10:
Running 20 games:

Your agent won 0.0% of matches against Random Agent

Unfair Match with a Random Opponent and Time Limit 300 milliseconds:
python run_match.py -r 10 -o RANDOM -t 300

Depth = 1:
Running 20 games:
+++++-+--+-+--++-+++
Your agent won 65.0% of matches against Random Agent

Depth = 3:
Running 20 games:
-+-+-++++++++-++-++
Your agent won 75.0% of matches against Random Agent

Depth = 7:
Running 20 games:

Your agent won 0.0% of matches against Random Agent

Depth = 10:
Running 20 games:

Your agent won 0.0% of matches against Random Agent

Unfair Match with a Random Opponent and Time Limit 600 milliseconds:
python run_match.py -r 10 -o RANDOM -t 600

Depth = 1:
Running 20 games:
+--+--+-+--+++-+++++
Your agent won 60.0% of matches against Random Agent

Depth = 3:
Running 20 games:
-++++-++-++++-++++--
Your agent won 70.0% of matches against Random Agent

Depth = 7:
Running 20 games:
---------------++-++
Your agent won 20.0% of matches against Random Agent

Depth = 10:
Running 20 games:

Your agent won 0.0% of matches against Random Agent

Unfair Match with a Random Opponent and Time Limit 900 milliseconds:
python run_match.py -r 10 -o RANDOM -t 900

Depth = 1:
Running 20 games:
-++++-+++-++-+-++++-
Your agent won 70.0% of matches against Random Agent

Depth = 3:
Running 20 games:
-+-+--+++-++++---+-+
Your agent won 55.0% of matches against Random Agent

Depth = 7:
Running 20 games:
---------+++++-+-++-
Your agent won 40.0% of matches against Random Agent

Depth = 10:
Running 20 games:

Your agent won 0.0% of matches against Random Agent

Self/Custom Agent:

Fair Match with a Custom Opponent and Time Limit 150 milliseconds:
python run_match.py -f -r 10 -o SELF -t 150

Depth = 1:
Running 20 games:
-----++--++-+--+-++-
Running 20 games:
+--+++++++++----++++
Your agent won 55.0% of matches against Custom TestAgent

Depth = 3:
Running 20 games:
-+----+---+-+-+-----
Running 20 games:
++-++-+++-++--+++--+
Your agent won 45.0% of matches against Custom TestAgent

Depth = 7:
Running 20 games:
+-+-+-+-+-+-+-+-+-+-
Running 20 games:
--++--++--++--++---++
Your agent won 50.0% of matches against Custom TestAgent

Depth = 10:
Running 20 games:
+-+-+-+-+-+-+-+-+-+-
Running 20 games:
--++--++--++--++--++
Your agent won 50.0% of matches against Custom TestAgent

Fair Match with a Custom Opponent and Time Limit 300 milliseconds:
python run_match.py -f -r 10 -o SELF -t 300

Depth = 1:
Running 20 games:
-++++-+-+++++++-+-+
Running 20 games:
+++---++-++--++-++--

Your agent won 65.0% of matches against Custom TestAgent

Depth = 3:
Running 20 games:
+-++--++-+-+-+-+-+
Running 20 games:
--+-+-+-++--++--++--
Your agent won 50.0% of matches against Custom TestAgent

Depth = 7:
Running 20 games:
+++-+-+-+-+-+-+-+-
Running 20 games:
-+++--++--++--++--++
Your agent won 55.0% of matches against Custom TestAgent

Depth = 10:
Running 20 games:
+-+-+-+-+-+-+-+-+-
Running 20 games:
--++--++--++--++--++
Your agent won 50.0% of matches against Custom TestAgent

Fair Match with a Custom Opponent and Time Limit 600 milliseconds:
python run_match.py -f -r 10 -o SELF -t 600

Depth = 1:
Running 20 games:
+--+-+-++-----+++++-
Running 20 games:
----++-----++-+--+++
Your agent won 45.0% of matches against Custom TestAgent

Depth = 3:
Running 20 games:
+-+++---+-+--+-+--+-
Running 20 games:
--+----+--++++--+-++
Your agent won 45.0% of matches against Custom TestAgent

Depth = 7:
Running 20 games:
++++++---+---+--+---

Running 20 games:

++++-+-+++-+++-+---+

Your agent won 55.0% of matches against Custom TestAgent

Depth = 10:
Running 20 games:

+-+-+-+-+-+-+-+-+-+-

Running 20 games:

--++--++--++--++--++

Your agent won 50.0% of matches against Custom TestAgent

Fair Match with a Custom Opponent and Time Limit 900 milliseconds:
python run_match.py -f -r 10 -o SELF -t 900

Depth = 1:
Running 20 games:

+--+-++++-+++--+-++-

Running 20 games:

----+++---+-----++++

Your agent won 50.0% of matches against Custom TestAgent

Depth = 3:
Running 20 games:

-+---++-+++--+++++--

Running 20 games:

++-+++++-++++++--+-+

Your agent won 65.0% of matches against Custom TestAgent

Depth = 7:
Running 20 games:

++----++-++++-++---+

Running 20 games:

-+-++-+-+++---+-+---

Your agent won 50.0% of matches against Custom TestAgent

Depth = 10:
Running 20 games:

+-+-+-+-+-+-+-+-+-+-

Running 20 games:

--++--++--++--++--++

Your agent won 50.0% of matches against Custom TestAgent

Unfair Match with a Custom Opponent and Time Limit 150 milliseconds:

python run_match.py -r 10 -o SELF -t 150

Depth = 1:
Running 20 games:
++-+---+++--+-++-++-
Your agent won 55.0% of matches against Custom TestAgent

Depth = 3:
Running 20 games:
+-+-+++-++-+-+-+----
Your agent won 50.0% of matches against Custom TestAgent

Depth = 7:
Running 20 games:
+-+-+-+-+-+-+++-+-+-
Your agent won 55.0% of matches against Custom TestAgent

Depth = 10:
Running 20 games:
+-+-+-+-+-+-+-+-+-
Your agent won 50.0% of matches against Custom TestAgent

Unfair Match with a Custom Opponent and Time Limit 300 milliseconds:
python run_match.py -r 10 -o SELF -t 300

Depth = 1:
Running 20 games:
--++---+-+--++-+++-+
Your agent won 50.0% of matches against Custom TestAgent

Depth = 3:
Running 20 games:
++-++--+-+-++--+-+--
Your agent won 50.0% of matches against Custom TestAgent

Depth = 7:
Running 20 games:
+-+-+-+-+-+-+-+-+-
Your agent won 50.0% of matches against Custom TestAgent

Depth = 10:
Running 20 games:
+-+-+-+-+-+-+-+-+-

Your agent won 50.0% of matches against Custom TestAgent

Unfair Match with a Custom Opponent and Time Limit 600 milliseconds:
python run_match.py -r 10 -o SELF -t 600

Depth = 1:
Running 20 games:
--+--++-++---++-++--
Your agent won 45.0% of matches against Custom TestAgent

Depth = 3:
Running 20 games:
--+--+--+----+--++++
Your agent won 40.0% of matches against Custom TestAgent

Depth = 7:
Running 20 games:
+-+-+-++--++++--+-++
Your agent won 60.0% of matches against Custom TestAgent

Depth = 10:
Running 20 games:
+-+-+-+-+-+-+-+-+-+-
Your agent won 50.0% of matches against Custom TestAgent

Unfair Match with a Custom Opponent and Time Limit 900 milliseconds:
python run_match.py -r 10 -o SELF -t 900

Depth = 1:
Running 20 games:
-+--++-+---+------+-
Your agent won 30.0% of matches against Custom TestAgent

Depth = 3:
Running 20 games:
+-+--+--++++--+-----
Your agent won 40.0% of matches against Custom TestAgent

Depth = 7:
Running 20 games:
----+-+-+++++--+----
Your agent won 40.0% of matches against Custom TestAgent

Depth = 10:
Running 20 games:
+-+-+-+-+-+-+-+-+-+-
Your agent won 50.0% of matches against Custom TestAgent

Questions:

What features of the game does your heuristic incorporate, and why do you think those features matter in evaluating states during search?

My Heuristic incorporates the Time Limit and Depth Limit features. These features matter in evaluating states during a search because they find a solution within a certain time constraint per turn as well as within a certain depth i.e a certain number of depth explored.

Analyze the search depth your agent achieves using your custom heuristic. Does search speed matter more or less than accuracy to the performance of your heuristic?

The Search Depth has an affect on the performance of the heuristic. If the Search Depth is too small or too large, then the performance is not good.

Search Speed and Accuracy are both equally important for my heuristic. For a heuristic that finds an inaccurate/invalid move in shorter periods of time, then there is no use playing such a game. Similarly, for a heuristic that finds an accurate/valid move in longer periods of time, the game is also not fun to play. Hence, finding an accurate move within a given time constraint is important.