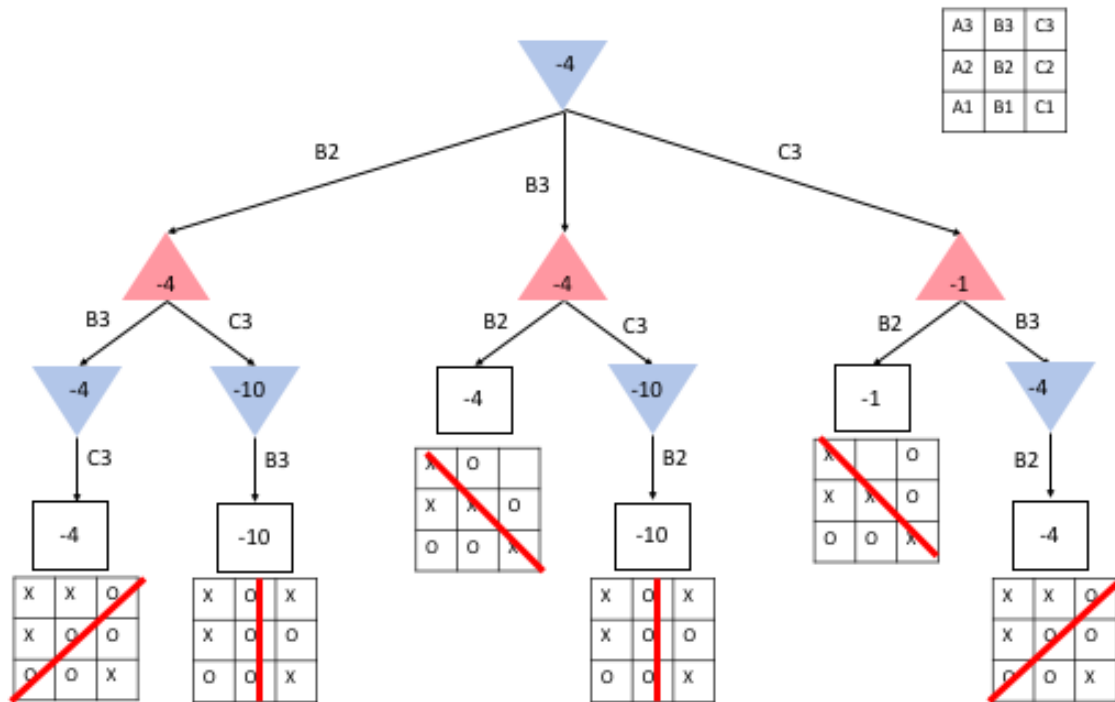


COMS W4701: Artificial Intelligence, Summer 2022

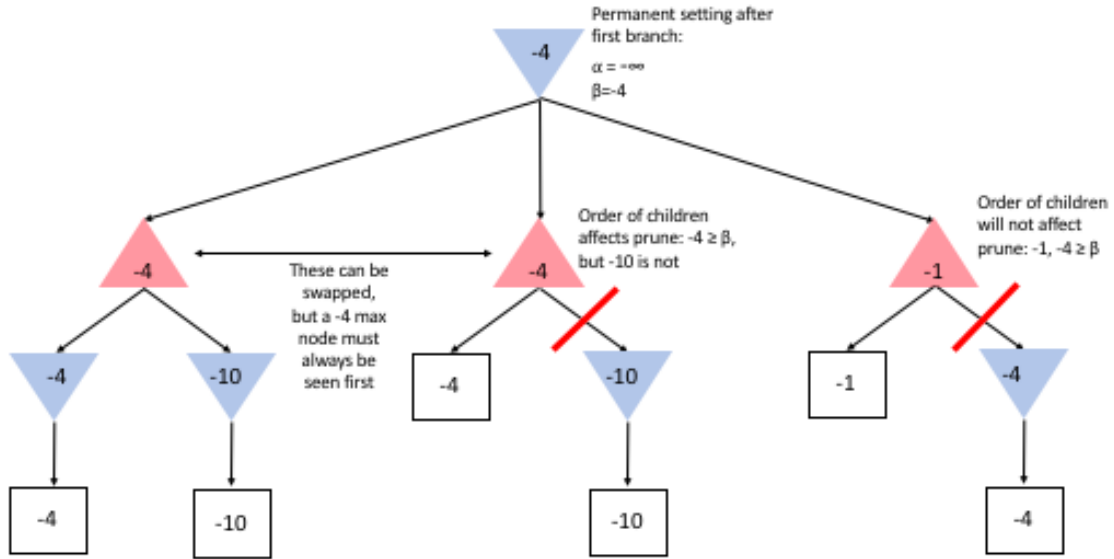
Homework 2 Solutions

Problem 1: Tic-Tac-Twist (22 points)

(a) The entire game tree is:



- (b) Propagated values of each node are also shown above. The best action for O to take is either B2 or B3, both resulting in an expected score of -4.
- (c) The maximum number of prunes is 2, one from a -4 max node and the other from the -1 max node. To achieve this result, a -4 max node must be seen first, so as to set $\alpha = -4$ and percolate the value up to the root to set $\beta = -4$.



After this, β can not be reset visiting the other two nodes, so order of max node visiting does not matter. However, when visiting the other -4 max node, we can only prune the -10 branch after seeing -4 first, as $-4 \geq -4$, triggering the beta prune condition. $-10 \not\geq -4$. Both -1 and -4 meet the beta prune condition in the -1 max node though, so whichever is not visited first will be pruned.

- (d) The max nodes become chance nodes. The new utility at the root will be $\min(-7, -7, -2.5) = -7$, and the best actions will remain the same as before.

Problem 2: Yahtzee (18 points)

- (a) $L_1 = 11, L_2 = L_3 = 10, L_4 = 11, L_5 = 15, L_6 = 8, L_7 = 9, L_8 = 10, L_9 = 11, L_{10} = 8, L_{11} = 9, L_{12} = 10, L_{13} = 11, C_1 = 11.5, C_2 = C_3 = 9.5, M = 11.5$. Best action is to reroll the 3 for expected utility C_1 .
- (b) The root node will now have as its successors L_1 (as before) and a new chance node, whose successors are C_1, C_2 , and C_3 . The rest of the tree structure remains the same. The new node's value is $\frac{1}{3}(C_1 + C_2 + C_3) = 10.167$, so the best action is to keep the current dice for expected utility $M = 11$.
- (c) There are three combinations of two from among the three dice that we have. So we still have three chance nodes coming from the root, as well as a leaf representing keeping all dice the same. So the tree structure doesn't change.

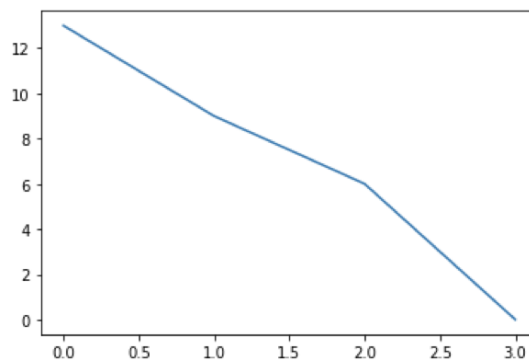
Problem 3: Sudoku (30 points)

3.3 Preliminary Tests (5 points)

Solved puzzle:

```
[[0 0 1 0]
 [0 2 0 0]
 [0 0 2 4]
 [0 4 0 0]]
```

```
[[4 3 1 2]
 [1 2 4 3]
 [3 1 2 4]
 [2 4 3 1]]
```

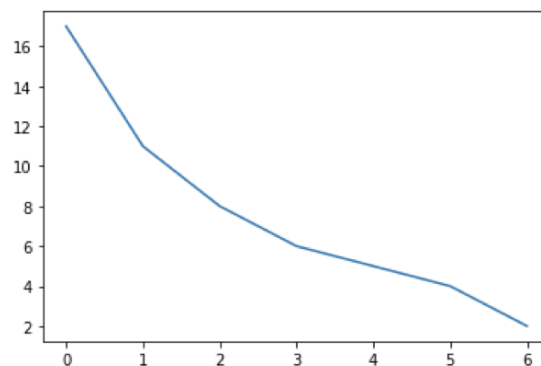


The left grid is the original problem, the middle grid is the returned solution state, and the right plot is numbers of errors over iterations.

Unsolved puzzle:

```
[[4 0 0 0]
 [0 1 0 4]
 [1 0 0 3]
 [0 0 0 0]]
```

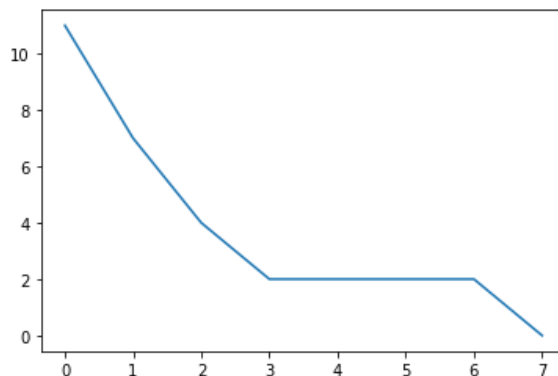
```
[[4 2 3 1]
 [3 1 2 4]
 [1 4 2 3]
 [2 3 4 1]]
```



Over 100 puzzles, the success rate was 53% and the average error was 1.95.

3.4 Sideways Moves (5 points)

A sample error plot with three sideways moves:



Over 100 puzzles, the success rate was 85% and the average error was 0.64.

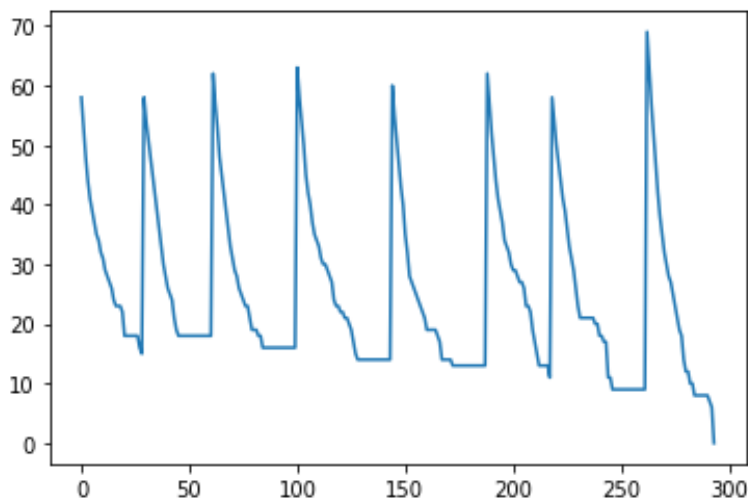
3.5 Random Restarts (5 points)

Batch of 100 with $n = 2$, $c = 5$, $\text{max_sideways} = 10$, $\text{max_restarts} = 10$: Success rate was 100%, average error was 0.

Successful solve on a puzzle with $n = 3, c = 40$, `max_sideways= 15`, `max_restarts= 20`:

```
[ [0 1 4 0 2 6 8 9 0]
  [5 0 0 9 8 0 0 7 4]
  [0 0 0 0 0 0 0 0 5 6]
  [1 4 0 0 0 7 3 0 0]
  [0 0 7 0 3 0 4 0 9]
  [8 3 5 1 0 9 6 2 7]
  [3 5 2 4 9 0 7 0 0]
  [0 0 8 0 0 1 5 0 0]
  [0 0 0 0 0 0 9 4 0]]
```

```
[ [7 1 4 5 2 6 8 9 3]
  [5 2 6 9 8 3 1 7 4]
  [9 8 3 7 1 4 2 5 6]
  [1 4 9 2 6 7 3 8 5]
  [2 6 7 8 3 5 4 1 9]
  [8 3 5 1 4 9 6 2 7]
  [3 5 2 4 9 8 7 6 1]
  [4 9 8 6 7 1 5 3 2]
  [6 7 1 3 5 2 9 4 8]]
```



Problem 4: Connect k (30 points)

Summary of results:

1. Connect 3 on 4x4 board: X wins
2. Connect 4 on 4x4 board: Draw

Connect 4 on 6x7 board:

1. X limit 5, O limit 5: Draw
2. X limit 6, O limit 6: O wins
3. X limit 6, O limit 5: X wins
4. X limit 6, O limit 4: X wins