CS440 Assignment 2 Report

Part 1: Constraint Satisfaction Problems

In order to solve the problem, we created a huge data structure. (Here is the detail for the data structure)



1. Letter-based assignment.

In this assignment, we fill in array one letter at a time. We loop each letter to see if there is a solution for it. If so, we mark the letter on our data structure and keep going on to solve the puzzle. If not, we just skip this letter. If iteration approaches to the end of the array, we print the result.

**Variables:** Size of output array.

**Domains:** letters possible at that position

**Constraints:**

All possible solutions & Search Tree for each puzzle:

**Puzzle 1**

Solution:

N N E M A N D Y E

N N E S A Y D Y E

N W E M A N D Y E

N W E S A Y D Y E

Search Tree

root -> N -> N -> E -> M -> A -> N -> D -> Y -> E -> (found result: NNEMANDYE)

S -> A -> Y -> D -> Y -> E -> (found result: NNESAYDYE)

W -> E -> M -> A -> N -> D -> Y -> E -> (found result: NWEMANDYE)

W -> E -> S -> A -> Y -> D -> Y -> E -> (found result: NWESAYDYE)

**Puzzle 2**

Solution:

H S I A I W N C S

H S I A I W N P S

H S I O I W N D S

H S I O I W N Y S

Search Tree

root -> H -> S -> I -> A -> I -> W -> N -> C -> S -> (found result: HSIAIWNCS)

P -> S -> (found result: HSIAIWNPS)

O -> I -> W -> N -> D -> S -> (found result: HSIOIWNDS)

Y -> S -> (found result: HSIOIWNYS)

**Puzzle 3**

Solution:

A S U L P E A

A S U L P I E

Search Tree:

root -> A -> S -> U -> L -> P -> E -> A -> (found result: ASULPEA)

I -> E -> (found result: ASULPIE)

**Puzzle 4**

Solution:

H E D I T Y R E

H E L I T Y R E

H E T I T Y R E

Search Tree:

root -> H -> E -> D -> I -> T -> Y -> R -> E -> (found result: HEDITYRE)

-> L -> I -> T -> Y -> R -> E -> (found result: HELITYRE)

-> T -> I -> T -> Y -> R -> E -> (found result: HETITYRE)

**Puzzle 5**

Solution:

I H T T N O I E N

I H T T Y O I E N

T H T T N O I E N

T H T T Y O I E N

Search Tree:

root -> I -> H -> T -> T -> N -> O -> I -> E -> N -> (found result: IHTTNOIEN)

Y -> O -> I -> E -> N -> (found result: IHTTYOIEN)

root -> T -> H -> T -> T -> N -> O -> I -> E -> N -> (found result: THTTNOIEN)

Y -> O -> I -> E -> N -> (found result: THTTYOIEN)

1. Word-based assignment.

In this assignment, we fill in the left array one word at a time. We go through each category and we go through each word in that category. Then we check if the word satisfies the constraint. If it can be appeared on the solution, we mark the word on the left array and keep going. If iteration approaches to the end of the array, we print the result.

**Variables:** Number of categories.

**Domains:** Number of words belong to the category.

**Constraints:**

All possible solutions & Search Tree for each puzzle:

**Puzzle 1**

Solution:

N N E M A N D Y E

N N E S A Y D Y E

N W E M A N D Y E

N W E S A Y D Y E

**Puzzle 2**

Solution:

H S I A I W N C S

H S I A I W N P S

H S I O I W N D S

H S I O I W N Y S

**Puzzle 3**

Solution:

A S U L P E A

A S U L P I E

**Puzzle 4**

Solution:

H E D I T Y R E

H E L I T Y R E

H E T I T Y R E

**Puzzle 5**

Solution:

I H T T N O I E N

I H T T Y O I E N

T H T T N O I E N

T H T T Y O I E N

Part 2: War Game

2.1. min-max & alpha-beta agents

Summary: We used a variable called level to control the depth of tree. The minmax used level of 3 and the alpha-beta used the level of 4. The evaluation function takes the difference between the total point on the board for the current player and the total point on the board for another player.

**Keren**

minimax(B) vs. minimax(G)

B B B B B B

B B B B B B

B B B B B B

B B B G B G

B B G B G B

B G B G B G

B score: 29

G score: 7

average time per move: 0.09368 milliseconds

total nodes expanded for B: 217740

total nodes expanded for G: 194736

average nodes expanded per move for B: 10818

average nodes expanded per move for G: 12096

minimax(B) vs. alphabeta(G)

G G G G G G

G G G G G G

G G G G G B

B B B B B B

B B B B B B

B B B B B B

B score: 19

G score: 17

average time per move: 0.6632 milliseconds

total nodes expanded for B: 194736

total nodes expanded for G: 473973

average nodes expanded per move for B: 26331

average nodes expanded per move for G: 10818

alphabeta(B) vs. minimax(G)

B B B B B B

B B B G B G

B B B B G B

B B B G B G

B B G G G G

G G G G G G

B score: 21

G score: 15

average time per move: 0.09844 milliseconds

total nodes expanded for B: 430325

total nodes expanded for G: 217740

average nodes expanded per move for B: 23906

average nodes expanded per move for G: 12096

alphabeta(B) vs. alphabeta(G)

G B G B G B

B G B G B G

G B G B G B

B G B G B G

G B G B G B

B G B G B G

B score: 18

G score: 18

average time per move: 0.5138 milliseconds

total nodes expanded for B: 25897

total nodes expanded for G: 22342

average nodes expanded per move for B: 1438

average nodes expanded per move for G: 1296

**Narvik**

minimax(B) vs. minimax(G)

B B G G B B

G G B G G B

G B G G G B

G B B B G G

B B B G G B

G G B B G B

B score: 900

G score: 900

average time per move: 2.5896 milliseconds

total nodes expanded for B: 217740

total nodes expanded for G: 194736

average nodes expanded per move for B: 12096

average nodes expanded per move for G: 10818

minimax(B) vs. alphabeta(G)

B B B B B B

B B B B B B

G B G B G B

B G B G B G

G G G G G G

G G G G G G

B score: 606

G score: 1194

average time per move: 1.8429 milliseconds

total nodes expanded for B: 217740

total nodes expanded for G: 104941

average nodes expanded per move for B: 12096

average nodes expanded per move for G: 5830

alphabeta(B) vs. minimax(G)

G G G G G G

G G G G G G

G G B G B G

G B G B B B

B B B B B B

B B B B B B

B score: 1096

G score: 704

average time per move: 1.4348 milliseconds

total nodes expanded for B: 54666

total nodes expanded for G: 194736

average nodes expanded per move for B: 3037

average nodes expanded per move for G: 10818

alphabeta(B) vs. alphabeta(G)

G B G B G B

G B G B G B

G B G B G B

G B G B G B

G B G B G B

G B G B G B

B score: 900

G score: 900

average time per move: 5.4966 milliseconds

total nodes expanded for B: 533936

total nodes expanded for G: 322253

average nodes expanded per move for B: 29663

average nodes expanded per move for G: 17902

**Sevastopol**

minimax(B) vs. minimax(G)

B G B B G B

G B G G B B

B G G G B G

G B G G B B

G G G B B B

B G G G B B

B score: 186

G score: 192

average time per move: 2.3747 milliseconds

total nodes expanded for B: 217740

total nodes expanded for G: 194736

average nodes expanded per move for B: 12096

average nodes expanded per move for G: 10818

minimax(B) vs. alphabeta(G)

B B B B B B

B B B B B B

B B B B B G

G B G G G G

G G G G G G

G G G G G G

B score: 46

G score: 332

average time per move: 21.7538 milliseconds

total nodes expanded for B: 217740

total nodes expanded for G: 3359423

average nodes expanded per move for B: 12096

average nodes expanded per move for G: 186634

alphabeta(B) vs. minimax(G)

G G G G G G

G G G G G G

G G G G G G

B B B B B B

B B B B B B

B B B B B B

B score: 336

G score: 42

average time per move: 22.0486 milliseconds

total nodes expanded for B: 3582898

total nodes expanded for G: 194736

average nodes expanded per move for B: 199049

average nodes expanded per move for G: 10818

alphabeta(B) vs. alphabeta(G)

G B G B G B

G B G B G B

G B G B G B

G B G B G B

G B G B G B

G B G B G B

B score: 189

G score: 189

average time per move: 49.7164 milliseconds

total nodes expanded for B: 4143769

total nodes expanded for G: 3983744

average nodes expanded per move for B: 230209

average nodes expanded per move for G: 221319

**Smolensk**

minimax(B) vs. minimax(G)

B B G G B G

G B B B G G

G G G B B B

B B B G B B

B G G B B G

G G G B G G

B score: 804

G score: 849

average time per move: 2.3627 milliseconds

total nodes expanded for B: 217740

total nodes expanded for G: 194736

average nodes expanded per move for B: 12096

average nodes expanded per move for G: 10818

minimax(B) vs. alphabeta(G)

B G B B B B

B B B B B B

G G B B B B

G G G B B B

G G G G G G

G G G G G G

B score: 522

G score: 1131

average time per move: 3.3147 milliseconds

total nodes expanded for B: 217740

total nodes expanded for G: 303143

average nodes expanded per move for B: 12096

average nodes expanded per move for G: 16841

alphabeta(B) vs. minimax(G)

G G G G G G

G G G G G G

B B G B G G

B B B G G G

B B B B B B

B B B B B B

B score: 1114

G score: 539

average time per move: 7.0961 milliseconds

total nodes expanded for B: 895903

total nodes expanded for G: 194736

average nodes expanded per move for B: 49772

average nodes expanded per move for G: 10818

alphabeta(B) vs. alphabeta(G)

G B G B G B

G B G B G B

G B G B G B

G B G B G B

G B G B G B

G B G B G B

B score: 754

G score: 899

average time per move: 9.899 milliseconds

total nodes expanded for B: 608034

total nodes expanded for G: 921486

average nodes expanded per move for B: 33779

average nodes expanded per move for G: 51193

**Westerplatte**

minimax(B) vs. minimax(G)

B G B G B G

B G B B B G

B G G B B G

B B G G G G

B G G B B G

B G B G G B

B score: 38

G score: 34

average time per move: 2.6724 milliseconds

total nodes expanded for B: 217740

total nodes expanded for G: 194736

average nodes expanded per move for B: 12096

average nodes expanded per move for G: 10818

minimax(B) vs. alphabeta(G)

B B B B B B

B B B B B B

B G B B G B

G G G G G B

B G G G G G

G G G G G G

B score: 30

G score: 42

average time per move: 2.2985 milliseconds

total nodes expanded for B: 217740

total nodes expanded for G: 164422

average nodes expanded per move for B: 12096

average nodes expanded per move for G: 9134

alphabeta(B) vs. minimax(G)

G G G G G G

G G G G G G

G B G G B G

G B B B B B

G B B B B B

B B B B B B

B score: 42

G score: 30

average time per move: 2.1291 milliseconds

total nodes expanded for B: 163939

total nodes expanded for G: 194736

average nodes expanded per move for B: 9107

average nodes expanded per move for G: 10818

alphabeta(B) vs. alphabeta(G)

G B G B G B

G B G B G B

G B G B G B

G B G B G B

G B G B G B

G B G B G B

B score: 36

G score: 36

average time per move: 10.4263 milliseconds

total nodes expanded for B: 689036

total nodes expanded for G: 891140

average nodes expanded per move for B: 38279

average nodes expanded per move for G: 49507