Artificial Intelligence Assignment Report

Victor Soto Berenguer

1. Introduction

Tetravex is a puzzle game where we have n*n pieces that are divided in four small triangles that contain a number and a color (k colors in total). The objective of the game is organizing the pieces in such a way that only two equal numbers are together. The game ends when all the pieces have been positioned correctly.

In this project we will model the game as a constraint satisfaction problem in MiniZinc.

2. Model

First, I sketched the model:

The variables would be p_i with i = [1,n*n]. For example, in the 3*3 case: p1,p2,..,p9.

The domain of each variable would be: d_i = ([1,1],[1,2],…,[n,n]). This indicates in which position is the piece located.

Regarding the constraints: no two pieces in the same position and the ones defined by the game (the numbers coincidence).

Then I proceeded to implement the model:

The model was written in the tetravex.mzn file:

This part is the data that comes from the data files (.dzn) such as the dimension of the table and the pieces we must organize.

```
% Tetravex n*n
int: n;
array[1..n*n,1..4] of int: pieces;
set of int: N = 1..n;
```

This part indicates that the solution is a 2-dimensional array where one dimension is the number of pieces and the other the position (row and column) where each of them should be placed.

```
%positions of each piece in the table (solution)
array[1..n*n,1..2] of var N: p;
```

Here start the constraints. The first one indicates that there cannot be two pieces in the same position (same row and same column at the same time). The rest of constraints indicate how the numbers must coincide to solve the puzzle.

```
%No two pieces in the same position
constraint forall(i in 1..((n*n)-1)) (forall(j in i+1..(n*n)) (if
p[i,1]==p[j,1] then p[i,2]!=p[j,2] endif));

%The piece at the right (piece j) must have the same number at the left as
piece i has at the right
constraint forall(i in 1..(n*n)) (forall(j in i+1..(n*n)) (if p[i,1]==p[j,1]
/\ p[j,2]==p[i,2]+1 then pieces[i,3]==pieces[j,1] endif));

%The piece at the left (piece j) must have the same number at the right as
piece i has at the left
constraint forall(i in 1..(n*n)) (forall(j in i+1..(n*n)) (if p[i,1]==p[j,1]
/\ p[j,2]==p[i,2]-1 then pieces[i,1]==pieces[j,3] endif));

%The piece at the bottom (piece j) must have the same number at the top as
piece i has at the bottom
constraint forall(i in 1..(n*n)) (forall(j in i+1..(n*n)) (if p[i,2]==p[j,2]
/\ p[j,1]==p[i,1]+1 then pieces[i,4]==pieces[j,2] endif));

%The piece at the top (piece j) must have the same number at the bottom as
piece i has at the top
constraint forall(i in 1..(n*n)) (forall(j in i+1..(n*n)) (if p[i,2]==p[j,2]
/\ p[j,1]==p[i,1]-1 then pieces[i,2]==pieces[j,4] endif));
```

These constraints can be all expressed in a single one like this:

```
constraint forall(i in 1..(n*n)-1) (forall(j in i+1..(n*n))
(if p[i,1]==p[j,1] /\ p[j,2]==p[i,2]+1 then pieces[i,3]==pieces[j,1]
elseif p[i,1]==p[j,1] /\ p[j,2]==p[i,2]-1 then
pieces[i,1]==pieces[j,3]
elseif p[i,2]==p[j,2] /\ p[j,1]==p[i,1]+1 then
pieces[i,4]==pieces[j,2]
elseif p[i,2]==p[j,2] /\ p[j,1]==p[i,1]-1 then
pieces[i,2]==pieces[j,4]
elseif p[i,1]==p[j,1] then p[i,2]!=p[j,2]
else true endif));
```

Here we are indicating that we want a solution satisfying the constraints and how the solution will be displayed, in this case indicating in which position of the table should each piece go.

```
% Find a solution that satisfies the constraints
solve satisfy;
```

```
output [ "Piece \(i):
[\(pieces[i,1]),\(pieces[i,2]),\(pieces[i,3]),\(pieces[i,4])] in position
[\(p[i,1]),\(p[i,2])]\n" | i in 1..(n*n) ];
```

3. Data examples and results

The data was written in .dzn files:

tetravex.dzn (3*3) and 9 colors:

Initial pieces

```
n = 3;

%1st number: left, 2nd number: top, 3rd number:
right, 4th number: bottom
pieces = array2d(1..n*n,1..4,
  [4,1,9,6, 6,1,4,0, 6,9,9,1,
   0,5,1,5, 6,0,6,9, 4,5,6,4,
   3,4,6,4, 1,7,6,1, 6,6,2,9
  ]);
```

```
Running tetravex.mzn with tetravex.dzn
Piece 1: [4,1,9,6] in position [2,3]
Piece 2: [6,1,4,0] in position [2,2]
Piece 3: [6,9,9,1] in position [1,3]
Piece 4: [0,5,1,5] in position [1,1]
Piece 5: [6,0,6,9] in position [3,2]
Piece 6: [4,5,6,4] in position [2,1]
Piece 7: [3,4,6,4] in position [3,1]
Piece 8: [1,7,6,1] in position [1,2]
Piece 9: [6,6,2,9] in position [3,3]
----------
Finished in 561msec
```

Solution in Minizinc

tetravex2.dzn (4*4) and 10 colors:

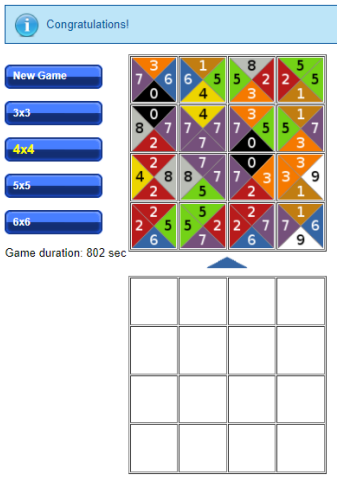
Initial pieces

```
n = 4;

%1st number: left, 2nd number: top, 3rd number:
right, 4th number: bottom
pieces = array2d(1..n*n,1..4,
        [8,0,7,2, 7,0,3,2, 5,8,2,3, 7,3,5,0,
         4,2,8,2, 2,5,5,1, 5,5,2,7, 3,3,9,1,
         7,1,6,9, 7,3,6,0, 2,2,5,6, 7,4,7,7,
         8,7,7,5, 5,1,7,3, 2,2,7,6, 6,1,5,4,
        ]);
```

```
Running tetravex.mzn with tetravex2.dzn
Piece 1: [8,0,7,2] in position [2,1]
Piece 2: [7,0,3,2] in position [3,3]
Piece 3: [5,8,2,3] in position [1,3]
Piece 4: [7,3,5,0] in position [2,3]
Piece 5: [4,2,8,2] in position [3,1]
Piece 6: [2,5,5,1] in position [1,4]
Piece 7: [5,5,2,7] in position [4,2]
Piece 8: [3,3,9,1] in position [3,4]
Piece 9: [7,1,6,9] in position [4,4]
Piece 10: [7,3,6,0] in position [1,1]
Piece 11: [2,2,5,6] in position [4,1]
Piece 12: [7,4,7,7] in position [2,2]
Piece 13: [8,7,7,5] in position [3,2]
Piece 14: [5,1,7,3] in position [2,4]
Piece 15: [2,2,7,6] in position [4,3]
Piece 16: [6,1,5,4] in position [1,2]
----------
```

Solution in Minizinc



4. Conclusion

In this project we have modeled a constraint satisfaction problem (CSP) and solved it for different data.

However, CSP problems are NP-complete, and as such, the time required to solve the problem increases rapidly as the size of the problem grows.

This can be seen here, since the solution from the 3*3 case and the 4*4 changes from being almost instantly to a little bit longer, and then for the 5*5 case is difficult for the computer to find a solution. Maybe with algorithms such as the backtracking and the use of heuristics to discard paths that lead to error it will be better to find the solutions when the puzzle size is bigger.