Search Algorithms in Java language (N-puzzle)

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Abstract—In this document it is described a simple game, formulating it as a search problem, solving it with different algorithms, then analysed the results and how we can benefit from them.

Keywords—Artificial Intelligence, Search, A\* Algorithm, Uniform Cost Algorithm, Greedy Algorithm and Breadth First Algorithm

# Introduction

In this project, an application capable of resolving instances of the game “N-Puzzle” was implemented, without any external interaction, using search algorithms of Artificial Intelligence, namely A\* Algorithm, Uniform Cost Algorithm, Greedy Algorithm and Breadth First Algorithm.

# Problem Description

* The game is played on a WxH board with WxH-1 pieces resulting in N pieces and thus giving the puzzle its name. The most common boards are of sizes 3x3, resulting in 8 pieces, and 4x4, resulting in 15 pieces. Each piece is numbered from 1 to N and can only move to an empty spot. The objective of the game is to move the pieces around until a specific pattern is reached. The challenge lays in the fact that some moves require damaging already finished grids of the board and can lead to complicated states.



* In 1891, Samuel Floyd took credit for inventing the 15-puzzle and, after his death, his son published the book “Cyclopedia of Puzzles” where he described in great detail the puzzle known today. The father also promised a 1000 dollars reward to anyone who could solve a particular instance of it, which is now known to be impossible. Regardless, we know that the first draft of the puzzle was actually done in 1874 by Noyes Palmer Chapman where the goal was to achieve a particular sum in each column and row. The postmaster applied for a patent in 1880 but was rejected for being too similar to an already existing patent owned by Ernest U. Kinsey, although his only described a sliding puzzle mechanism lacking any goal.



* Since then, the puzzle was been adapted and distributed by multiple companies and studied by even more mathematicians. Lycée Évariste Galois (October 25th, 1811 – May 31st, 1832; Paris) whose work on Number Theory and Permutations allowed Woolsey Johnson and William E. to publish “Notes on the ‘15’ Puzzle” where they proved not all instances of the puzzle lead to a solvable state, including the one proposed by Samuel Floyd.

# Formulation of the problem

State Representation: A board can be represented with a matrix of Wwidth and Hheight, whose positions range from (0, 0) on the topmost left to (*x*, *y*) on the bottommost right. Every piece can be represented with numbers ranging from “1” to N, N=W\*H-1, where each piece occupies a single position on the board. Since the original game includes a board position without a piece, in our implementation this will be represented with a piece numbered with “0”. Each piece can only be moved by swapping with the “0” piece.

Initial State: A board will always start with a pseudo-random placing of each piece. It is said pseudo since it was proven that not all random placements lead to solvable states.

Target State: The game ends when the board reaches a target position. In most implementation of the game, this is a state that when traversing the board horizontally, row by row, each board position will have a piece in increasing value. The last position won’t have a piece, but in our representation, this will be occupied by the piece labels as “0”.

Operators:

xPos – Position of the “0” piece within the horizontal axis.

yPos – Position of the “0” piece within the vertical axis.

N – Number of the previous piece.

|  |  |  |  |
| --- | --- | --- | --- |
| Name: | Pre-conditions: | Effects: | Costs: |
| MoveUp | yPos > 0; | (xPos, yPos-1) = N;  (xPos, yPos) = “0” | 1 |
| MoveDown | yPos < 5; | (xPos, yPos+1) = N;  (xPos, yPos) = “0” | 1 |
| MoveLeft | xPos > 0; | (xPos-1, yPos) = N;  (xPos, yPos) = “0” | 1 |
| MoveRight | yPos < 5; | (xPos+1, yPos) = N;  (xPos, yPos) = “0” | 1 |

# Related Work

During our research, there were several projects that we found which will likely assist us throughout the course of the development of the project. The first example details the development of a solver of the Unblock Me game [4]. It uses a Breadth First algorithm and it is implemented in C++ [5]. The second project is also an implementation of this game, but with a couple of differences. It is developed using the Python language and the algorithm implemented is the A\* [6].

# game Implementation

This project was developed using the Java programming language. I chose to implement this game in this specific language, not only because I already felt comfortable using it, but also because it is one of the most used programming languages in the world. Java is also widely used in the Artificial Intelligence context. Therefore, I believed that utilizing this language would be more beneficial than all other languages.

Moving on to the overall organization of the game implementation, we can begin by describing our approach to the illustration of the game board. As specified in the third section, a board is represented by a matrix of variable size. Below, we demonstrate how a 4\*4 matrix is represented in this implementation.

|05|01|03|04|

|02|00|07|08|

|10|06|11|12|

|09|13|14|15|

Figure 4 – Board Representation

In this implementation, each board is represented in the *Board* class. The code below represents the interface of this class.

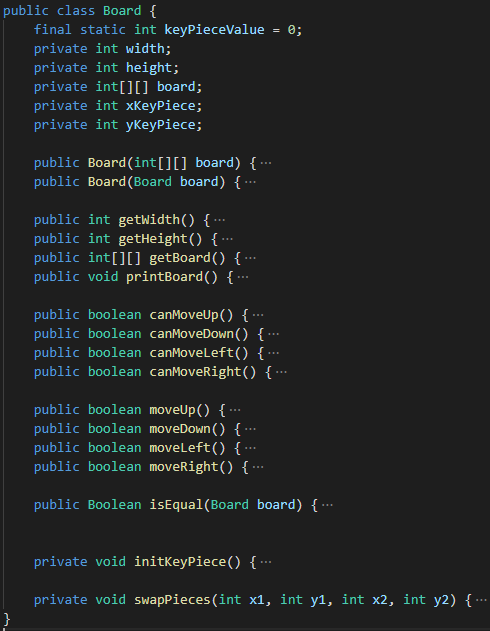


Figure 3 – Board class interface

Analysing the code above, the variables *xKeyPiece* and y*KeyPiece* represent the *x* and *y* coordinates of the “0” piece position, *width* and *height* represent the size of the board and theboard itself is stored as a 2dimensional array of integers.

The class contains methods create its objects, one from a 2dimensional array and the other from an already existing board. It can also retrieve its internal status as well as printing a formatted board. The *canMove()* and *move()* methods are the ones responsible for changing the internal status of a board.

The *isEqual()* method is used to compare boards and return true if their boards contents is equal regardless if it’s the same object.

# Search algorithms

Descrevendo os vários algoritmos de pesquisa utilizados e a sua implementação de modo a calcular a próxima jogada do PC ou retornar a solução final (conjunto de operações para transformar o estado inicial no estado objetivo). Devem ser implementados algoritmos para cálculo da solução utilizando pesquisa em largura, pesquisa em profundidade (se aplicável), aprofundamento progressivo, custo uniforme (se aplicável), pesquisa gulosa e Algoritmo A\* (estes último método utilizando várias heurísticas).

# Experiences and results

In order to easily visualize the results obtained, each one of the tables below will illustrate the outcome of the different algorithms for 5 experiments of different complexity.

Experience 1:

Descrevendo as experiências realizadas com os vários algoritmos para resolver diversos puzzles e os resultados obtidos a nível de tempo e custo da solução obtida em cada nível, por cada um dos métodos experimentados. Devem ser incluídas tabelas comparativas dos resultados obtidos na aplicação dos vários métodos aos vários puzzles (níveis do jogo) e discutidos os resultados.

# Conclusions and Development Prespectives

Sumário do trabalho realizado e conclusões que retira deste projeto. Análise crítica dos resultados obtidos em comparação com os resultados teóricos que seriam esperados. Trabalho futuro, ou seja, formas de melhorar o trabalho desenvolvido.

##### References

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Livros, artigos e páginas Web utilizados para desenvolver o trabalho. Todos os elementos bibliográficos devem ser citados no texto do trabalho, incluindo qualquer código fonte adaptado de uma dada fonte para a realização do trabalho.