From Scramble to Solution

Developing an Optimal Solver for a Rubik's Cube Variant

Samuel Borg

Supervisor: Ian Gent

March 20, 2025

School of Computer Science
University of St Andrews

Abstract

The Rubik's Cube is the most well-known combination puzzle of all time, and has led to the creation of numerous variants of the puzzle. One such puzzle is the Kilominx, a 2x2 dodecahedron-shaped puzzle with 12 faces and 20 cubies (individual cube elements of the puzzle). While the Rubik's Cube has already been extensively researched, the Kilominx has not been studied as widely.

This report describes the work that was accomplished to create an optimal solver for the Kilominx, guaranteeing a solution in as few moves as possible. The state of the Kilominx is represented as an array of cubies, each with an index and orientation. The solver uses an iterative-deepening A* (IDA*) algorithm to explore the search tree, using a number of pattern databases - large lookup tables which contain the number of moves needed to solve different sets of cubies - as a lower-bound heuristic. In order to index into the pattern databases, a Lehmer code is computed for the state of the Kilominx which can then be used to calculate the state's sequential index.

The solver performs very well up to a depth of 11, finding solutions in a matter of seconds. However, as solutions require longer sequences of moves to solve, the solver takes exponentially more time to find the optimal solution. With further optimisation, the solver could be used to help tighten the bounds on the Kilominx's God's Number, which is the maximum number of moves needed to solve the puzzle from any given state.

Declaration

I declare that the material submitted for assessment is my own work except where credit is explicitly given to others by citation or acknowledgement. This work was performed during the current academic year except where otherwise stated.

The main text of this project report is [insert word count] words long, including project specification and plan.

Acknowledgements

Contents

Chapter 1

Introduction

1.1 Objectives

Chapter 2

Context Survey

2.1 Korf's Algorithm for the Rubik's Cube

2.1.1 Iterative-Deepening A*

2.1.2 Pattern Databases

2.2 Sequential Indexing with Lehmer Codes

2.3 God's Number

Chapter 3

Requirements Specification

Chapter 4

Design

Chapter 5

Implementation

Chapter 6

Evaluation

6.1 Experimental Results

6.2 Evaluation Against Objectives

6.3 Critical Appraisal

Chapter 7

Conclusions

Appendix A

Testing Summary

Appendix B

User Manual