Solving Rubik's Cube using Genetic Algorithm

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Abstract

This rework is based on the paper "An Evolutionary Approach for Solving the Rubik's Cube Incorporating Exact Methods" by Nail El-Sourani, Sascha Hauke, and Markus Borschbach, University of Applied Science Germany. Solutions calculated by Evolutionary Algorithms have come to surpass exact methods for solving various problems. The Rubik's Cube multi-objective optimization problem is one such area. In this work we present an evolutionary approach to solve the Rubik's Cube with a low number of moves by building upon the classic Thistlethwaite's approach. We provide a group theoretic analysis of the subproblem complexity induced by Thistlethwaite's group transitions and design an Evolutionary Algorithm from the ground up including detailed derivation of our custom fitness functions. The implementation resulting from these observations is thoroughly tested for integrity and random scrambles, revealing performance that is competitive with exact methods without the need for pre-calculated lookup-tables.

1 Introduction

Evolutionary Algorithms have been successfully applied in a variety of fields,especially highly complex optimization problem. Oftentimes, superior solutions - as compared to classical algorithms have been achieved - notably in multi-objective cases (for example multi-constraint knapsack problems). This gives rise to the idea of applying Evolutionary Algorithms to the Rubik's Cube problem.

2 Methodology

All relevant approaches are based on dividing the solution space of the Rubik's Cube into mathematical groups, starting with Thistlethwaite, then Reid combining two of Thistlethwaite's groups resulting in total of 3 and finally Kociemba's and Rokicki's approach using 2 subgroups. This makes the group theoretic approach a reasonable starting point for designing Evolutionary Algorithms. It is of particular interest to us to determine how such an EA can solve the Cube without relying on extensive lookup-tables.

3 Approach

Thistlewaiste ES Strategy is used to solve Rubik's cube. Thistlewaiste Algorithm works on progressively using refined set of moves to move to refined states.

It divides these states into 4 subgroups: the last one representing the final solved state. Normal Thistlewaiste's algorithm involves the use of look up tables to move from one state to other. As there can be billions of permutations, so transitions in the look up table. Thistlewaiste ES Strategy starts with a scrambled cube and obtains the Thistlewaiste's group using the Evolutionary Approach: survival of the fittest, by applying penalties on certain cube combinations, multiplying the best ones and keep improving it to progress in a manner similar to the Thistlewaiste group progression.

4 References

1. An Evolutionary Approach for Solving the Rubik's Cube Incorporating Exact Methods by Nail El-Sourani, Sascha Hauke, and Markus Borschbach, University of Applied Sciences,Faculty of Computer Science, Germany.

2. Borschbach, M., Grelle, C.: Empirical Benchmarks of a Genetic Algorithm Incorporating Human Strategies. Technical Report, University of Applied Sciences, Ber-gisch Gladbach (2009)

3. Boyzejko, W., Wodecki, M.: A Hybrid Evolutionary Algorithm for some Discrete Optimization Problems. In: Proceedings of the 5th International Conference on Intelligent Systems Design and Applications, pp. 326–331. IEEE Computer Society,Washington (2005)

4. El-Sourani, N.: Design and Benchmark of different Evolutionary Approaches to Solve the Rubik's Cube as a Discrete Optimization Problem. Diploma Thesis, WWU Muenster, Germany (2009)

5. Florios, K., Mavrotas, G., Diakoulaki, D.: Solving Multiobjective, Multiconstraint Knapsack Problems Using Mathematical Programming and Evolutionary Algorithms. European Journal of Operational Research 203, 14–21 (2009)

6. Frey, A., Singmaster, D.: Handbook of Cubic Math. Enslow, Hillside (1982)

7. Herdy, M., Patone, G.: Evolution Strategy in Action, 10 ES-Demonstrations. Technical Report, International Conference on Evolutionary Computation (1994)

8. Kociemba, H.: Cube Explorer,http://kociemba.org/Cube.htm

9. Muehlenbein, H., Mahnig, T.: FDA - A Scalable Evolutionary Algorithm for the Optimization of Additively Decomposed Functions. Evol. Comput. 7, 353–376 (1999)

10. Reid, M.: Cube Lovers Mailing List, http://www.math.rwth-aachen.de/ Martin.Schoenert/Cube-Lovers/IndexbyAuthor.html

11. Rokicki, T.: Twenty-Five Moves Suffice for Rubik's Cube, http://Cubezzz.homelinux.org/drupal/?q=node/view/121

12. Rokicki, T.:http://www.newscientist.com/article/mg19926681.800-cracking-the-last-mystery-of-the-rubiks-Cube.html

13. Singmaster, D.: Notes on Rubik's Magic Cube. Enslow, Hillside (1981)

14. Thistlethwaite, M.B.: The 45-52 Move Strategy. London CL VIII (1981)

15. Zitzler, E.: Evolutionary Algorithms for Multiobjective Optimization: Methods andApplications. Penn State (1999)