Artificial Intelligence: CS 209 / 214
Project Proposal – Group 6
Evolutionary Algorithms for Mastermind: A Heuristic-Based Approach

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Abstract

This project proposal outlines the plan to explore and enhance algorithms for solving the classic code-breaking game, Mastermind. The game involves a codemaker creating a secret pattern of colored pegs, and a codebreaker attempting to deduce the pattern through a series of guesses and feedback. The feedback, in the form of black and white pegs, tells the codebreaker about the number of characters/colours in the guess that are in the right position, as well as ones that are in the wrong position. Mastermind presents a challenging problem, versions of which have been proven to be NP-complete. It offers opportunities for heuristic-based approaches to improve algorithmic efficiency.

The proposed project aims to build on previous research, particularly the work of Donald Knuth and subsequent mathematicians who devised algorithms to solve Mastermind efficiently. Since the actual game can be modeled as a search problem with a high branching factor in its state space tree, our approach involves implementing a simplified version of the game initially, gradually increasing complexity over time to monitor and enhance algorithm performance.

We plan to employ evolutionary algorithms to address the problem, leveraging heuristic-based strategies to reduce computation and optimize the search process. Our focus will be on adapting and improving existing evolutionary algorithms and exploring the creation of novel strategies for the game. The initial problem model will involve distinct colors, reducing the branching factor and state space tree size.

References to previous research, including Knuth's optimal strategy, Koyama and Lai's exhaustive search, and evolutionary algorithms by Merelo-Guervós et al., will guide our approach. We aim to contribute to the existing body of knowledge by developing more efficient algorithms for Mastermind, ultimately enhancing the game-solving process. The implementation will be iterative, with performance monitoring and algorithm modification throughout the project.

Following Mevelo-Guerv'os' papers [2][8], we create a fitness function that judges how close a combination played is to the code. The operators used to increase diversity include permutations, crossovers and circular mutations. We plan to use modified versions of these diversity changer operations, including random mutations and test their performance against the ones in these papers.

Suggestions and feedback are welcomed as the project progresses, and we anticipate that our research will contribute to advancements in heuristic-based approaches for solving complex combinatorial problems like Mastermind.

References

[1] Berghman, L., Goossens, D., Leus, R.: Efficient solutions for Mastermind using genetic algorithms. Computers and Operations Research 36(6), 1880–1885 (2009), https://doi.org/10.1016/j.cor.2008.06.004

[2] Bernier, J.L., Herr´aiz, C.I., Merelo-Guerv´os, J.J., Olmeda, S., Prieto, A.: Solving mastermind using GAs and simulated annealing: a case of dynamic constraint optimization. In: Ebeling, W., Rechenberg, I., Voigt, H.-M., Schwefel, H.-P. (eds.) PPSN 1996. LNCS, vol. 1141, pp. 554–563. Springer, Heidelberg (1996), https://doi.org/10.1007/3-540-61723-X_1019

[3] Bestavros, A., Belal, A.: Mastermind, a game of diagnosis strategies. Bulletin of the Faculty of Engineering, Alexandria University (December 1986), http://citeseer.ist.psu.edu/bestavros86mastermind.html, available from http://www.cs.bu.edu/fac/best/res/papers/alybull86.ps

[4] Irving, R.W.: Towards an optimum mastermind strategy. Journal of Recreational Mathematics 11(2), 81–87 (1978–1979)

[5] Kendall, G., Parkes, A., Spoerer, K.: A survey of NP-complete puzzles. ICGA Journal 31(1), 13–34 (2008), https://www.graham-kendall.com/papers/kps2008.pdf

[6] Knuth, D.E.: The computer as Master Mind. J. Recreational Mathematics 9(1), 1–6 (1976–1977)

[7] Kooi, B.: Yet another Mastermind strategy. ICGA Journal 28(1), 13–20 (2005), https://dx.doi.org/10.3233/ICG-2005-28105

[8] Merelo-Guerv´os, J.J., Castillo, P., Rivas, V.: Finding a needle in a haystack using hints and evolutionary computation: the case of evolutionary MasterMind. Applied Soft Computing 6(2), 170–179 (2006), `https://dx.doi.org/10.1016/j.asoc.2004.09.003`

[9] Neuwirth, E.: Some strategies for Mastermind. Zeitschrift fur Operations Research. Serie B 26(8), B257–B278 (1982)

[10] Runarsson, T.P., Merelo, J.J.: Adapting heuristic Mastermind strategies to evolutionary algorithms. In: NICSO 2010 Proceedings. LNCS. Springer.