

CAPSTONE PROJECT 1
Planning Document

**Evaluation of Nature-inspired Optimisation
Algorithms in Solving Versus Tetris**

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Abstract

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1 Introduction

Tetris is a popular video game created in 1984 by computer programmer Alexey Pajitnov [1]. It is a puzzle game that requires players to strategically place sequences of pieces known as "Tetriminos" into a rectangular Matrix (refer to Figure 1.1). In the classic game, players attempt to clear as many lines as possible by completely filling horizontal rows of blocks, but if the Tetriminos surpass the top of the Matrix, the game ends.

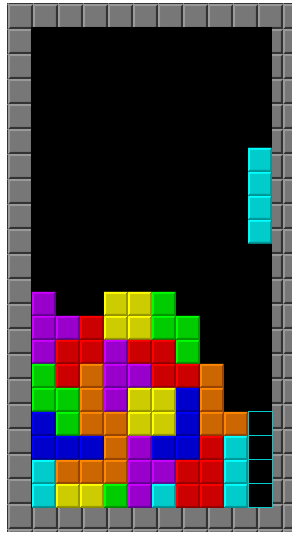


Figure 1.1: A Typical Tetris Game

Since its release, mathematicians and computer scientists have been intrigued by the game of Tetris, leading to a diverse array of research endeavours exploring the various facets of the game, including its computational complexity [2], and its possibility of being won [3] [4].

1.1 Motivation

In their paper, Demaine, Hohenberger, and Liben-Nowell showed that it is NP-complete to optimise several natural objective functions of Tetris [2]. NP-completeness poses a significant challenge in computational problem-solving, as it denotes the absence of polynomial-time algorithms for efficient solutions [5]. Moreover, the discovery of a polynomial-time algorithm for any NP-complete problem implies that any problem in the set of NP, encompassing efficiently verifiable but potentially difficult problems, could be solved in polynomial time [5]. NP-completeness extends beyond Tetris, with real-life instances of NP-complete arising in diverse fields such as route optimisation [6], job scheduling [7], and medicine [8].



Figure 1.2: A Screenshot of a Game of Tetr.io, a Fan-made Versus Tetris Game

To address these challenges, researchers have explored alternative approaches to tackle NP-complete problems, including the use of nature-inspired algorithms [9]. Although they might fail at finding optimal solutions, nature-inspired algorithms are able to return acceptable solutions in shorter running times [10]. In the context of optimising Tetris gameplay, studies have shown the effectiveness of using nature-inspired algorithms in playing the classic single-player game [11] [12]. However, there remains limited research on the effectiveness of nature-inspired optimisation algorithms in the multiplayer versus variant of the game.

1.2 Problem Statement

Versus Tetris (refer to Figure 1.2) presents a unique challenge in computational gaming due to its complex dynamics and real-time competitive nature. While previous research regarding the use of nature-inspired algorithms for Tetris optimisation have focused on single-player scenarios, the effectiveness of these algorithms in the multiplayer context remains largely unexplored. Despite the demonstrated success of these algorithms in improving single-player Tetris gameplay, their application to the multiplayer variant poses distinct challenges due to a different rule set and differing objectives that require further investigation.

1.3 Aim

The aim of this capstone project is to assess the effectiveness of nature-inspired optimisation algorithms in solving the game of Versus Tetris. By integrating insights from nature-inspired algorithms, the project seeks to create a robust and adaptable Tetris-playing software capable of competing against human players or other Tetris-playing programs. Through this endeavour, the project aims to contribute valuable insights into the application of nature-inspired algorithms in addressing computationally complex problems.

1.4 Objectives

The objectives of this project are as follows:

1. Formulate the problem of Versus Tetris for game AI.
2. Research and implement a variety of nature-inspired optimisation algorithms to determine their suitability for optimising gameplay strategies in Versus Tetris.
3. Design a comprehensive framework for objectively evaluating and comparing the performance of the algorithms.
4. Develop a playable game of Tetris that simulates gameplay and training.
5. Using the game, do comparative analyses with the designed framework to assess the effectiveness and efficiency of each algorithms.
6. Summarize findings from the comparative analyses.
7. Share the software with Tetris players of varying aptitudes to find the level of play for each algorithm.

1.5 Project Scope

This project will focus specifically on the evaluation of nature-inspired optimisation algorithms in the context of multiplayer versus Tetris. It will entail the development of a playable Tetris game capable of simulating gameplay and the training of algorithms. This simulation environment will facilitate in the analysis and evaluation of these algorithms' performances. The scope includes the exploring of a range of nature-inspired algorithms to address the unique challenges inherent in Versus Tetris.

2 Literature Review

2.1 Tetris is NP-complete

2.2 Addressing NP-complete Problems

2.3 Nature-inspired Algorithms

2.4 Optimising Tetris with Nature-inspired Algorithms

2.5 Identifying the Research Gaps

2.6 Concluding the Review

3 Technical Plan

4 Work Plan

5 References

- [1] Tetris Inc., *About Tetris*, <https://tetris.com/about-us>, [accessed Apr. 22, 2024].
- [2] E. D. Demaine, S. Hohenberger, and D. Liben-Nowell, “Tetris is hard, even to approximate,” in *Computing and Combinatorics*, T. Warnow and B. Zhu, Eds., Berlin, Heidelberg: Springer Berlin Heidelberg, 2003, pp. 351–363, ISBN: 978-3-540-45071-9.
- [3] J. Brzustowski, “Can you win at tetris?” Master’s Thesis, University of Waterloo, 200 University Ave W, Waterloo, ON N2L 3G1, Canada, 1988.
- [4] H. Burgiel, “How to lose at tetris,” *The Mathematical Gazette*, vol. 81, no. 491, pp. 194–200, 1997. DOI: 10.2307/3619195.
- [5] M. Sipser, “Np-completeness,” in *Introduction to the Theory of Computation*, Cengage Learning, 2013.
- [6] V. Lesch, M. König, S. Kounev, A. Stein, and C. Krupitzer, “A case study of vehicle route optimization,” *CoRR*, vol. abs/2111.09087, 2021.
- [7] J. D. Ullman, “Np-complete scheduling problems,” *Journal of Computer and System sciences*, vol. 10, no. 3, pp. 384–393, 1975.
- [8] J. Arle and K. Carlson, “Medical diagnosis and treatment is np-complete,” *Journal of Experimental & Theoretical Artificial Intelligence*, vol. 33, pp. 1–16, Mar. 2020. DOI: 10.1080/0952813X.2020.1737581.
- [9] L. Davis, “Job shop scheduling with genetic algorithms,” in *Proceedings of the First International Conference on Genetic Algorithms and Their Applications*, 1985, pp. 136–140.
- [10] W. Korani and M. Mouhoub, “Review on nature-inspired algorithms,” *Operations Research Forum*, vol. 2, Jul. 2021. DOI: 10.1007/s43069-021-00068-x.
- [11] J. Lewis, “Playing tetris with genetic algorithms,” 2015. [Online]. Available: <https://api.semanticscholar.org/CorpusID:17416568>.
- [12] L. Langenhoven, W. S. van Heerden, and A. P. Engelbrecht, “Swarm tetris: Applying particle swarm optimization to tetris,” in *IEEE Congress on Evolutionary Computation*, 2010, pp. 1–8. DOI: 10.1109/CEC.2010.5586033.