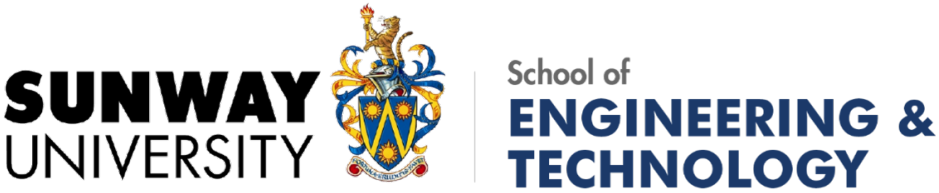

CAPSTONE PROJECT 1
Activity Log

Playing Versus Tetris with Nature-inspired Optimisation Algorithms

by

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Contents

1 Timeline

In this chapter, the project's progression is meticulously documented. In these pages, the critical stages of the project are depicted, each accompanied by a concise description illuminating the strategies and rationales behind the allocated times.

Furthermore, the week-by-week tasks undertaken are outlined within these sections. Thus, offering a granular insight into the day-to-day endeavours taken to propel the project towards its culmination.

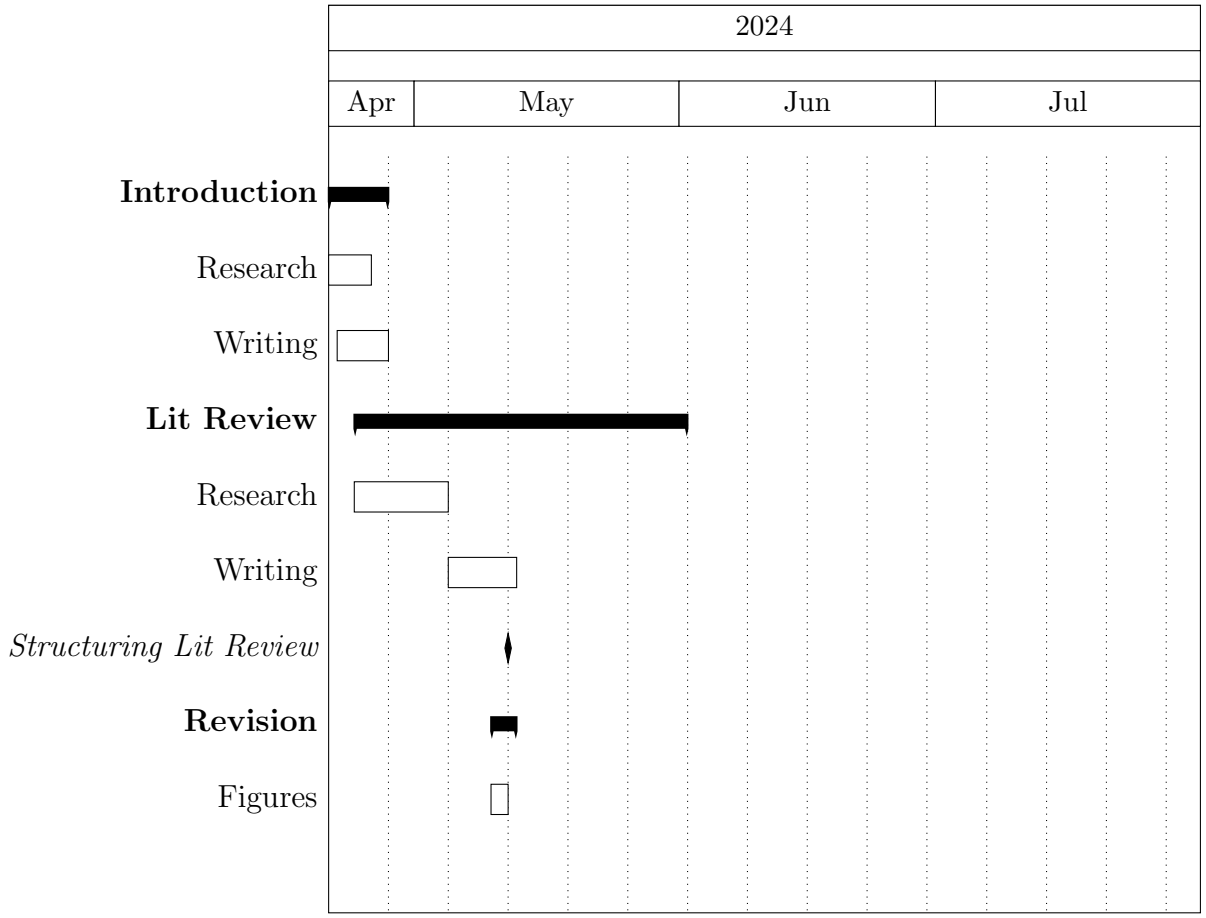

Figure 1.1: Gantt Chart of Timeline

1.1 Writing an Introduction

The introduction serves as the project's foundation, providing essential background information, introducing the topic, and articulating the project's objectives. Recognising its pivotal role, **one week** of time was allocated for its composition. This deliberate time-frame aimed to allow ample time for thoroughness, ensuring no essential elements were overlooked in writing a comprehensive and compelling introduction.

1.1.1 Week 1 (21 April - 27 April)

This week, a significant portion of my time was dedicated to researching resources for the introduction section of the project. I looked into various academic papers and online resources to gather insights and background information relevant to the topic. Utilising Google Scholar, I tried to familiarise myself with existing research on Tetris, nature-inspired algorithms and NP-completeness to write a compelling introduction.

The latter part of the week was primarily focused on drafting and refining the introduction section. After seeking feedback from Dr Richard, he provided me constructive critiques on my initial motivation and challenged me to think deeper about the broader significance of the project. His feedback encouraged me to explore avenues beyond the mere identification of a research gap.

After several iterations, I believe the introduction is now in a more robust and coherent state, with a clearer articulation of the project's motivation and objectives. Dr Richard's guidance helped me realise the importance of grounding the project in broader contexts and considering its potential implications beyond academic research.

1.2 Conducting the Literature Review

The literature review is one of the chapters that will take up a lot of space in the planning document. It is important to be thorough and correct about the information written on these pages. As such, a generous time of **seven weeks** were allocated to research and write this section.

1.2.1 Week 1 (21 April - 27 April)

While writing the introduction, I found numerous papers that could be used for the literature review section of the project. I tried to read up on and digest information on NP-completeness, proving a problem is NP-complete, multi-objective functions and nature-inspired algorithms.

1.2.2 Week 2 (28 April - 4 May)

As more time goes by, the semester naturally gets heavier. All practical classes started this week. Subsequently, more time was allocated to my other subjects. I took this week to get accustomed to managing my time, balancing my lectures, practicals as well as research.

When I did have time this week, I read up on the articles and papers that I have

found in Week 1 (refer to Subsection 1.2.2) and began writing annotations for the bibliography. I tried to digest what I read and create atomic notes on ideas that could help when writing the literature review.

1.2.3 Week 3 (5 May - 11 May)

Most of this week was dedicated to structuring the literature review. I tried to think of a flow that would help the reader understand as much as possible. I knew that I wanted to delve into the mathematics of NP-completeness, argue why I chose to use nature-inspired algorithms, and eventually divert attention back to optimising Tetris.

1.2.4 Week 4 (12 May - 18 May)

I spent the first half of the week looking at textbooks and online lectures to gain a deeper understanding of computational complexity. As Tetris being NP-complete is one of the central motivations of the project, understanding complexity and the proof was extremely important.

After doing some research, I started on the literature review. I split the first section into two parts. The first part is dedicated to explaining certain key concepts of complexity, including complexity classes, the P vs NP problem, etc. The second part is planned to delve into reductions, explain the 3-partition problem briefly, and take a closer look at the Tetris proof.

I also had my second meeting with Dr Richard this week, where he gave me some recommendations on what to include in each section of the review.

1.2.5 Week 5 (19 May - 25 May)

As the assignments started pouring in this week, I spent less time working on the project. I did eventually complete the first section of the literature review, but a quick chat with Dr Richard revealed that the section was a little directionless. This meant that I needed to completely restructure the section.

1.2.6 Week 6 (26 May - 1 June)

This week was dedicated to rewriting most of the first section of the literature review, on the topic of complexity and justifying the use of non-traditional algorithmic approaches. I spent most of the week finding where certain pieces of content can be placed more appropriately in the new structure.

I also had a meeting with Dr Richard, where he approved of the new direction I

was taking with the literature review. He also recommended that I start thinking about the methodology of the project.

1.2.7 Week 7 (2 June - 8 June)

This week, I hit a bit of a slump. With the many assignments that I was taking on and other deadlines to meet, I ended up neglecting the project a little too much. In the end, I only finished the first section of the literature review hastily. It will probably need some refinement before submission.

1.2.8 Week 8 (9 June - 15 June)

This week, I had a meeting with Dr Richard to discuss the trajectory of the literature review. He gave me some insights into what I should be doing for the sections that I have written, and some future chapters. In the coming week, I aim to finish at least another section of the literature review, and completely finish it by our next meeting.

1.2.9 Week 9 (16 June - 22 June)

Most of the week was spent on finding resources for the rest of the literature review. Some time was spent on deciding on the structure of the remaining sections. Additionally, I finally started on the second section of the literature review.

1.2.10 Week 10 (23 June - 29 June)

1.2.11 Week 11 (30 June - 6 July)

1.2.12 Week 12 (7 July - 13 July)

1.3 Coming Up With a Technical Plan

1.4 Creating a Work Plan

1.5 Making Revisions

1.5.1 Week 3 (5 May - 11 May)

Besides working on the literature review this week (refer to Subsection 1.2.3), I also spent some time refining the figures used in the introduction. With the help of Dr Richard, I learnt to use the tikz LaTeXpackage in order to draw better figures. This was also done to

achieve more consistent figures, as I found having screenshots and images from different sources led to a messier paper.

2 Bibliography

[1] Tetris Inc., *About Tetris*, https://tetris.com/about-us, [accessed Apr. 22, 2024].

In this webpage, the game of Tetris is described as an addictive puzzle game, there are references to some rules of the game, which includes the clearing of lines and the losing condition. There is also a section on the creator of Tetris. As this is the 'About Us' page of the official Tetris website, this is treated as a credible source. This source will be used to introduce the Tetris game. It gives readers a good amount of information without being too overwhelming.

[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.

In their paper, Demaine et al. mathematically proves that the natural objectives of Tetris - minimising the height of an occupied square, maximising the number of pieces placed, maximising the number of cleared rows and maximising the number of Tetrises (clearing four lines in a row) are NP-complete. This paper is credible because rigorous mathematical proof is used to come to its conclusions. This source will be used to introduce the NP-completeness of Tetris, a central motivation behind the project.

[3] J. Brzustowski, "Can you win at tetris?" Master's Thesis, University of Waterloo, 200 University Ave W, Waterloo, ON N2L 3G1, Canada, 1988.

In this thesis, Brzustowski proves that the classic game of Tetris is unwinnable if the computer is aware of and reacting to the player's moves. This is because certain pieces will lead to a loss given to the player in a sequence. This thesis is referenced in several different research papers relating to the game. This source will be used as an example for the research that is being done on Tetris.

[4] H. Burgiel, "How to lose at tetris," *The Mathematical Gazette*, vol. 81, no. 491, pp. 194–200, 1997. DOI: 10.2307/3619195.

In this article, Burgiel proved that any game of Tetris is unbeatable, regardless of whether the machine is aware of the player's move. Rigorous mathematical proof is provided to show that this is true. This article will be used as an example for the research that is being done on Tetris.

[5] M. Sipser, in *Introduction to the Theory of Computation*, Cengage Learning, 2013.

In a of theis textbook, Sipser describes NP-completeness and shares some characteristics of NP-complete problems. Sipser is an American theoretical computer scientist who made many contributions in the field of computational complexity. This source will be used to describe the properties of NP-complete problems.

[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.

In their paper, Lesch et al. introduces vehicle route optimisation as an NP-complete problem. They then utilise nature-inspired algorithms including ant colony optimisation and genetic algorithms to tackle route optimisation. This source will be used to introduce route optimisation as a proven NP-complete problem.

[7] J. D. Ullman, "Np-complete scheduling problems," *Journal of Computer and System sciences*, vol. 10, no. 3, pp. 384–393, 1975.

In this article, Ullman demonstrates that several scheduling problems including single execution time scheduling and two processor scheduling are NP-complete. This source will be used to introduce job scheduling as a proven NP-complete problem.

[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.

In this article, Arle and Carlson show that medical diagnosis and treatment (MDT) is NP-complete. This is done by reducing the travelling salesman problem and set-cover problems to MDT. This source will be used to show that NP-complete problems also exist within the field of medicine.

[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.

In this paper, Davis highlights the limitations of deterministic scheduling algorithms and introduces genetic algorithms as a non-deterministic approach to solving the job shop scheduling problem. Through a series of experiments, he demonstrates the efficacy of genetic algorithms in generating schedules that optimize profit, even in the face of changing constraints and uncertainties typical of real-world job shops. This paper provides valuable insights into the application of a nature-inspired algorithm, genetic algorithms, in solving NP-complete problems.

[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.

This paper is a review of nature-inspired algorithms, focusing on their performance analysis, reporting of experimental evaluation results, and guidelines for proposing new nature-inspired techniques. This source will be used to demonstrate the effectiveness of using nature-inspired algorithms over traditional exact methods.

[11] J. Lewis, "Playing tetris with genetic algorithms," 2015. [Online]. Available: https://api.semanticscholar.org/CorpusID:17416568.

In this paper, Lewis explores the application of genetic algorithms to optimise Tetris gameplay. It delves into representing Tetris states using features such as game score and board configuration, with moves selected based on weighted feature sums. Through a genetic algorithm framework involving population-based selection, mutation, and crossover, the paper demonstrates the evolution of Tetris-playing strategies over 30 generations. Results indicate significant improvements in gameplay efficiency, with optimised players achieving an average game length of 179,531 moves and an average score efficiency of 2.5. This paper will be used as an example of using nature-inspired algorithms in tackling Tetris.

[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.

This paper investigates the use of particle swarm optimization (PSO) to train neural network agents for playing the game of Tetris. The experimental results show the learning progress of the algorithm and compare it to a hand-optimized Tetris playing algorithm. The study concludes that a swarm-based approach is feasible for Tetris and suggests avenues for future work to further optimize the training algorithm parameters and improve the performance of the neural agents. The paper provides valuable insights into the application of computational intelligence techniques to game-playing agents.

[13] S. Asif, M. Coulombe, E. Demaine, *et al.*, "Tetris is np-hard even with o(1) rows or columns," *Journal of Information Processing*, vol. 28, pp. 942–958, Jan. 2020. DOI: 10.2197/ipsjjip.28.942.

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3 Meeting Records