

CAPSTONE PROJECT 2

Activity Log

Playing Versus Tetris with a Genetic Algorithm

by

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1 Timeline and Activities

1.1 CP1 Timeline

In this section, the CP1's progression is meticulously documented. In these pages, the critical stages of the project are depicted in the form of tables. A Gantt chart of the timeline is also provided to give an overview of the project's temporal progression.

Table 1.1: CP1 Overall Work Activities

Phases	Work Activities	Work Product	Risk Factors	Time Allocated
Introduction	Write a comprehensive introduction, including the motivation, problem statement, aim, objectives and scope of the project.	A comprehensive introduction	Misunderstanding of concepts	1 Week
Literature Review	Find and read a wide variety of literature to write a comprehensive review that (1) justifies the use of non-traditional algorithms and (2) showcase past approaches to the game.	A comprehensive literature review that has a diverse set of sources	Lack of understanding of concepts, misunderstanding concepts	12 Weeks

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Table 1.1: CP1 Overall Work Activities (Continued)

Methodology	Come up with a methodology that covers all bases, it should include rule definition, algorithm selection, problem formulation and evaluation metrics	A well-defined methodology	Inadequate explanation of rules, trouble formulating problem formally	4 Weeks
Work Plan	Create a work plan that includes this table, a Gantt chart summarising what has been done in the planning phase of the project, as well as a similar table and Gantt chart for the implementation phase.	A well-defined work plan with goals to be met	Time constraints, formatting issues	1 Week

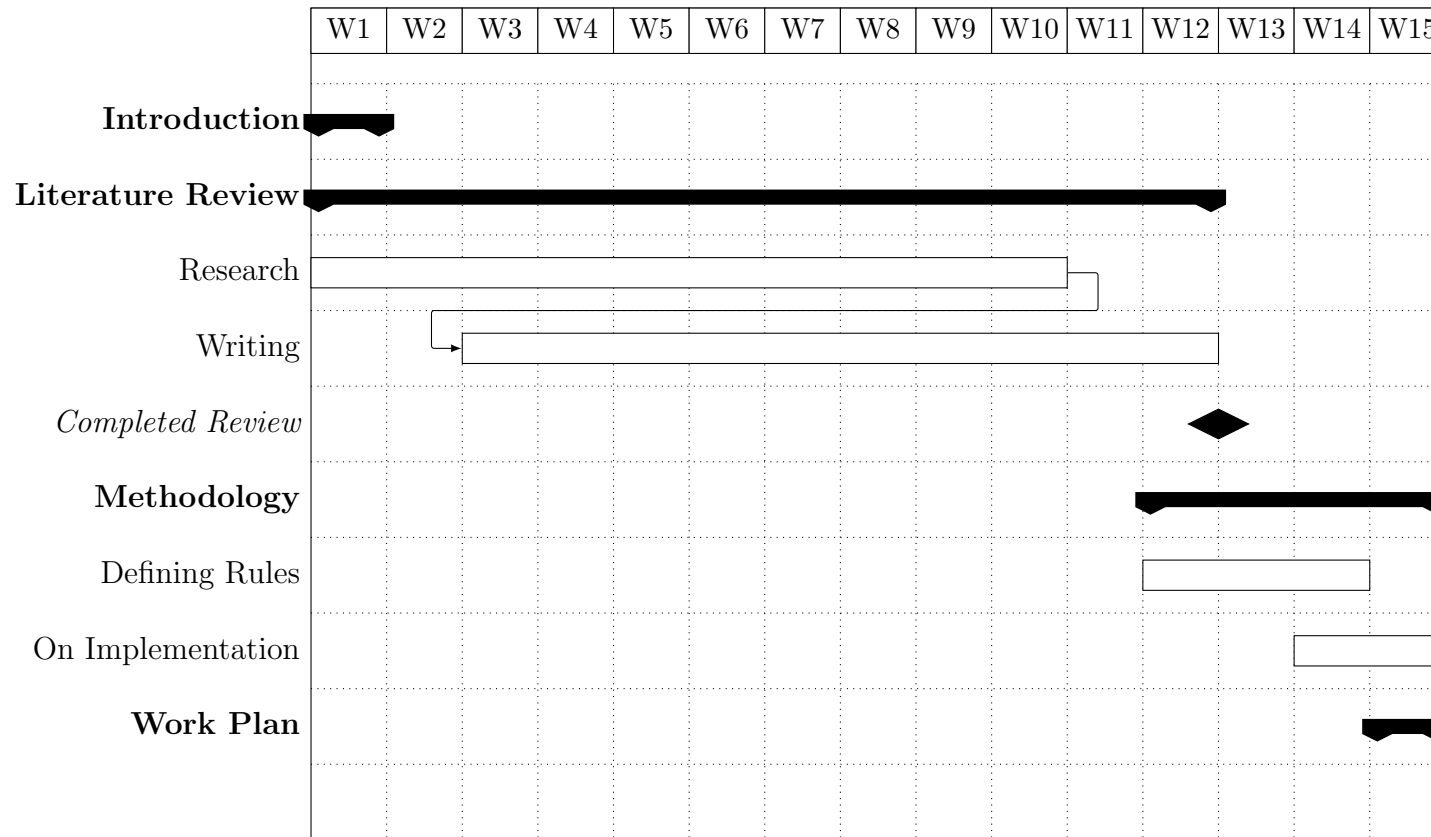


Figure 1.1: CP1 Timeline

1.1.1 CP1 Weekly Breakdown

In this section, a week-to-week overview that summarises work done that particular week will be shown in table form. Each subsection will contain a table that showcases work done for a particular chapter of the planning document.

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.

Table 1.2: Weekly breakdown of work done for Introduction Chapter.

Week	Work Done
1	<ul style="list-style-type: none">• Researched existing literature on Tetris, NP-completeness and Nature-inspired algorithms.• Wrote the introduction chapter.• Learnt the tikz \LaTeX package to draw better figures.

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 **twelve weeks** were allocated to research and write this section.

Table 1.3: Weekly breakdown of work done for Literature Review Chapter.

Week	Work Done
1	<ul style="list-style-type: none">• Found and read literature on NP-completeness.• Tried to understand computational complexity as a whole.
2	<ul style="list-style-type: none">• Continued researching NP-completeness.• Understood enough computational complexity for the project: complexity classes, reductions, P and NP, etc.
3	<ul style="list-style-type: none">• Found and read literature on the difficulty of Tetris.• Began writing the first section of the literature review, dedicated to showing the intrinsic difficulty of the game of Tetris.

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Table 1.3: Weekly breakdown of work done for Literature Review Chapter. (Continued)

4	<ul style="list-style-type: none"> • Finished writing first section of literature review. • Created images for clarity.
5	<ul style="list-style-type: none"> • Found literature that utilise different approaches to playing Tetris with AI.
6	<ul style="list-style-type: none"> • Continued finding different approaches taken to play Tetris. • Specifically read and digested paper on imitation learning. • Began structuring second section of the literature review, dedicated to showcasing some of the approaches taken to play Tetris that aren't nature-inspired.
7	<ul style="list-style-type: none"> • Completed a subsection on the use of imitation learning for playing Tetris • Read up on Monte-Carlo Tree Search, UCB1, and how it is used as an approach to Tetris.
8	<ul style="list-style-type: none"> • Completed a subsection on the use of UCB1 for playing Tetris. • Read up on some deep reinforcement learning concepts because some papers were found that used Q-learning to play Tetris.
9	<ul style="list-style-type: none"> • Read literature that described the use of deep reinforcement learning for Tetris. • Completed a subsection on the use of deep reinforcement learning for playing Tetris. • Found and read papers that utilise non nature-inspired meta-heuristics like Harmony Search Algorithm and MVP Algorithm to play Tetris. • Found literature on using Genetic Algorithms and Particle Swarm Optimisation to play Tetris.
10	<ul style="list-style-type: none"> • Found and read literature on the use of Ant Colony Optimisation to play Tetris. • Completed a subsection on the use of different meta-heuristic algorithms for playing Tetris. • Started writing section dedicated to demonstrating the use of nature-inspired algorithms in playing Tetris.
11	<ul style="list-style-type: none"> • Completed a subsection on the use of genetic algorithms in playing Tetris.
12	<ul style="list-style-type: none"> • Completed a subsection on the use of Particle Swarm Optimisation in playing Tetris. • Completed a subsection on the use of Ant Colony Optimisation in playing Tetris.

Methodology

The methodology is arguably the most important chapter of the review as it sets up the entire project in the implementation phase (CP2). **Four weeks** were allocated to write up the methodology, which should define everything that will be done in a structured manner.

Table 1.4: Weekly breakdown of work done for Methodology Chapter.

Week	Work Done
12	<ul style="list-style-type: none">• Structured the Methodology chapter• Began writing section on rules, defining the piece randomiser and matrix dimensions.
13	<ul style="list-style-type: none">• Researched Tetris spin rules.• Continued writing rules section, defining spins, gravity and other features.
14	<ul style="list-style-type: none">• Researched Tetris attack rules.• Completed writing rules section, adding attack rules to the rules.• Completed section on algorithm selection.• Began problem formulation section.
15	<ul style="list-style-type: none">• Completed problem formulation section.• Completed section on evaluation metrics.

Work Plan

Careful consideration needs to be taken when coming up with a work plan. Risk factors need to be thought of and time needs to be allocated to each task. However, since the work plan takes up the least space in the document, only **one week** of time was allocated to it.

Table 1.5: Weekly breakdown of work done for Work Plan Chapter.

Week	Work Done
15	<ul style="list-style-type: none">• Came up with tasks that need to be done.• Created table to showcase work activities, risk factors, and time allocated for all tasks.• Created Gantt chart to visualise the timeline.

1.2 CP2 Timeline

Much like for CP1, this section will be used to outline CP2's progression. Here, we will discuss the critical stages of the project are depicted them in the form of tables. A Gantt chart of the timeline is also provided to give an overview of the project's progression.

Table 1.6: CP2 Overall Work Activities

Phases	Work Activities	Work Product	Risk Factors	Time Allocated
Building Simulation	Create a robust simulation with all rules included in CP1's planning document.	A complete simulation tool	Bugs, Issues with bot, development issues.	4 Weeks
Creating Bot	Build a bot that is able to find most if not all legal placements, using an evaluation function to decide on its moves.	A bot that can find most if not all legal placements, evaluation function of bot.	Difficulty finding legal placements, unexpected bot behaviour, bugs.	8 Weeks
GA Implementation	Implement Genetic Algorithm to optimise weight vectors. GA should have justifiable fitness functions, mutation rate and other metrics. GA should be able to generate data to be evaluated.	A complete genetic algorithm	Issues with implementation, GA definition, GA runtime too long.	3 Weeks

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Table 1.6: CP2 Overall Work Activities (Continued)

Report Writing	Make changes to methodology if any, gather data for results, write results and complete conclusion	A complete final report	Time constraints, formatting issues	3 Weeks
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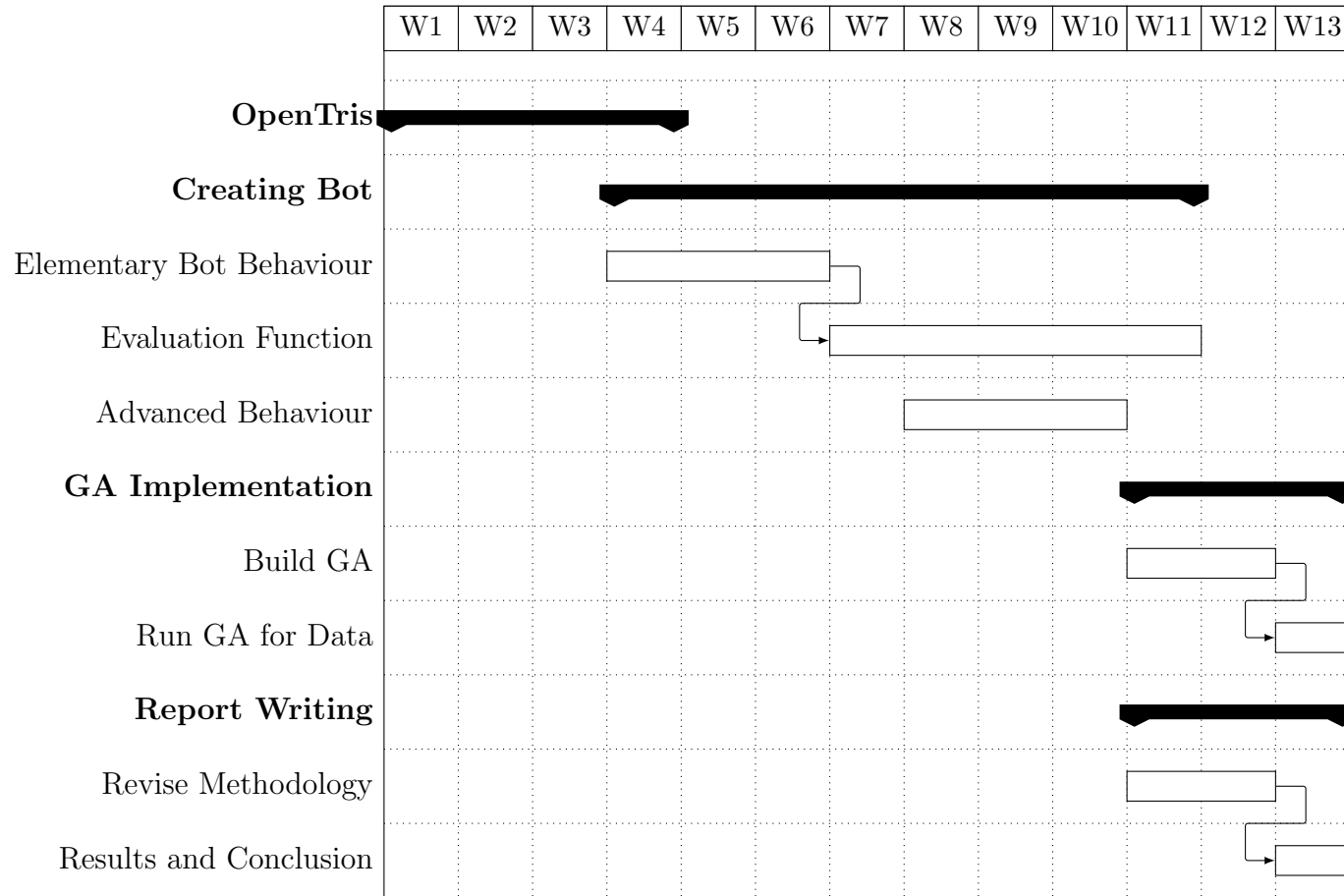


Figure 1.2: CP2 Timeline

1.2.1 CP2 Weekly Breakdown

Much like for CP1, this section will be dedicated to summarising the work done in a particular week in table form. Each subsection will contain a table that showcases work done implementing the project and completing the final report.

Building OpenTris

Since I could not find any simulations of Versus Tetris suited to my use case, I decided to build my own simulation. I built OpenTris for my exact use case, a simulation capable of pitting bots against each other, using an evaluation function to play. I spent **4 weeks** working on the simulation to ensure everything ran smoothly.

Table 1.7: Weekly breakdown of work done for OpenTris.

Week	Work Done
1	<ul style="list-style-type: none">• Planning the simulation, coming up with necessary classes.• Started working on simple rendering engine and a bot that only hard drops.
2	<ul style="list-style-type: none">• Worked on game logic, including wall kicks, rotations, movements as well as a seeded randomiser for piece sequence generation.
3	<ul style="list-style-type: none">• Refined game logic, cleaned up code, made changes to ensure correct mechanics.
4	<ul style="list-style-type: none">• Worked on garbage mechanics, creating stored attacks.• Improved player movement controls.

Creating Bot

In order to test the weight vectors generated from the genetic algorithms, a bot had to be created that was able to take those weights and plug them into an eval function. I gave myself a generous 8 weeks to complete the development of the bot completely.

Table 1.8: Weekly breakdown of work done for the bot.

Week	Work Done
4	<ul style="list-style-type: none">• Planning bot behaviour, including placements and actions to reach those placements.
5	<ul style="list-style-type: none">• Wrote an elementary bot capable of finding legal placements.• Found a way for bot to take sequences of actions to reach final placements.

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Table 1.8: Weekly breakdown of work done for the bot. (Continued)

6	<ul style="list-style-type: none"> • Got stuck on implementing a way for the bot to do tucks and spins. • Tentatively stick with current bot behaviour.
7	<ul style="list-style-type: none"> • Started working on a simple evaluation function that looked at pile height and hole count as features.
8	<ul style="list-style-type: none"> • Started working on finding ways to include tucks and spins into considered placements.
9	<ul style="list-style-type: none"> • Came up with a way for the bot to perform tucks. • Added hole depth to evaluation function.
10	<ul style="list-style-type: none"> • Came up with a way for the bot to perform spins.
11	<ul style="list-style-type: none"> • Finalised evaluation function by adding column transitions, row transitions, cumulative well depth, row holes, line clears, attacks and back-to-back as features.

GA Implementation

The genetic algorithm is the main purpose of this project. I had to ensure that it was able to produce results in the limited amount of time I had left. Thus, I decided to spend the rest of the **3 weeks** of CP2 working on the GA.

Table 1.9: Weekly breakdown of work done for the GA implementation.

Week	Work Done
11	<ul style="list-style-type: none"> • Began planning GA representation, crossover, selection, etc. • Began implementation and testing of GA.
12	<ul style="list-style-type: none"> • Added logging functions to retrieve information on each population and their fitness, along with the best fit individual in each population. • Tweaked GA parameters, decreased population size due to time constraints.
13	<ul style="list-style-type: none"> • Let the GA run. • Obtain data successfully.

Report Writing

After I was done with programming the bot, I started work on the final report. I had to revise the methodology to fit my current implementation, and also adjust the report as I decided to focus only on a single nature-inspired algorithm instead of several. I spent the final **3 weeks** of CP2 working on the final report.

Table 1.10: Weekly breakdown of work done for the final report.

Week	Work Done
11	<ul style="list-style-type: none"> • Found discrepancies between methodology and current implementation. • Began aligning methodology accordingly.
12	<ul style="list-style-type: none"> • Completed methodology refinement.
13	<ul style="list-style-type: none"> • Obtained results • Wrote results chapter • Wrote conclusion

2 Meeting Records

Throughout the semester, I had six meetings with Dr Richard. Each time we discussed the work that had been done between the current and previous meeting. Dr Richard gave me plenty of pointers, as well as personal advice to produce a better project.

The following pages contain all meeting records, including the date and time of the meeting, the items discussed, and the expected work outcomes before the next meeting.

SCHOOL OF ENGINEERING AND TECHNOLOGY
DEPARTMENT OF COMPUTING AND INFORMATION SYSTEMS

SUPERVISION MEETING RECORD

Meeting 1

Date: 19 September 2024

Time: 10:30 AM - 11:00 AM

Student: Yap Wei Xiang

Supervisor: Dr Richard Wong Teck Ken

Items Discussed this Meeting:

- Set up meeting times for Capstone 2.
- Outlined structure of the final report.

Work for the Coming Meeting:

- Start work on the Tetris simulation.

Supervisor Signature:



Dr Richard Wong

Student's Signature:



SUPERVISION MEETING RECORD

Meeting 2

Date: 04 October 2024

Time: 02:00 PM - 02:30 PM

Student: Yap Wei Xiang

Supervisor: Dr Richard Wong Teck Ken

Updates From the Previous Meeting:

- Made progress on simulation
 - ❖ Including visual rendering of the game state, correct wall kicks, rotation logic, movement logic, a seeded randomizer, and some preliminary controls.

Items Discussed this Meeting:

- Some concerns of the potential outputs.
 - ❖ Speed of convergence depends heavily on the starting points given to each algorithm, which is random.
- Update in methodology
 - ❖ Methodology needs to be updated from CP1, some decisions were made during the development of the simulation.
- The evaluation function might need to be dynamic, but Dr Richard advised me to stick to using static weights for now.

Work for the Coming Meeting:

- Complete simulation (stored attack, garbage lines, etc.)
- Begin work on an evaluation function which would be a weighted sum of numerical features.

Supervisor Signature:



Dr Richard Wong

Student's Signature:



SUPERVISION MEETING RECORD

Meeting 3

Date: 18 October 2024

Time: 02L00 PM - 02:30 PM

Student: Yap Wei Xiang

Supervisor: Dr Richard Wong Teck Ken

Updates From the Previous Meeting:

- Completed simulation
 - ❖ Including game mechanics involving stored attacks, garbage lines, and improved movement controls.

Items Discussed this Meeting:

- Clarification of the purpose of evaluation function.
 - ❖ To help the bots make decisions on placements.
- Potential ideas for Bot AI.
 - ❖ Utilising tree search to find potential best placements.

Work for the Coming Meeting:

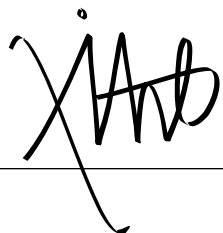
- Start work on bot behaviour (evaluation function, numerical feature collection, pathfinding, etc.)
- Update methodology

Supervisor Signature:



Dr Richard Wong

Student's Signature:



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DEPARTMENT OF COMPUTING AND INFORMATION SYSTEMS

SUPERVISION MEETING RECORD

Meeting 4

Date: 08 November 2024

Time: 02:00 PM - 02:30 PM

Student: Yap Wei Xiang

Supervisor: Dr Richard Wong Teck Ken

Updates From the Previous Meeting:

- Having trouble with bot decisions, can't figure out how to find legal placements.

Items Discussed this Meeting:

- Decided on using a search tree to help find legal placements
- Dr Richard suggested several things to shorten the time it might take to find the "best" move for a piece.
 - ❖ Use Q-learning.
 - ❖ Don't take into account all lookahead pieces.

Work for the Coming Meeting:

- Complete function to find all legal placements.

Supervisor Signature:



Dr Richard Wong

Student's Signature:



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DEPARTMENT OF COMPUTING AND INFORMATION SYSTEMS

SUPERVISION MEETING RECORD

Meeting 5

Date: 22 November 2024

Time: 02:00 PM - 02:30 PM

Student: Yap Wei Xiang

Supervisor: Dr Richard Wong Teck Ken

Updates From the Previous Meeting:

- Started work on finding legal placements.

Items Discussed this Meeting:

- Next steps:
 - ❖ Enable bot to find spin opportunities.
 - ❖ Figure out numerical features that should be added into evaluation function.
 - ❖ Begin implementation on genetic algorithm.
- Shift focus from several nature-inspired algorithms to just one - Genetic Algorithm

Work for the Coming Meeting:

- Complete evaluation function and bot functionalities.
- Begin work on genetic algorithm
- Begin report writing.

Supervisor Signature:



Dr Richard Wong

Student's Signature:



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DEPARTMENT OF COMPUTING AND INFORMATION SYSTEMS

SUPERVISION MEETING RECORD

Meeting 6

Date: 06 December 2024

Time: 02:00 PM - 02:30 PM

Student: Yap Wei Xiang

Supervisor: Dr Richard Wong Teck Ken

Updates From the Previous Meeting:

- Bot behaviour fully implemented.
- Started work on genetic algorithm.

Items Discussed this Meeting:

- GA taking a while to complete.
 - ❖ Suggested using less individuals.
 - ❖ Let the current implementation run fully.
- Methodology and result writing.

Work for the Coming Meeting:

- Complete document and code.

Supervisor Signature:



Dr Richard Wong

Student's Signature:

