Problem Statement and Goals
Software Engineering

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Table 1: Revision History

Date	Developer(s)	Change
Sept. 17th	Matthew	Added preliminary problem statement for sections 1-1.4
Sept. 21st	Jake	Added goals and stretch goals sections and polished document
Sept. 21st	Jake	Added personal reflection

1 Problem Statement

1.1 Problem

The project aims to create an AI-enabled digital twin for the board game *Settlers of Catan*. The core problem is that *Catan*'s complexity, with its numerous possible moves and game states, makes it challenging for human players to calculate optimal strategies. This project seeks to leverage AI, specifically reinforcement learning (RL), to overcome this limitation. **The AI will provide real-time decision support offering in-game advice to help players learn and improve, as well as post-game analysis to review critical moments.

1.2 Inputs and Outputs

The system's high-level inputs are the game state information of a *Catan* match. This includes the positions of roads, settlements, and cities, the resources and development cards held by each player, and the location of the robber. This information can be fed into the system in various ways, such as a manual entry of a static snapshot or **through real-time video feeds that are processed to

detect the game state. The high-level outputs recommended actions for the player and the ability to simulate gameplay against one or more AI bots, each having their own unique playstyle **(e.g., longest road, largest army). **This includes suggesting the best move to make during a turn, such as where to build a road or what to trade. It also includes providing post-game advice, such as identifying a past decision that could have been made differently to alter the game's outcome.

1.3 Stakeholders

The primary stakeholders for this project are:

- Players of *Settlers of Catan*: The end-users who will use the AI for in-game and post-game analysis to improve their skills, or train against various skilled AI bots.
- Dr. Istvan David: The project supervisor who provides guidance, expertise, and oversight.
- The Project Team: The developers responsible for designing, implementing, and testing the software.
- The Department of Computing and Software (CAS) at McMaster University: The organization hosting the project, which benefits from the academic and technical achievements of its students and faculty.

1.4 Environment

The project requires a hardware and software environment to support the various modules. The core of the system will run on a central processing unit (for example, a server or a high-powered laptop) capable of handling the computational demands of AI.

On the software side, the system will need:

- A game simulator to serve as a training environment for the RL agents.
- A reinforcement learning framework (for example, Farama Foundation's Gymnasium) to train the AI.
- A computer vision library (for example, YOLO) to process video feeds and translate them into a digital game state representation.
- A user-facing application for the player, for example a website or mobile application .
- A visual display (for example, a virtual board or text) to show a digital representation of the game state and the AI's actions.

On the hardware side, the project requires:

- A computer with a processor and GPU to run the AI and computer vision modules.
- Devices (for example, laptops or smartphones) for the players to use the application and stream video of the game board.
- A physical *Catan* board game for testing the computer vision and digital twin functionalities.

2 Goals

The following are the major goals for the project:

- Create a simulation environment for *Catan*, encoding game rules such that in a given state, a set of potential moves is returned.
- Devise starting states/confer with experts to find some initial board setups and corresponding strategies to aid the model's early learning.
- Utilize the simulation environment to train a deep reinforcement learning model to play *Catan* to at least the level of the average human player.
- Use computer vision/sensors to transfer the current state of a physical table-top *Catan* game to our simulation (Create a digital twin).
- Send the move generated by the model back to the user in some form.
- Develop a visualisation of the game on the digital twin's side to help explain actions.

3 Stretch Goals

In addition to the project's primary goals the following are stretch goals we will aim to complete if possible:

- Construct personas relating to various kinds of players and the strategies they will typically utilize in the game's trading system in order to improve the model's predictions.
- Improve the model to the extent that it performs better than the average *Catan* player, perhaps even finding strategies unknown to current competitive players.
- Generate explanations of "what could've been" following a game via LLM integration.
- Further augment the physical board to simulation transfer via the use of multiple camera angles or smart glasses.

4 Extras

[For CAS 741: State whether the project is a research project. This designation, with the approval (or request) of the instructor, can be modified over the course of the term. —SS]

[For SE Capstone: List your extras. Potential extras include usability testing, code walkthroughs, user documentation, formal proof, GenderMag personas, Design Thinking, etc. (The full list is on the course outline and in Lecture 02.) Normally the number of extras will be two. Approval of the extras will be part of the discussion with the instructor for approving the project. The extras, with the approval (or request) of the instructor, can be modified over the course of the term. —SS]

Appendix — Reflection

1. What went well while writing this deliverable?

2. What pain points did you experience during this deliverable, and how did you resolve them?

3. How did you and your team adjust the scope of your goals to ensure they are suitable for a Capstone project (not overly ambitious but also of appropriate complexity for a senior design project)?

The purpose of reflection questions is to give you a chance to assess your own learning and that of your group as a whole, and to find ways to improve in the future. Reflection is an important part of the learning process. Reflection is also an essential component of a successful software development process.

Reflections are most interesting and useful when they're honest, even if the stories they tell are imperfect. You will be marked based on your depth of thought and analysis, and not based on the content of the reflections themselves. Thus, for full marks we encourage you to answer openly and honestly and to avoid simply writing "what you think the evaluator wants to hear."

Please answer the following questions. Some questions can be answered on the team level, but where appropriate, each team member should write their own response:

Jake Read:

1. Most aspects of this deliverable went quite smoothly. We were able to fairly split the work, in such a way that we all contributed important sections, but were able to work in our own time, reducing time spent in meetings. I believe we were able to balance things in such a way that despite working on different sections, each of us still has a general understanding of the content in each part. What I'm happiest about is that we all seem to be working well together. There hasn't been any conflict between the four of us, and we were upfront about our schedules and availability and have stuck to the expectations we set. Whenever I ran into issues or had questions, it was easy to get a hold of someone in our Discord to help. The Discord server I set up has been perfect for organization, we have a general chat and various channels for sources, notes, resources, etc. Whenever we had any questions none of us could answer, we reached out to our TA or our supervising professor, who were happy to help.

2. We had a couple pain points during the project selection. We knew we wanted to work with AI/ML in the project, but not what project we wanted to do, so we began by running polls in our Discord server on the various potential projects. After voting and a subsequent meeting, we narrowed our options down to two. I was mostly interested in the *Catan* project, while the rest of the team was less certain which they

preferred. We decided to schedule a meeting with the supervising profs of both projects, to get a more in-depth idea of what each one involved. This worked, and we ended up going with the *Catan* project. During this whole process, one teammate missed both meetings with little explanation, and was very slow to answer messages. After a discussion with the group, we agreed that we were concerned by the lack of communication, and decided to gracefully part ways with our fifth member.

3. Decisions surrounding scope were quite complex, as none of us had extensive prior experience with reinforcement learning. This made it hard to judge how long certain aspects of the project would take, so we turned to our supervisor, Professor Istvan David. He was able to give us rough estimates regarding the scope/viability of various goals, which was a great help. The nature of our project made it quite simple to separate goals however, as the design process is rather modular (build simulation, train model, return data, etc.). The existing project description provided in the potential projects document also helped in this regard, as certain milestones were already marked as optional, making them clear contenders for stretch goals.