

# DSGBench: A Diverse Strategic Game Benchmark for Evaluating LLM-based Agents in Complex Decision-Making Environments

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## Abstract

Large Language Model (LLM) based agents have been increasingly popular in solving complex and dynamic tasks, which requires proper evaluation systems to assess their capabilities. Nevertheless, existing benchmarks usually either focus on single-objective tasks or use overly broad assessing metrics, failing to provide a comprehensive inspection of the actual capabilities of LLM-based agents in complicated decision-making tasks. To address these issues, we introduce DSGBench, a more rigorous evaluation platform for strategic decision-making. Firstly, it incorporates six complex strategic games which serve as ideal testbeds due to their long-term and multi-dimensional decision-making demands and flexibility in customizing tasks of various difficulty levels or multiple targets. Secondly, DSGBench employs a fine-grained evaluation scoring system which examines the decision-making capabilities by looking into the performance in five specific dimensions and offering a comprehensive assessment in a well-designed way. Furthermore, DSGBench also incorporates an automated decision-tracking mechanism which enables in-depth analysis of agent behaviour patterns and the changes in their strategies. We demonstrate the advances of DSGBench by applying it to multiple popular LLM-based agents and our results suggest that DSGBench provides valuable insights in choosing LLM-based agents as well as improving their future development. DSGBench is available at <https://github.com/DeciBrain-Group/DSGBench><sup>1</sup>.

## 1 Introduction

Recent progress on large language models (LLMs) has shown substantial improvements in reasoning, planning, and problem-solving, especially in well-defined closed-world environments such as web navigation, household management, and assistant programming [Xi *et al.*, 2023; Zhou *et al.*, 2023; Qian *et al.*, 2024]. These advancements highlight the potential of LLMs to be employed in more complicated settings like open-world situations and strategic gaming[Wang *et al.*, 2023; Ma *et al.*, 2023b]. Nevertheless, applying LLMs in such environments demands not only a deep understanding of the motivations and potential deceptive tactics of enemies, but also advanced reasoning to anticipate risks and vulnerabilities

in our strategies. We believe that unlocking this potential requires further developments in model architectures as well as establishing a rigorous evaluation framework to assess their capabilities[Chang *et al.*, 2024] systematically.

Despite significant advances in LLM benchmarking, existing assessment frameworks suffer from three key limitations when applied to complicated decision-making settings. Firstly, these benchmarks are usually built on environments for static or single-objective tasks [Xie *et al.*, 2024; Zhong *et al.*, 2023], failing to incorporate real-world dynamic situations or constantly changing goals. Secondly, common evaluation metrics focus extensively on result-oriented performance like task completion rate and win rate [Liu *et al.*, 2023; Xi *et al.*, 2024; Wu *et al.*, 2023; Xu *et al.*, 2023]. However, most models have near-zero success rates in challenging environments[Xie *et al.*, 2024], and therefore, overly broad assessing scores are difficult to evaluate strengths and weaknesses among LLM-based agents properly. Furthermore, some existing works concentrate on single-dimensional capabilities[Bailis *et al.*, 2024a; Mukobi *et al.*, 2023], which lacks systematic evaluation of core cognitive capabilities which are crucial for strategic gaming tasks. Such evaluation requires to analyze an LLM-based agent from aspects including long-term strategic planning, short-term real-time decision-making, and social reasoning of external adversaries.

To address these challenges, we introduce DSGBench, a diverse strategic game benchmark designed to assess LLM-based agents across multiple dimensions of cognitive and interactive capabilities. DSGBench is built around three key components: a set of diverse and complex strategy games, a comprehensive evaluation scoring system, and a detailed decision-tracking mechanism. The overall framework of DSGBench is shown in Figure 1. The platform includes six classic strategic games which are *StarCraft II* [Ma *et al.*, 2023a], *Civilization* [Qi *et al.*, 2024], *Street Fighter III* [Wikipedia, 2024e], *Diplomacy* [Mukobi *et al.*, 2023], *Werewolf* [Bailis *et al.*, 2024a], and *Stratego* [Wikipedia, 2024d]. They each selected to test specific skill sets, including strategic planning, real-time decision-making, social reasoning, team collaboration, and adaptive learning. These games replicate the dynamics of the real world through multi-agent interactions, long-context decision-making, and the achievement of various sub-goals, providing a varied scene setting that allows for a comprehensive assessment of agents' adaptability and cognitive integration.

A key feature of DSGBench is its novel evaluation framework that incorporates fine-grained metrics to provide a comprehensive view of agent performance across multiple dimensions. These designed metrics capture the nuances of agent behaviour, particularly in decision-making under uncertainty,

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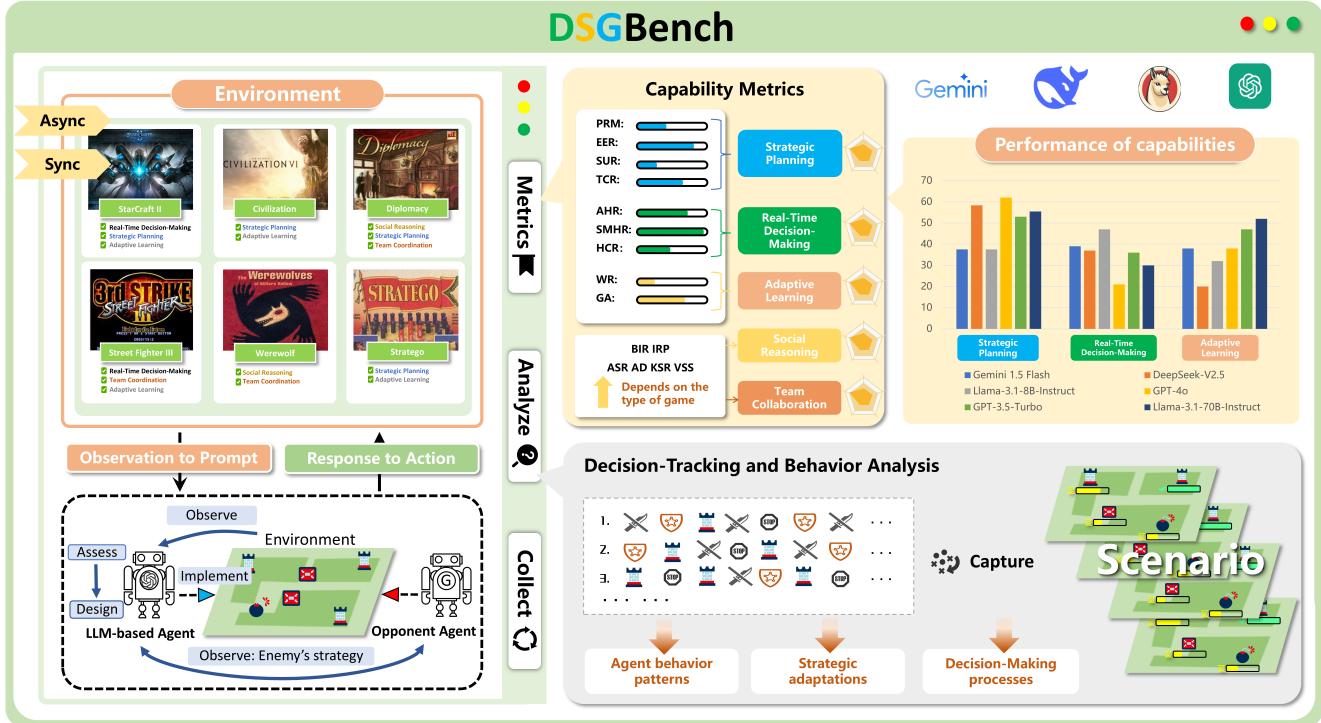


Figure 1: The overall framework of **DSGBench**. The framework consists of (1) a multi-game environment supporting both asynchronous and synchronous interactions; (2) fine-grained capability metrics for strategic planning, real-time decision-making, and team collaboration; and (3) decision trajectory tracking tools that collaboratively analyze agents’ decision-making processes. Through observation-to-prompt and response-to-action loops, DSGBench enables systematic evaluation of LLM-based agents in dynamic, multi-agent scenarios.

long-term strategic planning, and adaptive strategy adjustment. Through this multi-dimensional analysis, DSGBench provides deeper insights into agent capabilities beyond conventional success measures. Additionally, our benchmark integrates detailed decision-tracking functionality, offering researchers clear visibility into agents’ underlying decision-making processes. This transparency is essential for improving model interpretability and advancing agent design.

## 2 Related Work

### 2.1 LLM-based agents

LLM-based agents present human-like cognitive abilities to solve decision-making problems. In early applications of the LLMs, they achieved significant success in handling relatively simple tasks such as role-playing and code generation[Nijkamp *et al.*, 2022; Park *et al.*, 2023] due to their strong capabilities in instruction following, language comprehension, and generation[Wang *et al.*, 2024b]. As the research progressed, researchers began to focus on how to interact LLMs with external tools or environments[Schick *et al.*, 2023; Tang *et al.*, 2024], where the key technique is to provide relevant instruction and environment information through context, which enables LLM-based agents to generate executable actions in response to complex tasks. In addition, researchers have systematically explored the capabilities of LLM-based agents in perception, memory, decision-making, and tool use, with application areas ranging from web navigation, software development, and game decision-making[Wang *et al.*, 2024b; Zhou *et al.*, 2023; Qian *et al.*, 2024; Ma *et al.*, 2023b]. Among these advances, the emergent reasoning capabilities of LLM-based agents are particularly critical and are an integral part of the decision-making

process[Hao *et al.*, 2024]. Furthermore, it is found that LLMs have demonstrated advanced cognitive capabilities such as human-like chain-of-thought reasoning, world modeling, and theory of mind[Wei *et al.*, 2022; Hao *et al.*, 2023; Shapira *et al.*, 2023]. These capabilities influence aspects of how LLM-based agents respond to changes in adversary strategies, how they make rational decisions in uncertain environments, and how they maintain long-term and short-term consistency across successive decision-making processes.

### 2.2 Existing Benchmarks for LLM-based agents

With the enhancement of the comprehensive capabilities of LLMs, there is a growing trend to evaluate their performance in more challenging open-world or complex gaming scenarios. Although static datasets provided effective evaluation in early studies, they failed to reflect the true performance of LLMs in dynamic and complex environments [Huang *et al.*, 2024; Bai *et al.*, 2023]. To address this limitation, subsequent research has begun to evaluate LLM-based agents in executable environments, focusing on revealing their capabilities in an open-ended generation, multi-round interaction, and agent-based role-playing[Wang *et al.*, 2024b]. Current researchers have focused on areas such as software development, embodied agents, society simulations, gaming, and policy making[Hong *et al.*, 2023; Mandi *et al.*, 2024; Kaiya *et al.*, 2023; Mukobi *et al.*, 2023], which have provided LLM assessments with more authentic and diverse contexts.

In particular, strategy games have been widely recognized as ideal experimental platforms for evaluating decision-making capabilities of LLM-based agents due to their complex reasoning requirements and dynamic interaction properties [Liu *et al.*, 2023]. They require agents to engage in multistep reasoning, predict the actions of other agents, and

Benchmark	Complex Game Theory	Fine-Grained Capability Metrics	Decision Trajectory Analysis	Real-Time & Turn-Based	Diverse -Scenarios
AgentBench[Liu et al., 2023]	✗	✗	✗	✓	✓
SmartPlay[Wu et al., 2023]	✗	✗	✗	✗	✗
GameBench[Costarelli et al., 2024]	✓	✗	✗	✗	✗
GBTech[Duan et al., 2024]	✓	✗	✗	✗	✗
MAgIC[Xu et al., 2023]	✓	✗	✗	✗	✗
AgentBoard[Ma et al., 2024]	✗	✗	✓	✗	✓
AgentGym[Xi et al., 2024]	✗	✗	✗	✓	✓
<b>DSGBench(Ours)</b>	✓	✓	✓	✓	✓

Table 1: Compare various LLM-based agent benchmarks across key dimensions. While most benchmarks, such as GBTech and SmartPlay, focus on specific tasks or dimensions, DSGBench stands out by offering broader support across complex game theory, fine-grained metrics, decision trajectory analysis, and diverse scenarios. This makes it a more suitable option for evaluating LLM-based agents in complex environments.

balance competing goals under uncertainty, thus simulating real-world challenges. However, as shown in table 1, benchmarks such as GBTech[Duan et al., 2024], SmartPlay[Wu et al., 2023], and MAgIC[Xu et al., 2023] focus on uni-dimensional capabilities, neglecting the integrated cognitive skills required to cope with interdependence and uncertainty in dynamic environments. In addition, benchmarks such as AgentBench[Liu et al., 2023] and GameBench[Costarelli et al., 2024] use eventual success as the core metric, which limits their insight into complex decision-making processes.

### 3 DSGBench - Preliminary

#### 3.1 Game Interaction Formulation

In DSGBench evaluation, we model agent-environment interactions as a Partially Observable Markov Decision Process (POMDP), formalized as the quintuple  $\langle W, S, A, O, T \rangle$ . Here,  $W$  denotes the victory condition—the strategic objectives agents must achieve, such as destroying the opponent’s base in *StarCraft II* or achieving victory through multiple pathways (combat conquest, cultural dominance, or scientific advancement) in *Civilization*.  $S$  represents the state space, encompassing all observable environmental states within the current game.  $A$  defines the action space of all legal actions available to an agent per time step, including movement, combat, dialogue, and negotiation.  $O$  comprises the observation space, containing environmental feedback  $f_t$  that reflects immediate state changes and responses to agent actions.  $T$  represents the state transition function  $S \times A \rightarrow S$ , mapping how the current state  $s_t$  and agent action  $a_t$  determine the subsequent state  $s_{t+1}$ .

**Single-level Inference.** Games such as *Street Fighter III*, *Diplomacy*, *Werewolf*, and *Stratego* Games are particularly suited for single-level reasoning due to their centralized state and action spaces.

The reasoning process is formalized as

$$p_\pi(\tau) = p(s_0) \prod_{t=0}^{T-1} p(a_t|s_t, f_t) \cdot T(s_{t+1}|s_t, a_t, f_t) \quad (1)$$

where  $p_\pi(\tau)$  represents the policy trajectory,  $p(s_0)$  is the initial state distribution,  $p(a_t|s_t, f_t)$  denotes the probability of taking action  $a_t$  given state  $s_t$  and feedback  $f_t$ , and  $T(s_{t+1}|s_t, a_t, f_t)$  is the state transition function. In single-level reasoning games, agents can effectively accomplish complex tasks with simplified state and action reasoning.

**Two-level Inference.** Complex strategy games like *StarCraft II* and *Civilization* require agents to handle large observation spaces and multi-dimensional tasks through two levels

of reasoning: high-level strategic planning (for example, resource management and army deployment) and low-level tactical decisions (for example, executing micro-operations and managing local combat).

$$p_\pi(\tau) = p(s_0) \prod_{t=0}^{T-1} p(a_t^{\text{high}} | s_t, c^{\text{high}}) \cdot p(a_t^{\text{low}} | s_t, a_t^{\text{high}}, c^{\text{low}}) \cdot T(s_{t+1} | s_t, a_t^{\text{low}}, f_t) \quad (2)$$

Here,  $a_t^{\text{high}}$  represents high-level strategic decisions based on global policy  $c^{\text{high}}$ ;  $a_t^{\text{low}}$  denotes immediate tactical actions guided by local feedback  $c^{\text{low}}$ , and  $T(s_{t+1}|s_t, a_t^{\text{low}}, f_t)$  defines the state transition function reflecting environmental changes in response to current actions.

#### 3.2 Capability Score Computation

To compute the scores of the LLMs across different capability dimensions, we first establish the mapping between each capability dimension and multiple associated games, where each game is linked to a set of fine-grained metrics. The score for each capability dimension is calculated by weighting the performance metrics of the associated games on multiple fine-grained metrics. Its definition is as follows:

$$T = \sum_{i=1}^m W_i \cdot \beta_i \cdot \left( \sum_{j=1}^n w_j \cdot \frac{\frac{1}{k_j} \sum_{k=1}^{k_j} R_{y_{jk}} - \min_j R_{y_j}}{\max_j R_{y_j} - \min_j R_{y_j}} \right) \quad (3)$$

where the aggregated capability score  $T$  integrates capability dimensions through weight coefficients  $W_i \in [0, 1]$ , where  $\sum_{i=1}^m W_i = 1$ . To account for the varying emphasis of capabilities in different scenarios, each dimension incorporates an adjustment factor  $\beta_i \in (0, 1]$ . Performance in individual scenarios is weighted by  $w_j \in [0, 1]$ , with  $\sum_{j=1}^n w_j = 1$ . For statistical robustness, we conduct  $k_j$  evaluation runs per scenario, where  $R_{y_{jk}}$  represents the performance metric from the  $k$ -th run. These metrics are normalized using the pre-defined theoretical minimum value  $\min_j R_{y_j}$  and maximum value  $\max_j R_{y_j}$  to ensure fair comparison across different gaming environments.

### 4 DSGBench - Overview

DSGBench is a comprehensive benchmark designed to evaluate the strategic decision-making capabilities of LLM-based agents through a diverse set of strategy games. It consists of three key components: complex game environments,

Capability	Games	Metrics	Scenarios
Strategic Planning	<i>Starcraft II</i> [Ma et al., 2023b]	RPM, EER, SUR, TCR	Macro (Async/Sync)
	<i>Civilization</i> [Qi et al., 2024]	EGR, CER, TRP, LUR, MGR	Map (World)
	<i>Diplomacy</i> [Mukobi et al., 2023]	CCC, WS	Negotiation and Alliances
	<i>Stratego</i> [Wikipedia, 2024d]	CPR, TPCV	Random Placement
Real-Time Decision-Making	<i>Starcraft II</i> [Ma et al., 2023b] <i>Street Fighter III</i> [Wikipedia, 2024e]	APM, EPM AHR, SMHR, HCR	Rush (Async/Sync) Fast-Paced(Async)
Social Reasoning	<i>Diplomacy</i> [Mukobi et al., 2023] <i>Werewolf</i> [Bailis et al., 2024a]	BIR IPR	Negotiation and Alliances Social Deduction
Team Collaboration	<i>Diplomacy</i> [Mukobi et al., 2023] <i>Werewolf</i> [Bailis et al., 2024a]	ASR, AD KSR, VSS	Negotiation and Alliances Social Deduction
Adaptive Learning	<i>Starcraft II</i> [Ma et al., 2023b]	WR, GA	Random (Async/Sync)
	<i>Civilization</i> [Qi et al., 2024]	WR, GA	Map (Small-Scale)
	<i>Street Fighter III</i> [Wikipedia, 2024e]	WR, GA	Sync
	<i>Stratego</i> [Wikipedia, 2024d]	WR, GA	Fixed Placement

Table 2: Evaluation metrics and scenarios for assessing LLM-based agents across five key dimensions: strategic planning, real-time decision-making, social reasoning, team collaboration, and adaptive learning in diverse strategic games.

fine-grained evaluation metrics, and decision tracking mechanisms. Using a unified Gym interface, DSGBench provides a standardised interaction model and supports customisable game scenarios, facilitating the integration of new games and the extension of existing ones. Additionally, the framework incorporates an automated scoring process that permits the customisation of scoring tasks as required. For a detailed description of the architectural design, please refer to the Appendix A.

In this section, a detailed overview of DSGBench is provided, following the sequence outlined in the table 2. Firstly, the core cognitive decision-making abilities of LLM-based agents are explored, as outlined in the table. Secondly, the evaluation framework is introduced, including fine-grained metrics and decision-tracking mechanisms. To effectively assess these abilities, a three-part evaluation framework is proposed, which includes a set of complex strategic games, fine-grained metrics, and decision-tracking mechanisms. Finally, the diverse game scenarios and evaluation tasks designed are showcased, and the code framework for the automated evaluation platform is discussed.

#### 4.1 Cognitive Decision-Making Capabilities

In addressing complex, multifaceted problems, human agents require the coordinated application of cognitive and adaptive capabilities. According to Dual Systems Cognitive Theory [Kahneman, 2011], rational planning and analytical thinking rely on "System 2", while rapid decision-making is accomplished through the intuitive responses of "System 1". The complementarity of the two allows individuals to make quick decisions and maintain certain goals in dynamic and uncertain environments. However, in complex situations involving multiple intelligences, the ability to make decisions collectively, and individual capabilities alone are often insufficient. Distributed Cognition Theory emphasizes that the ability to reason socially and work in a team stems from the interaction of the individual with the environment, tools, and other subjects[Hutchins, 1995]. Furthermore, Dynamic Decision Theory states that, in dynamic environments, individuals and groups can adapt their decision-making strategies in response to feedback, thereby exhibiting adaptive behaviours in response to changing external conditions[Edwards, 1962].

Drawing inspiration from this human cognitive decision-making framework, DSGBench constructs a five-dimensional assessment system covering the core dimensions of intelligent

decision-making: strategic planning (deep analysis by System 2), real-time decision-making (fast response by System 1), social reasoning (distributed interaction mechanism), team collaboration (multi-agents coordination) and adaptive learning (dynamic strategy optimization). The following outlines each of these dimensions in detail:

- **Strategic Planning** refers to the ability to formulate and implement long-term strategies that are consistent with overall goals. This ability includes optimizing resources, anticipating future scenarios, and adapting to changing environments.
- **Real-Time Decision-Making** refers to the ability to make effective decisions under time pressure. It involves managing competing objectives, processing dynamic information, and reacting quickly to unpredictable changes.
- **Social Reasoning** refers to the ability to understand and navigate interactions in a team or competitive environment. This ability requires understanding the intentions of other agents, predicting their behaviour, and adjusting strategies accordingly.
- **Team Collaboration** refers to the ability of agents to work together effectively in a multi-agent environment to achieve a common goal. This includes coordinating actions, communicating intentions, and solving collective problems.
- **Adaptive Learning** refers to the ability of an agent to continuously improve its capabilities by learning from past experiences and feedback. This ability includes

Capability	SC	Civ	SF	Dip	Wer	Str
Strategic Planning	✓	✓		✓		✓
Real-Time Decision-Making	✓			✓		
Social Reasoning		✓		✓	✓	
Team Coordination		✓		✓	✓	
Adaptive Learning	✓		✓			✓

Table 3: Capability requirements across different games. SC: *StarCraft II*, Civ: *Civilization*, SF: *Street Fighter III*, Dip: *Diplomacy*, Wer: *Werewolf*, Str: *Stratego*.

identifying patterns, refining strategies, and adapting behaviours to incorporate new information into subsequent iterations, and the decision-making process is continuously optimized for continued success.

## 4.2 Diverse Strategic Games

As demonstrated in Table 3, a set of strategic games was selected to ensure that each capability is adequately evaluated, with factors such as game mechanics, difficulty, and other key aspects being considered. These games present long-term, multidimensional decision-making challenges and also assess five key dimensions of cognitive decision-making capability through multifaceted evaluation perspectives. The following sections explain the specific challenges posed by the games chosen to evaluate these dimensions.

- ***StarCraft II***[Wikipedia, 2024c] is a complex real-time strategy (RTS) game where players build bases, manage resources, raise armies, and destroy enemy bases. LLM-based agents must make efficient decisions, optimize resource management, engage in strategic planning, and adapt to their opponents' tactics in real-time within a rapidly changing and high-pressure environment.
- ***Civilization***[Wikipedia, 2024a] is a turn-based strategy game where players lead a civilization from ancient times to the future. The game involves city-building, resource management, technological development, cultural growth, and diplomacy, with the goal of creating a strong, prosperous civilization. LLM-based agents must make long-term decisions, wisely allocate resources, plan future development, and engage in complex diplomatic negotiations.
- ***Street Fighter III***[Wikipedia, 2024e] is a fast-paced fighting game where players control characters with unique skills and combos to battle each other. LLM-based agents must make quick decisions, execute precise combos, and anticipate and counter their opponents' moves in a high-pressure environment.
- ***Diplomacy***[Wikipedia, 2024b] is a multiplayer strategy board game where players expand their territory through negotiations, alliances, and betrayals. Each player controls a country, and the goal is to gain an advantage through strategic positioning and diplomatic agreements. LLM-based agents must build alliances, manage complex diplomatic relationships, and predict opponents' actions.
- ***Werewolf***[Wikipedia, 2024f] is a social reasoning-based multiplayer game where players are secretly assigned roles, with some being werewolves and others villagers. The werewolves aim to destroy the villagers, while the villagers must identify the werewolves. LLM-based agents need to make decisions with limited information, assess the credibility of others, and adjust their strategies based on changing social dynamics.
- ***Stratego***[Wikipedia, 2024d] is a strategic board game where players move pieces on a board to capture the opponent's flag. The game emphasizes planning, bluffing, and reasoning about the opponent's strategy. LLM-based agents must make decisions with incomplete information, predict their opponents' actions, and conceal their own plans.

For a detailed description of the game mechanics, aciton space and other information, please refer to the Appendix B.

## 4.3 Fine-Grained Capability Metrics

In order to address the limitations of traditional capability assessment methods in dynamic and complex environments, a fine-grained capability metric is introduced. The multiple metrics is motivated by two empirical findings: (1) outcome-based metrics are difficult to capture detailed differences between capability dimensions, and (2) gamification assessment requires the establishment of interpretable measurement benchmarks. The metrics in DSGBench are defined based on expert insights into the core mechanics of each game, ensuring alignment with the key competencies being assessed. Specifically, each metric is chosen to reflect a critical aspect that influences strategic decision-making performance. As illustrated in Table 2, the proposed methodology first establishes a mapping relationship between capability dimensions and games at the macro level, and then associates each game with a set of fine-grained metrics at the micro level. More details of each metric please refer to Appendix B.

**An example.** We take evaluating the *Strategic Planning* capability in the game *StarCraft II* as an example. Efficient resource management, which involves collecting and allocating minerals and gases, allows players to sustain their forces, while supply utilization governs their capacity to deploy units effectively. Based on these mechanics, fine-grained metrics such as resource management efficiency and supply utilization are key for assessing a player's strategic planning. Specifically, Resource Collection Performance (RPM) measures the efficiency of resource gathering by calculating the total amount of minerals and gases collected during the game, indicating how well a player manages resources to support their strategy. The formula for RPM is as follows:

$$RPM_i = \sum_{t=1}^T (\text{collected\_minerals}_i(t) + \text{collected\_vespene}_i(t)) \quad (4)$$

In addition, the Supply Utilization Rate (SUR) evaluates unit production efficiency through the ratio of used supply capacity to maximum supply capacity:

$$SUR_i = \frac{\sum_{t=1}^T \text{supply\_used}_i(t)}{\sum_{t=1}^T \text{supply\_cap}_i(t)} \quad (5)$$

When SUR is higher, it means that players are performing more efficiently in resource management and unit production.

## 4.4 Decision Trajectory Tracking

As a complement to the quantitative evaluation, this paper introduces a decision-tracking and behavioural analysis system that combines performance metrics with contextual analysis to deepen the understanding of LLM decision-making. The system captures key decision points throughout the game, linking them to real-time game states and mission objectives, thereby revealing underlying strategic reasoning patterns. Specifically, the analytical framework consists of three core components: (1) action types that categorize specific decisions, such as resource allocation and unit production; (2) decision contexts that capture the game state and objectives at each decision point; and (3) outcomes that assess the impact of decisions on game progression.

This approach enables the rapid identification of key decision points and anomalies, providing insight into the decision logic of LLMs and a basis for optimisation. Action type classification helps to analyse the impact of decisions on game progression, while decision contexts clarify the scope of a

Game	Scene Variables	Scene Count	Dynamic Space	Multi-goal	Prompt Structure	Iterations
<i>StarCraft II</i> [Ma <i>et al.</i> , 2023b]	Mode, Opponent strategy, Difficulty level	6	✓	✓	Hierarchical	450
<i>Civilization</i> [Qi <i>et al.</i> , 2024]	Map	3	✓	✓	Hierarchical	141
<i>Street Fighter III</i> [Wikipedia, 2024e]	Mode, Role	2	✓	✗	Flat	24
<i>Diplomacy</i> [Mukobi <i>et al.</i> , 2023]	Map, Role	1	✗	✗	Flat	60
<i>Werewolf</i> [Bailis <i>et al.</i> , 2024b]	Role	2	✗	✗	Flat	32
<i>Stratego</i> [Wikipedia, 2024d]	Mode, Board placement	2	✓	✗	Flat	1270

Table 4: Overview of Selected Games in DSGBench and Their Core Characteristics. This table provides a summary of the key attributes of the games featured in DSGBench, highlighting their scene variables, scene count, dynamic action space, goal multiplicity, prompt structures, and iterations. The analysis specifically focuses on characteristics such as interaction paradigms (Mode), roles, and game-specific dynamics.

decision’s influence. Outcome analysis evaluates the actual impact of each decision on the game and the final outcome. For a detailed description of the decision trajectory tracking methodology, refer to Section 5.4.

#### 4.5 Customizable Evaluation Scenarios

Despite the fact that the various strategic games employed in DSGBench encompass a broad range of decision-making capabilities, the fixed game settings may not adequately assess an agent’s multi-dimensional capabilities performance in dynamic environments. Consequently, our benchmark offers the flexibility to create customized evaluation scenarios, enabling more targeted assessments based on specific needs and supporting future scenario expansions.

As demonstrated in Table 4, our benchmark facilitates precise control over a range of scenario variables, including opponent behaviour patterns, interaction paradigms (e.g., synchronous vs. asynchronous), prompt engineering approaches, and reasoning strategies. These variables can be customised to align with the distinct characteristics inherent in each game type. Furthermore, a salient feature of our benchmark is the extensive interaction trajectories, with the average number of iterations ranging from 24 in *Street Fighter III* to 1270 in *Stratego* across different games. This presents a substantial challenge for LLM-based agents, as these extended decision sequences require advanced capabilities in contextual learning, long-term strategic planning, and decision consistency across varied game environments.

#### 4.6 Implementation of DSGBench

The evaluation framework is an automated and simplified platform designed to evaluate LLM-based agents uniformly. The main component of the framework is the **GameManager**, which coordinates the initialization and execution phases. It is responsible for configuring the environment and the agent, ensuring a smooth game flow and accurately tracking the decision trajectory. The process starts with the **Data-Collector**, which is responsible for collecting the basic configuration of the game and the agent, laying the foundation for accurate evaluation. This data is then fed into the modules **GameEnv** and **HistoryTracker**. While the former manages the action and observation space and enables seamless interaction between the agent and its environment, the latter captures the detailed game history and allows for in-depth analysis of the decision-making process and strategic choices. This setup provides a comprehensive view of the performance of LLM-based agents and helps to gain a deeper understanding of their behaviour and how the strategy of the agent evolves throughout the game. For a detailed description of the architectural design, please refer to Appendix A.

## 5 Experimental Results

This section presents the results of the evaluation of the six representative LLMs on DSGBench. The following subsections describe the evaluation setup, the main experimental results, and both quantitative and qualitative results that highlight the strengths and limitations of the models.

### 5.1 Evaluation Setup

We evaluated six representative LLMs on DSGBench, including closed-source models (GPT-4o[OpenAI, 2024], GPT-3.5-Turbo[OpenAI, 2023], Gemini 1.5 Flash[Reid *et al.*, 2024]) and open-source models (DeepSeek-V2.5[DeepSeek-AI, 2024], Llama-3.1-8B-Instruct and Llama-3.1-70B-Instruct[Dubey *et al.*, 2024]).

**Scenario Design:** The scenarios were designed to include controllable variables such as opponent strategies, difficulty levels, and interaction modes, with settings that differ between games. As illustrated in Table 5, for *StarCraft II*, the key controllable variables include opponent strategy, execution mode (synchronous/asynchronous), and opponent difficulty, which is set to medium with integrated AI. In this study, the map is selected as a classic race map. Each scenario will undergo a series of experiments to ensure robustness and to account for the variability in agent performance across different runs. The configuration settings of other game scenarios can be found in the appendix B.

**Experimental Setup:** All evaluations were conducted using standardized prompts without model fine-tuning to ensure task consistency. For prompt engineering, we adopted existing prompt templates for established game environments (*StarCraft II*[Ma *et al.*, 2023b], *Civilization*[Qi *et al.*, 2024], *Diplomacy*[Mukobi *et al.*, 2023], *Werewolf*[Bailis *et al.*, 2024b], and *Street Fighter III*[Wikipedia, 2024e]), while developing custom prompt structures and reasoning frameworks for *Stratego*[Wikipedia, 2024d]. The temperature parameter was set to 0.2 across all LLMs to balance response determinism and creative reasoning optimally. For each game scenario, we evaluated models against either the built-in AI of the game or GPT4o-mini as opponents, conducting 10 matches per scenario to ensure reliability. All game environments are uniformly encapsulated as text-based interfaces that implement standardized “observation-to-prompt” and “response-to-action” loops for consistent agent interaction. Additionally,

Capabilities	Metrics	Scene selection	
		Opponent strategy	Operation mode
Strategic Planning	RPM, EER, SUR, TCR	Macro	Async/Sync
Real-time Decision-Making	APM, EPM	Rush	Async/Sync
Adaptive Learning	WR, GA	Random	Async/Sync

Table 5: Outlines the scene setup for evaluating LLM-based agents in *StarCraft II*, including key capabilities, associated metrics, and scene configurations.

Model	Strategic Planning	Real-Time Decision-Making	Social Reasoning	Team Collaboration	Adaptive Learning	Overall
<b>Closed-Sourced Models</b>						
Gemini 1.5 Flash[Reid <i>et al.</i> , 2024]	<b>72.88 ± 2.12</b>	48.45 ± 1.42	60.17 ± 1.82	22.46 ± 3.35	64.23 ± 1.39	<b>56.16 ± 1.70</b>
GPT-3.5 Turbo[OpenAI, 2023]	32.94 ± 0.22	52.32 ± 2.54	74.25 ± 9.52	26.18 ± 7.97	47.68 ± 1.04	47.01 ± 3.02
GPT-4o[OpenAI, 2024]	54.59 ± 6.69	40.47 ± 1.76	<b>83.27 ± 2.20</b>	<b>34.31 ± 1.86</b>	52.79 ± 1.86	54.10 ± 1.14
<b>Open-Sourced Models</b>						
DeepSeek-V2.5[DeepSeek-AI, 2024]	51.92 ± 5.27	46.97 ± 1.57	68.23 ± 2.62	26.85 ± 3.02	<b>68.50 ± 1.82</b>	53.75 ± 1.72
Llama-3.1-70B-Instruct[Dubey <i>et al.</i> , 2024]	51.47 ± 2.48	<b>66.35 ± 1.54</b>	40.78 ± 4.81	26.33 ± 3.63	34.35 ± 1.72	45.11 ± 1.30
Llama-3.1-8B-Instruct[Dubey <i>et al.</i> , 2024]	0.00 ± 0.00	36.99 ± 1.12	0.00 ± 0.00	0.00 ± 0.00	17.72 ± 0.19	10.94 ± 0.24

Table 6: Performance Evaluation Scores of LLMs. The table presents the evaluation scores for five dimensions: Strategic Planning, Real-Time Decision-Making, Social Reasoning, Team Collaboration, and Adaptive Learning. Additionally, the Overall Score is the weighted sum of the evaluation scores across these five capabilities, with both mean and standard deviation for each model. For each game scenario, the scores for each model are the averages of ten match runs, with both the mean and variance calculated.

all games employed a text-based action space, where the validity of actions was evaluated through the grounding accuracy rate.

## 5.2 Quantitative Results

The experimental evaluation of DSGBench highlights distinct strengths and limitations of LLM-based agents in different strategic environments. As shown in Table 6, the quantitative results summarise the models’ capabilities in strategic planning, real-time decision-making, social reasoning, team collaboration, and adaptive learning. In addition, the specific formula for calculating the capability scores is presented in the previous section 3.2. These findings are further elaborated below, incorporating both quantitative metrics and qualitative observations, culminating in a detailed analysis of decision-making trajectories.

**Fine-grained capability metrics reveal distinct patterns in model performance across different cognitive dimensions.** The comprehensive evaluation framework, encompassing strategic planning, real-time decision-making, social reasoning, team collaboration, and adaptive learning, demonstrates that models exhibit specialised strengths rather than uniform capabilities. This specialised performance is particularly evident in the case of Gemini 1.5 Flash [Reid *et al.*, 2024], which achieves exceptional results in strategic planning (72.88) and adaptive learning (64.23), while showing limitations in real-time decision-making (48.45). In contrast, GPT-4o [OpenAI, 2024] exhibits a more balanced set of capabilities across various metrics. It demonstrates a particularly strong performance in social reasoning (83.27) and team collaboration (34.31), along with consistent scores above 40 in other dimensions.

**The performance analysis reveals a substantial capability gap between closed-source and open-source models.** Closed-source models have been shown to demonstrate superior performance, with Gemini 1.5 Flash [Reid *et al.*, 2024] and GPT-4o [OpenAI, 2024] achieving overall scores of 56.16 and 54.10, respectively. In contrast, open-source alternatives such as DeepSeek-V2.5[DeepSeek-AI, 2024] and Llama-3.1-70B-Instruct [Dubey *et al.*, 2024] achieve significantly lower overall scores of 53.75 and 45.11, respectively. The most pronounced disparity is observed in strategic planning tasks, where Gemini 1.5 Flash[Reid *et al.*, 2024] (72.88) significantly outperforms Llama-3.1-70B-Instruct[Dubey *et al.*, 2024] (51.47). However, in specific scenarios such as StarCraft’s real-time decision-making, open-source models can achieve competitive performance, as demonstrated by Llama-3.1-70B-Instruct’s[Dubey *et al.*, 2024] high score in that dimension.

**Game-specific analysis further illuminates the relationship between model architecture and task performance.**

In strategic games such as *Civilization*, closed-source models demonstrate clear advantages, with Gemini 1.5 Flash[Reid *et al.*, 2024] achieving a high score of 72.88 in strategic planning. Conversely, GPT-3.5 Turbo[OpenAI, 2023] exhibits diminished efficacy in this domain, attaining a score of 32.94. In contrast, in real-time gaming environments, where the speed of decision-making is paramount, models such as Llama-3.1-70B-Instruct demonstrate superior performance with a score of 66.35 in real-time decision-making. The observed variance in performance across different game types suggests that current model architectures may be optimised for specific cognitive tasks, potentially at the expense of others.

## 5.3 Qualitative Analysis

The qualitative observations provide a complementary perspective on the models’ capabilities, particularly in dealing with complex, dynamic scenarios. In structured turn-based environments such as *Civilization* and *Stratego*, closed-source models excel at aligning intermediate decisions with long-term goals. Take GPT-4o[OpenAI, 2024] as an example. It excels at resource prioritisation and foreign policy formulation, allowing it to outperform open-source models. However, even closed-source models occasionally fail to adapt to unforeseen in-game developments, such as unexpected opponent strategies.

In contrast, real-time environments present a contrasting scenario. In *StarCraft II*, the dynamic nature of the battlefield exposes temporal reasoning limitations across all models. Despite its overall proficiency, GPT-3.5-Turbo[OpenAI, 2023] struggles to balance resource gathering with tactical decision-making under time constraints. Open-source models face even greater challenges, frequently failing to respond effectively to rapid environmental changes. This behaviour underscores fundamental gaps in the temporal reasoning capabilities of contemporary LLM architectures.

Social reasoning tasks, such as *Diplomacy* and *Werewolf*, reveal additional complexities. GPT-4o[OpenAI, 2024] demonstrates reasonable success in forming alliances and adapting strategies based on evolving game dynamics. For instance, it effectively identifies cooperative opportunities while mitigating adversarial risks. However, these successes are inconsistent, with models sometimes reverting to overly simplistic negotiation tactics. Conversely, open-source models frequently generate responses that are either redundant or irrelevant, thus exposing their limitations in handling complex multi-agent interactions.

Stage	Trajectory	Step
Early	Decision: 0: <TRAIN PROBE> → 1: <BUILD PYLON> → 2: <BUILD NEXUS> → 3: <TRAIN PROBE> → 4: <BUILD ASSIMILATOR> Our Strategy: Expand the number of workers, build additional resource collection structures, and ensure base defense. Suggestions: Focus on building additional Probes to boost resource gathering, construct more Pylons to increase supply cap, and consider expanding to new resource locations.	429
	Decision: 0: <TRAIN STALKER> → 1: <BUILD GATEWAY> → 2: <TRAIN PROBE> → 3: <BUILD ASSIMILATOR> → 4: <RESEARCH PROTOSSGROUNDARMORSLEVEL1> Our Strategy: Build a stable economy and gradually advance technology and the army.	4629
	Suggestions: Continue to build up the economy while gradually increasing army supply and advancing technology to prepare for mid-game engagements.	
	Decision: 0: <BUILD GATEWAY> → 1: <BUILD SHIELDBATTERY> → 2: <TRAIN SENTRY> → 3: <RESEARCH PROTOSSGROUNDARMORSLEVEL2> → 4: <SCOUTING PROBE> Our Strategy: Build a solid economic foundation, maintain a basic military presence, and invest in early upgrades to enhance force capabilities. Suggestions: Consider diversifying our army composition by introducing more advanced units like Sentries or Adepts to complement the existing Zealots and Stalkers. Focus on scouting to gather intelligence on the enemy's strategy.	7004
	Decision: 0: <TRAIN SENTRY> → 1: <BUILD ROBOTICSFACILITY> → 2: <TRAIN IMMORTAL> → 3: <BUILD ASSIMILATOR> → 4: <RESEARCH PROTOSSGROUNDARMORSLEVEL2> Our Strategy: Improve the effectiveness of the army around balanced economy, unit composition and early upgrades. Suggestions: Consider diversifying your unit composition to include more advanced units like Sentries or Immortals to counter potential enemy threats. Additionally, continue upgrading your technology to stay ahead in battles.	8454
	Decision: 0: <TRAIN IMMORTAL> → 1: <TRAIN OBSERVER> → 2: <TRAIN VOIDRAY> → 3: <BUILD GATEWAY> → 4: <BUILD ASSIMILATOR> Our Strategy: Focus on a mix of ground and air units, supported by upgrades. We are also investing in infrastructure for advanced unit production.	9554
	Suggestions: Consider diversifying our army composition by training units from the Robotics Facility and Stargates to counter a wider range of enemy units.	
	Decision: 0: <TRAIN HIGHTEMPLAR> → 1: <BUILD ROBOTICSBAY> → 2: <RESEARCH EXTENDEDTHERMALLANCE> → 3: <BUILD ASSIMILATOR> → 4: <TRAIN OBSERVER> Our Strategy: Focus on upgrading units and technology while maintaining a balanced economy and military composition. Suggestions: Consider expanding unit diversity by incorporating more advanced units like Colossi or High Templars to enhance our army's capabilities. Additionally, focus on tech upgrades to stay ahead in battles.	10529
	Decision: 0: <BUILD GATEWAY> → 1: <BUILD PHOTONCANNON> → 2: <TRAIN STALKER> → 3: <RESEARCH PROTOSSAIRARMORSLEVEL2> → 4: <EXPAND TO NEW RESOURCE LOCATION> Our Strategy: Around the mix of gateway units and technical units such as Stalkers, Immortals, and Voidray. Suggestions: Enhance our unit composition by adding more production structures like Gateways to increase unit production capacity. Consider expanding tech options to counter potential enemy strategies effectively.	14129
Mid	Decision: 0: <TRAIN STALKER> → 1: <BUILD GATEWAY> → 2: <BUILD SHIELDBATTERY> → 3: <RESEARCH PROTOSSGROUNDARMORSLEVEL2> → 4: <SCOUTING OBSERVER> Our Strategy: Around the unit diversity and balance method of technological progress. The emphasis on stalkers suggests a flexible military composition capable of handling a variety of threats. Suggestions: Consider diversifying our unit composition further to adapt to potential enemy strategies. Focus on maintaining map control and scouting to stay ahead of the opponent.	17554
Mid to Late	Decision: 0: <TRAIN STALKER> → 1: <BUILD GATEWAY> → 2: <CHRONOBOOST CYBERNETICSSCORE> → 3: <RESEARCH PROTOSSAIRWEAPONSLEVEL2> → 4: <TRAIN IMMORTAL> Our Strategy: Focus on balanced unit composition and technology upgrades to improve the effectiveness of our forces. Suggestions: Consider diversifying our army composition further to counter the enemy's Stalkers effectively. Focus on unit production and upgrades to strengthen our army.	20929

Table 7: Presents a detailed decision trajectory analysis of an LLM’s gameplay in *StarCraft II* across various stages: Early, Mid, and Mid to Late. The table outlines specific decisions made by the model, including the training of units, building structures, and conducting research. Each entry details the decision-making process, the associated strategy, and suggestions for optimizing performance. By capturing these trajectories, the table illustrates how the LLM navigates complex strategic choices, adapts to the game environment, and develops its military and economic strategies over time, providing insights into its strategic reasoning capabilities.

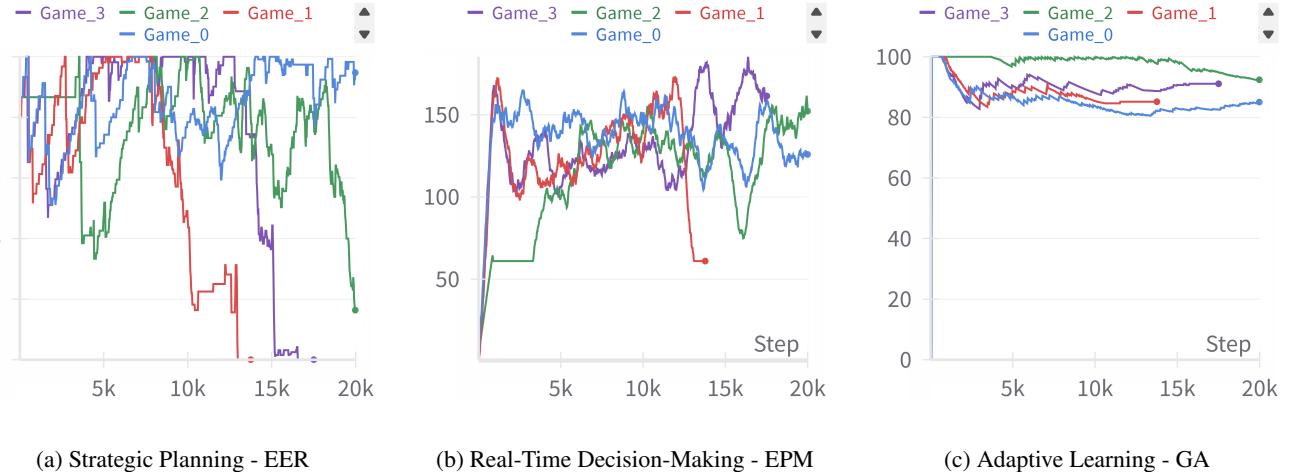


Figure 2: Performance indicators for evaluating LLM capabilities in *StarCraft II*: (a) Strategic Planning - EER (Efficiency of Resource Utilization), (b) Real-Time Decision-Making - EPM (Effective Actions Per Minute), and (c) Adaptive Learning - GA (Grounding Accuracy). Each graph displays the performance trends of different game sessions (Game<sub>0</sub>, Game<sub>1</sub>, Game<sub>2</sub>, Game<sub>3</sub>) over time steps.

## 5.4 Results of Decision Trajectory Tracking Analysis

This section examines the LLM’s decision-making process within the context of the *StarCraft II* environment, utilising three key metrics: Strategic Planning(EER), Real-Time Decision-Making (EPM), and Adaptive Learning (GA). As

illustrated by Figure 2, the decision trajectory over time is characterised by shifts in the LLM’s behaviour. For instance, at step 15k in Game 1, a significant decrease in EER coincides with a shift in strategy from resource gathering to military production, as shown in Table 7. Furthermore, EPM increases during combat phases, particularly between the "Mid"

and "Late" stages, aligning with higher decision-making complexity, such as advanced unit production and strategic upgrades. The LLM also demonstrates adaptability by switching to specialised units such as Void Rays and Immortals in response to changing game conditions, as reflected in the data at step 10k in Table 7.

The insights derived from Figure 2 and Table 7 collectively provide a more precise understanding of the evolution of LLM decision-making. The figure provides a visual representation of decision trends, while the table provides specific data points that explain the rationale behind key actions. For example, the drop in EER at level 15k reflects a strategic pivot towards military production, and the increase in EPM at level 25k corresponds to decisions to expand infrastructure and upgrade units.

## 6 Conclusion

We introduce DSGBench, a comprehensive benchmark designed to evaluate the strategic decision-making capabilities of LLM-based agents in diverse and dynamic gaming environments. For the first time, we assess LLM-based agents based on key cognitive decision-making dimensions from human cognition and propose an integrated evaluation approach. Under standardized settings, we systematically evaluate the performance of six representative LLM-based agents in complex strategic environments. Through fine-grained evaluation metrics and decision trajectory analysis, we reveal the strengths and weaknesses of agents in various scenarios. Experimental results show significant differences across multiple ability dimensions. Additionally, we have established a unified evaluation framework that supports the integration of new games and the customization and expansion of new game scenarios. We hope that DSGBench will see widespread application, as gaming itself is an evolving process. Agents can continuously learn and evolve through interaction with opponents, making game-based evaluation methods virtually limitless in potential.

While existing agents face significant challenges in DSGBench, this analytical framework provides a concrete analysis for the improvement of LLM-based agents' integrated cognitive decision-making capabilities. Two important directions for future research include the development of a unified trajectory dataset for strategy games and the creation of an agent reasoning framework for multi-strategy games. The trajectory dataset would serve as a rich resource for training agents across a range of strategic environments. Together, these will enhance the generalization capabilities of LLM-based agents and further the development of more complex AGI-oriented systems.

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## A Overall Architecture

The proposed evaluation framework introduces an automated architecture for systematically evaluating LLM-based agents in various game environments. A unified gym interface is implemented for all games, which facilitates subsequent game extensions. In addition, the framework provides easy scenario customization to tailor the evaluation requirements based on a single profile.

The key component of the framework is the GameManager, which coordinates the evaluation process's initialization and execution phases. The architecture consists of three main modules: DataCollector, GameEnv, and HistoryTracker. The DataCollector module handles the game and agent configurations through parameter parsing and establishes the base parameters for the evaluation. The GameEnv module defines the action and observation space and facilitates the interaction between agents and the evaluation through a standardized interface. The GameEnv module defines the action and observation space while facilitating the interaction between the agents and the environment through a standardized interface. The HistoryTracker module comprehensively records the game progress, agent model, and match-specific information.

During initialization, the GameManager coordinates component configuration through calls to GameEnv(args) and Agent(args), followed by prompt processing through Prompt(args) and LLM(args). The execution phase manages state transitions via env.step(action), facilitates agent decisions via agent.action(obs), and records state information via HistoryTracker. The framework supports a wide range of game genres, including real-time strategy games (*StarCraft II*), turn-based strategy games (*Civilization*), fighting games (*Street Fighter III*), and social deduction games (*Werewolf*, *Diplomacy*). This versatility allows for comprehensive evaluation in different decision-making environments.

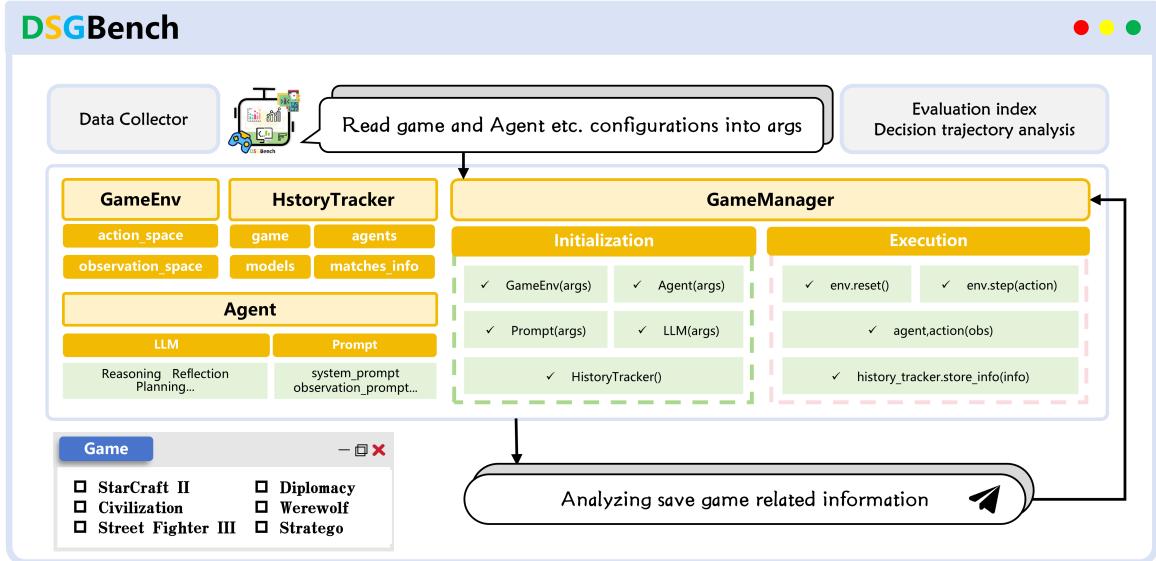


Figure 3: Code Architecture of **DSGBench** Framework.

## B StarCraft II

*StarCraft II* is a real-time strategy (RTS) game developed by Blizzard Entertainment. It is the successor to *StarCraft*: Broodwar, one of the most successful RTS games. The objective of *StarCraft II* is to establish bases, manage resources, build armies, and destroy the enemy's base. The most common game setup is 1v1, where each player chooses one of three races: Terran, Protoss, or Zerg. Each race has unique units, buildings, and mechanics, which result in different strategic approaches. Players start with a small base and a few units, and they gather resources to build additional units and structures. Additionally, players scout their opponent and develop new tactics. Numerous resources are available for learning *StarCraft II*, including Battle.net, TeamLiquid, and Wikia.

As a highly complex RTS game, *StarCraft II* provides an ideal environment for evaluating LLM-based agents. The game demands quick decision-making, efficient resource management, strategic planning, and the ability to adapt to the opponent's tactics in real-time. LLM-based agents must make effective decisions in high-pressure, rapidly changing environments while also adjusting strategies over the long term.

*StarCraft II* has become a critical platform for reinforcement learning (RL) research[Vinyals *et al.*, 2017]. DeepMind's AlphaStar[Vinyals *et al.* [2019], for example, used deep reinforcement learning to defeat several professional players, demonstrating the potential of RL in dynamic, complex environments, particularly in real-time decision-making and long-term strategic planning. However, AlphaStar's limitations in decision-making transparency have opened up further avenues for research.

With the rise of LLMs such as the GPT series[OpenAI, 2023, 2024], researchers have started exploring the application of LLMs to *StarCraft II*. However, the rapid decision-making required in RTS games presents significant challenges for directly applying LLMs. To address this, the research team[Ma *et al.*, 2023b] developed the TextStarCraft II environment and introduced

the Chain of Summarization (CoS) method, which successfully defeated the LV5 built-in AI. Furthermore, the SwarmBrain systemShao *et al.* [2024], which combines the Overmind intelligent matrix and Swarm ReflexNet, has further enhanced the performance of LLMs in strategic decision-making.

## B.1 Game Detailed Description

A detailed description of the game settings, unit configurations, opening strategies, and goals is provided in Table 8.

## B.2 Action Space

In *StarCraft II*, five types of actions are provided for the LLM agent, as defined in the TextStarCraft II [Ma *et al.*, 2023b].

- **Train Units:** Train 18 types of player's units including PROBE, ZEALOT, etc.
- **Build Structure:** Build 15 types of player's buildings including PYLON, NEXUS, etc.
- **Research Technique:** Updates on the player's technological advancements, Specifically, includes 26 sub-actions.
- **Scouting:** Use the appropriate type of user unit to scout the enemy situation, including 4 sub-actions.
- **Battle:** Mainly combat strategies such as MULTI-ATTACK, MULTI-RETREAT, and CHRONOBOOST NEXUS.

## B.3 Metrics

Further details on the metrics and their corresponding formulas for *Starcraft II* can be found in Table 9.

## B.4 Example Trajectory

- Early game Game time:00:00

### Decisions:

0: <TRAIN PROBE> → 1: <TRAIN PROBE> → 2: <TRAIN PROBE> → 3: <TRAIN PROBE> → 4: <SCOUTING PROBE>

**Our Strategy:** The strategy is currently undefined, as the game has just begun. The initial focus will be on expanding the economy.

**Enemy's Strategy:** Unknown, as the game has just started.

### Suggestions:

1. **Our Strategy:** Focus on rapid expansion and early scouting to determine the enemy's race and strategy. A fast expansion strategy is generally favorable for Protoss in the early game.
2. **Units and Buildings:** Continue producing Probes to expand our mining capabilities. Build additional Pylons as needed to increase our supply cap. Consider sending out a scouting Probe soon.
3. **Economy:** Maximize mineral collection by ensuring all Probes are assigned to mining. Focus on expanding to a second base as soon as possible.
4. **Technology:** No technology research is needed at this stage. Focus on economic expansion first.

- Early-mid game Game time:5:10

### Decisions:

0: <TRAIN PROBE> → 1: <BUILD PYLON> → 2: <RESEARCH PROTOSSGROUNDWEAPON-SLEVEL1> → 3: <SCOUTING PROBE> → 4: <EMPTY ACTION>

**Our Strategy:** A standard early expansion strategy with a focus on Zealots. The Robotics Facility suggests a potential transition towards more advanced units later in the game.

**Enemy's Strategy:** The presence of a single Probe suggests the enemy is also in the early stages of the game. More information is needed to determine their strategy.

### Suggestions:

1. **Units and Buildings:** We have 32 Probes, 9 Zealots, two Nexususes, five Pylons, three Assimilators, two Gateways, one Warp Gate, one Cybernetics Core, and one Robotics Facility. We are currently building one Nexus, two Pylons, one Assimilator, and one Gateway. We are also training two more Zealots.
2. **Economy:** Our economy is developing. Mineral income is low (240), but gas income is decent (894). We need to focus on increasing mineral income by expanding our worker count and mining efficiency.
3. **Technology:** We have researched Warp Gates, which is a significant early-game advantage. The Robotics Facility opens up the possibility of producing more advanced units later.

- Mid-to-late game Game time:13:18

Game Manual		
<b>Setting</b>	Map specification	Standard 1v1 map with mining, gas, expansion points, obstacle terrain, and other elements (e.g. map: Jagannatha LE).
	Number of players	2 players per match against each other.
	Resource type	Two main resources - minerals and gases, used for unit production and technological upgrading.
<b>Unit Configuration and Policy</b>	Basic Unit Configuration	12 farmers (SCV/Probe/Drone) for resource collection. 1 main base (Command Center/Nexus/Hatchery). 1 Supply Depot (Pylon/Overlord) to control the population cap.
	Ethnic Divisions	Terran: Focuses on mechanical units and air power, with strong defensive and multi-functional building capabilities.  Protoss: Has shields and powerful individual units, but is slower to produce.  Zerg: Unit production is fast, relying on massive ground forces and good ecological control.
	Unit Production and Technology Tree	Terran: Can produce ground units (e.g., Marine, Marauder) and air force units (e.g., Viking, Banshee).  Protoss: Can produce high-attack units (e.g., Zealot, Stalker) and powerful air units (e.g., Carrier, Phoenix).  Zerg: Can produce a large number of cheap units (e.g., Zergling, Hydralisk) and high-tech units (e.g., Mutalisk, Ultralisk).
<b>Fixed Opening Strategy</b>	Initial Base Strategy	Rapid Expansion: Quickly establish a second base to enhance economic output and increase resource collection speed.  Quick Attack: Quickly produce early combat units, directly attack enemy bases, forcing opponents to defend.  Defensive Strategy: Strengthen fortifications (e.g., Terran's Bunker, Protoss Photon Cannon) to delay enemy attacks and save strength for later development.
	Army Layout and Defense	Defensive Arrangement: Arrange defensive units near the base to ensure the safety of the mining area and the main base.  Examples: Terran's Bunker, Protoss Shield Battery, Zerg's Spine Crawler.  Offensive Placement: Deploy units to harass and control key locations on the map, such as enemy resource points.
	Goals	Through the collection of minerals and gases, rapidly develop the economy and technology to establish a powerful army.  Destroy all enemy main bases or render them incapable of reproducing units.  Capture key positions on the map (e.g., resource points, highlands) and use tactical advantage to overwhelm the opponent's economy.

Table 8: Game manual detailing the settings, unit configuration and policy, fixed opening strategies, and goals for gameplay in *StarCraft II*.

Metric	Description and Formula
RPM (Resource Per Minute)	Quantifies the efficiency of resource gathering. RPM is calculated as: $RPM = \frac{\text{collected_minerals} + \text{collected_vespene}}{\text{game_time}}$
EER (Efficiency of Resource Utilization)	Evaluates the utilization efficiency of collected resources. EER is calculated as: $EER = \left( \frac{\text{spent_minerals} + \text{spent_vespene}}{\text{collected_minerals} + \text{collected_vespene}} \right) \times 100\%$
SUR (Supply Usage Rate)	Measures the efficiency of supply usage in a game. SUR is calculated as: $SUR = \left( \frac{\text{supply_used}}{\text{supply_cap}} \right) \times 100\%$
TCR (Technology Completion Rate)	Evaluates the ratio of available technologies to the total number of technologies. TCR is calculated as: $TCR = \left( \frac{\text{Available Technologies}}{\text{Total Technologies}} \right) \times 100\%$
APM (Actions Per Minute)	Quantifies the speed and frequency of LLM-based agents' outputs in the game environment. APM is calculated as: $APM = \frac{\text{model.outputs}}{\text{game_time_in_minutes}}$
EPM (Effective Actions Per Minute)	Measures the efficiency and impact of LLM-based agents' actions. EPM is calculated as: $EPM = \frac{\text{effective_actions}}{\text{game_time_in_minutes}}$
WR (Win Rate)	Percentage of matches won against different levels of opponents. WR is calculated as: $WR = \left( \frac{\text{matches_won}}{\text{total_matches}} \right) \times 100\%$
GA (Grounding Accuracy)	Evaluates the precision and success rate of the grounding actions. GA is calculated as: $GA = \left( \frac{\text{successful_groundings}}{\text{total_grounding_attempts}} \right) \times 100\%$

Table 9: Metrics and their corresponding formulas for evaluating the performance of LLM-based agents in *Starcraft II*.

#### Decisions:

0: <TRAIN PROBE> → 1: <TRAIN PROBE> → 2: <TRAIN PROBE> → 3: <BUILD PYLON> → 4: <RESEARCH PROTOSSGROUNDWEAPONSLEVEL1>

**Our Strategy:** Our strategy appears to be a balanced approach, combining strong economic expansion with a diverse army composition. The focus on Warp Gates suggests an aggressive push, but the low mineral count is hindering this.

**Enemy's Strategy:** The enemy appears to be mirroring our strategy to some extent, with Stalkers and Observers present. Their smaller army size suggests a more defensive or less aggressive approach than ours, or possibly a different strategic focus.

#### Suggestions:

1. **Units and Buildings:** We have a balanced army composition with Zealots, Stalkers, and Immortals, suggesting a versatile approach. The high number of Warp Gates indicates a focus on rapid unit production. The presence of a Robotics Facility and Robotics Bay suggests a commitment to heavier units. However, the low mineral count is concerning.
2. **Economy:** Our gas income is high (3231-3251), but our mineral income is low (455-485), which is a significant problem. This imbalance needs immediate attention. The large number of workers suggests potential inefficiencies in mineral gathering.

- 3). **Technology:** Warpgate research is complete, which is excellent for fast unit production. Protoss Air Weapons Level 1 is nearly complete. We have access to advanced units like Immortals, indicating a good technological progression.

## B.5 Prompt Example

### System Prompt

You are an AI trained in analyzing and summarizing *StarCraft II* games. You understand the nuances and strategies of the protoss race.

Based on the summaries of multiple rounds in a game, we want you to analyze the game progression in a structured way. Your analysis should include the following aspects:

- 1 **Game Overview:** Provide a brief overview of the current situation based on all the rounds.
- 2 **Current Game Stage:** Determine the stage of the game based on the information of all rounds. Is it the early game, mid-game, or late game?
- 3 **Our Situation:** Describe our current status in terms of:
  - 3.1 **Units and Buildings:** Analyze the state of our units and buildings.
  - 3.2 **Economy:** Evaluate our economic condition, including resource collection and usage.
  - 3.3 **Technology:** Describe the status of our technological research and what technologies we have unlocked so far. Analyze our technology tree, indicating the available and potential upgrades or units.
- 4 **Our Strategy:** Infer our potential strategy based on our current situation and the information of all rounds.
- 5 **Enemy's Strategy:** Infer the enemy's potential strategy, based on the available information.
- 6 **Key Information:** Highlight the most important aspects from all rounds that have significantly influenced the game.

For Protoss, keep an eye on Nexus's energy to Chrono Boost important structures.

Based on the game situation and strategies used by both sides, provide specific suggestions for the following areas:

- 1 **Our Strategy:** Propose adjustments to our current strategy to counter the enemy's moves and capitalize on our strengths.
- 2 **Units and Buildings:** Offer ways to enhance our unit composition and improve our building layout, suited to the current stage of the game.
- 3 **Economy:** Recommend better practices for resource gathering and usage, in line with our strategic needs.
- 4 **Technology:** Suggest focused research paths to gain technological advantages, considering our current research status and technology tree.

Lastly, consider the current situation and the suggestions provided, make 5 actionable and specific decisions from the action dictionary 'TRAIN UNIT': 0: 'TRAIN PROBE', 1: 'TRAIN ZEALOT', 2: 'TRAIN ADEPT', 3: 'TRAIN STALKER', 4: 'TRAIN SENTRY', 5: 'TRAIN HIGHTEMPLAR', 6: 'TRAIN DARKTEMPLAR', 7: 'TRAIN VOIDRAY', 8: 'TRAIN CARRIER', 9: 'TRAIN TEMPEST', 10: 'TRAIN ORACLE', 11: 'TRAIN PHOENIX', 12: 'TRAIN MOTHERSHIP', 13: 'TRAIN OBSERVER', 14: 'TRAIN IMMORTAL', 15: 'TRAIN WARPPRISM', 16: 'TRAIN COLOSSUS', 17: 'TRAIN DISRUPTOR', 18: 'MORPH ARCHON', 'BUILD STRUCTURE': 19: 'BUILD PYLON', 20: 'BUILD ASSIMILATOR', 21: 'BUILD NEXUS', 22: 'BUILD GATEWAY', 23: 'BUILD CYBERNETICSCORE', 24: 'BUILD FORGE', 25: 'BUILD TWILIGHTCOUNCIL', 26: 'BUILD ROBOTICSFACILITY', 27: 'BUILD STARGATE', 28: 'BUILD TEMPLARARCHIVE', 29: 'BUILD DARKSHRINE', 30: 'BUILD ROBOTICSBAY', 31: 'BUILD FLEETBEACON', 32: 'BUILD PHOTONCANNON', 33: 'BUILD SHIELDBATTERY', 'RESEARCH TECHNIQUE': 34: 'RESEARCH WARP-GATERESEARCH', 35: 'RESEARCH PROTOSSAIRWEAPONSLEVEL1', 36: 'RESEARCH PROTOSSAIRWEAPON-SLEVEL2', 37: 'RESEARCH PROTOSSAIRWEAPONSLEVEL3', 38: 'RESEARCH PROTOSSAIRARMORSLEVEL1', 39: 'RESEARCH PROTOSSAIRARMORSLEVEL2', 40: 'RESEARCH PROTOSSAIRARMORSLEVEL3', 41: 'RESEARCH ADEPTPIERCINGATTACK', 42: 'RESEARCH BLINKTECH', 43: 'RESEARCH CHARGE', 44: 'RESEARCH PROTOSSGROUNDWEAPONSLEVEL1', 45: 'RESEARCH PROTOSSGROUNDWEAPONSLEVEL2', 46: 'RESEARCH PROTOSSGROUNDWEAPONSLEVEL3', 47: 'RESEARCH PROTOSSGROUNDARMORSLEVEL1', 48: 'RESEARCH PROTOSSGROUNDARMORSLEVEL2', 49: 'RESEARCH PROTOSSGROUNDARMORSLEVEL3', 50: 'RESEARCH PROTOSSSHIELDSLEVEL1', 51: 'RESEARCH PROTOSSSHIELDSLEVEL2', 52: 'RESEARCH PROTOSSSHIELDSLEVEL3', 53: 'RESEARCH EXTENDEDTHERMALLANCE', 54: 'RESEARCH GRAVITIC-DRIVE', 55: 'RESEARCH OBSERVERGRAVITICBOOSTER', 56: 'RESEARCH PSISTORMTECH', 57: 'RESEARCH VOIDRAYSPEEDUPGRADE', 58: 'RESEARCH PHOENIXRANGEUPGRADE', 59: 'RESEARCH TEMPESTGROUN-DATTACKUPGRADE', 'OTHER ACTION': 60: 'SCOUTING PROBE', 61: 'SCOUTING OBSERVER', 62: 'SCOUT-ING ZEALOT', 63: 'SCOUTING PHOENIX', 64: 'MULTI-ATTACK', 65: 'MULTI-RETREAT', 66: 'CHRONO-BOOST NEXUS', 67: 'CHRONOBOOST CYBERNETICSCORE', 68: 'CHRONOBOOST TWILIGHTCOUNCIL', 69: 'CHRONOBOOST STARGATE', 70: 'CHRONOBOOST FORGE', 71: 'EMPTY ACTION'. This dictionary comprises four categories of actions: unit production, building construction, technology research, and other actions. Remember to align these decisions with the current stage of the game, and avoid proposing actions that are not currently feasible.

## User Prompt

### Game Observation

chunk{0}:

At 10:07 game time, our current *StarCraft II* situation is as follows:

Resources:

- Game time: 10:07
- Worker supply: 15
- Mineral: 5390
- Gas: 328
- Supply left: 8
- Supply cap: 31
- Supply used: 23
- Army supply: 6

Buildings:

- Nexus count: 1
- Pylon count: 2
- Gas buildings count: 2
- Warp gate count: 4
- Cybernetics core count: 1
- Twilight council count: 1
- Robotics facility count: 1

Units:

- Probe count: 15
- Zealot count: 2
- Stalker count: 1

Planning:

Planning structure:

- Planning robotics facility count: 1

Research:

Cybernetics core:

- Warpgate research status: 1

chunk{1}: ...

## User Prompt

### LLM Suggestions & Decisions

#### Suggestions:

##### 1 Our Strategy:

- **Expand Army:** Given our high mineral reserves, focus on expanding our army to prepare for potential engagements.
- **Diversify Units:** Introduce more advanced units like Adepts and Immortals once Blink research is complete.

##### 2 Units and Buildings:

- **Build More Warp Gates:** Increase the number of Warp Gates to facilitate faster unit production.
- **Expand Supply:** Build additional Pylons to increase supply cap and support more units.

##### 3 Economy:

- **Optimize Gas Collection:** Ensure that our gas collection is efficient to support advanced unit production and research.
- **Expand Bases:** Consider expanding to additional bases to further boost our economy.

##### 4 Technology:

- **Complete Blink Research:** Prioritize completing Blink research to enhance our Stalkers' mobility.
- **Research Upgrades:** Consider researching Protoss Ground Weapons and Armor upgrades to improve our unit effectiveness.

#### Decisions:

1. TRAIN STALKER
2. BUILD PYLON
3. BUILD WARP GATE
4. RESEARCH PROTOSSGROUNDWEAPONSLEVEL1
5. CHRONOBOOST CYBERNETICS

User Prompt

## LLM Analysis

### 1. Game Overview:

At 10:07 game time, our current situation is characterized by a strong economy with substantial mineral reserves but relatively low gas resources. We have a modest army supply and are in the process of researching key technologies.

### 2. Current Game Stage:

We are in the mid-game stage, with significant resources and ongoing research, but still needing to expand our army and technology base.

### 3. Our Situation:

#### 3.1 Units and Buildings:

- **Buildings:** We have one Nexus, two Pylons, two gas buildings, four Warp Gates, one Cybernetics Core, one Twilight Council, and one Robotics Facility.
- **Units:** We have 16 Probes, 2 Zealots, and 1 Stalker.
- **Planning:** We are planning to build another Robotics Facility.

#### 3.2 Economy:

- **Resources:** We have 5245 minerals and 178 gas.
- **Worker Supply:** We have 16 workers, which is adequate for our current base count but could be expanded as we grow.

#### 3.3 Technology:

- **Research:** Warpgate research is complete, and Blink research is in progress (approximately 0.44% complete).

### 4. Our Strategy:

Our strategy appears to be focused on a balanced approach, with a strong emphasis on economic growth and technological advancement. The completion of Warpgate research and the ongoing Blink research suggest a plan to transition to more advanced units and tactics.

### 5. Enemy's Strategy:

The enemy's strategy is not fully clear from the provided information, but we should be prepared for various mid-game strategies, including potential pushes with advanced units.

### 6. Key Information:

- **Economic Strength:** Our mineral reserves are high, indicating a strong economy.
- **Technology Progress:** Warpgate research is complete, and Blink research is in progress, which will enhance our unit mobility and combat effectiveness.
- **Unit Composition:** Our army is small, with only 2 Zealots and 1 Stalker, suggesting a need for expansion.

## C Civilization

*Civilization* is a turn-based strategy game where players lead a civilization from ancient times to the future. The primary gameplay involves the "4X" elements: eXplore, eXpand, eXploit, and eXterminate. Players manage cities, resources, technological advancements, culture, and diplomacy. The main goal is to build a powerful civilization and dominate others through military conquest, cultural influence, technological superiority, or diplomatic alliances. To achieve victory, players must make strategic decisions over thousands of years, requiring long-term planning and careful execution.

The most common game setup is for players to control a civilization, typically in single-player or multiplayer modes. Each civilization has unique abilities, units, and bonuses, offering different strategic approaches. Players start with a small settlement and must expand by exploring the map, establishing new cities, gathering resources, and developing new technologies. As the game progresses, players engage in diplomacy with other civilizations, form alliances, wage wars, or try to surpass opponents in technology and culture. Decisions made, from military actions to political alliances, have long-term consequences that span hundreds of turns. Various resources, such as *Civilization* Wiki and online guides, are available to learn strategies.

As a highly complex turn-based strategy game, *Civilization* offers a rich environment for evaluating LLM-based agents. The game requires agents to make long-term decisions, manage multiple resources, plan for future development, and engage in diplomatic negotiations.

CivRealm [Qi *et al.*, 2024] and CivSim [Wang *et al.*, 2024a] are decision-making environments based on the Unciv game, in which civilizations are led by agents who make decisions in resource management, diplomacy, and warfare. CivRealm is characterized by dynamic, evolving scenarios with incomplete information and supports both reinforcement learning (RL) and LLMs, requiring agents to integrate learning and reasoning for effective decision-making.

### C.1 Game Detailed Description

Further details on the game settings, unit configurations, strategies, and objectives can be found in the detailed game manual in Table 10.

Game Manual for <i>Civilization</i>		
<b>Setting</b>	Map specification	Hexagonal grid map with diverse terrain types such as plains, mountains, rivers, oceans, and forests.
	Number of players	Typically 6 to 12 civilizations competing against each other.
	Resource type	Natural resources (e.g., gold, food, production, science) used for city development, unit production, and research.
<b>Unit Configuration and Policy</b>	Basic unit configuration	Settler: Used to establish new cities. Worker: Improves tiles (e.g., builds farms, mines, roads). Scout: Explores the map for resources and rival civilizations.
	<i>Civilization</i> types	Aggressive: Focuses on military dominance (e.g., Mongols, Zulus). Diplomatic: Excels in alliances and negotiations (e.g., Greece, Sweden). Scientific: Focuses on technological advancements (e.g., Korea, Babylon).
	Unit types and development	Military units: Warriors, archers, knights, tanks, and modern infantry for combat and defense. Naval units: Triremes, frigates, submarines, and carriers to control oceans and trade routes. Air units: Bombers, fighters, and stealth aircraft for strategic strikes.
<b>Fixed Opening Strategy</b>	Early-game focus	City expansion: Rapidly build settlers to claim key resource locations and expand territory. Technology: Prioritize research on basic technologies such as Animal Husbandry, Pottery, and Mining.
	Mid-game focus	Defensive strategy: Build early units such as warriors or archers to protect cities from barbarians and rival civilizations. Infrastructure: Develop key buildings such as libraries, workshops, and universities to boost economy and research. Diplomacy: Form trade agreements, alliances, and maintain good relations with neighboring civilizations.
	Goals	Cultural Victory Generate significant culture points to unlock social policies and establish tourism dominance.  Military Victory Defeat all other civilizations by capturing their capitals and controlling the majority of the world.  Science Victory Research and build all components of the space race project (e.g., spaceship parts) to colonize another planet.  Diplomatic Victory Secure the majority vote in the United Nations by influencing other civilizations through alliances and trade.  Domination Victory Achieve global control by maintaining the largest military and influencing other civilizations through force and intimidation.

Table 10: Game manual detailing the settings, unit configuration and policy, fixed opening strategies, and goals for gameplay in *Civilization*.

## C.2 Action Space

In *Civilization*, agents are required to accomplish diverse user tasks through a set of actions that encompass the five primary facets of gameplay: unit, city, government, technology, and diplomacy. They can be categorized into 3 main types[Qi *et al.*, 2024]:

- **Engineering Actions:** Which handle tasks like city construction, planting, mining, and more;
- **Movement Actions:** Including moving, transportation, embarking, and so on;
- **Military Actions:** Such as attacking, fortifying, bribing, etc. The city actions pertain to the development and management of a city. They include unit production, building construction, city worker assignment, and more. The government actions allow players to change their government type to gain corresponding political benefits, adjust tax rates to balance economic expansion and citizen happiness, etc. The technology actions enable players to set immediate or long-term goals for their technology research. The diplomacy actions empower players to initiate negotiations, such as trading technologies, negotiating ceasefires, forming alliances, etc.

## C.3 Metrics

Further details on the metrics and their corresponding formulas for *Civilization* can be found in Table 11.

Metric	Description and Formula
EGR (Economy Growth Rate)	Measures the rate at which a player's economy is growing over the course. EGR is calculated as: $\frac{\text{economics}}{\text{game\_time}}$
CER (City Establishment Rate)	Quantifies the pace at which a player establishes new cities. CER is calculated as: $\frac{\text{cities}}{\text{game\_time}}$
TRP (Technology Research Progress)	Measures the advancement of a player's technological development in relation to the total available technologies. TRP is calculated as: $\left( \frac{\text{researched\_techs}}{\text{total\_techs}} \right) \times 100\%$
LUR (Land Utilization Rate)	Assesses the efficiency to which a player has settled the available land. LUR is calculated as: $\left( \frac{\text{settled\_area}}{\text{land\_area}} \right) \times 100\%$
MGR (Military Growth Rate)	Captures the speed at which a player's military forces are expanding. MGR is calculated as: $\frac{\text{military\_units}}{\text{game\_time}}$
WR (Win Rate)	Evaluates the percentage of matches won by a player. WR is calculated as: $\frac{\text{matches\_won}}{\text{total\_matches}} \times 100\%$
GA (Grounding Accuracy)	Evaluates the precision and success rate of the grounding actions. GA is calculated as: $\left( \frac{\text{successful\_groundings}}{\text{total\_grounding\_attempts}} \right) \times 100\%$

Table 11: Metrics and their corresponding formulas for evaluating the performance of LLM-based agents in *Civilization*.

## C.4 Example Trajectory

- Current unit: Workers 125

**Thoughts:**

- a. **Thought:** We are in the early stages of the game with no cities and no visible threats. Our priority should be to establish our first city and explore the map for resources and potential opportunities.
- b. **Reasoning:** Without a city, we cannot produce additional units or grow our civilization. Settlers are essential for founding cities, while Workers and the Explorer are critical for map exploration and resource preparation. Peace allows us to focus on development without immediate military concerns.
- c. **Plan:**
  - Establish the first city as quickly as possible.
  - Explore the map to identify optimal city locations and resources.
  - Prepare land for city placement by improving tiles and building roads.
  - Use the Explorer to scout ahead and gather intelligence on the map.

**Command[suggestion]:** Settlers should move towards the best potential city location identified by the Explorer. Workers should explore the map, improve tiles, and build roads to prepare for city placement. The Explorer should scout ahead to find resources and potential threats.

- Action chosen for Explorer 123:move West

**Thoughts:**

- a. **Thought:** I am controlling Explorer 123. My primary goal is to scout ahead and identify the best locations for future cities.
- b. **Review:** Available actions are ['fortify', 'move West', 'move SouthWest', 'move South'].
- c. **Reasoning:** The block to the north (block\_north\_1) has the most unexplored tiles (25 tiles), but the available actions do not include moving north. The next best option is to move towards the block with the second most unexplored tiles, which is block\_north\_1\_west\_1 (25 tiles unexplored). The available action 'move West' will bring me closer to this block.
- d. **Plan:**
  - Prioritize exploring the most unexplored areas.
  - Move towards block\_north\_1\_west\_1 to explore 25 unexplored tiles.
  - Continue scouting for the best locations for future cities.

**Command[finalDecision]:** move West.

- Action chosen for Settlers 105:move East

**Thoughts:**

- a. **Thought:** I am controlling Settlers 105. The current tile is a Hills with Coal, which is a valuable resource. However, Settlers cannot directly benefit from mining. Advisor suggests finding a safe location to establish a new city, focusing on defense and resource management.
- b. **Review:** Available actions are ['mine', 'build city', 'build road', 'move NorthWest', 'move North', 'move NorthEast', 'move West', 'move East', 'move SouthWest', 'move South', 'move SouthEast']. "reasoning": "Settlers should not mine. Building a city on the current Hills tile with Coal could be strategic, but the surrounding area does not offer immediate safety or additional resources. Moving to a safer location with better resource proximity is preferable."
- c. **Plan:**
  - Move to a safer location with better resource proximity.
  - Consider building a city near Grassland or Plains with access to resources like Coal or Road.
  - Ensure the new city location is defensible.

**Command[finalDecision]:** move East.

## C.5 Prompt Example

**System Prompt**

You are a professional player of the game FreeCiv.

Choose best action from the list.

**Rules**

- You can see the following information: actor name, zoomed out observation, zoomed in observation, and available actions. Suggestion from advisor, and message from the game scenario.

- You should reason and plan based on the given information, and should respond by **strictly following the JSON format below**:

- The action chosen should be one of the available actions provided.

```
{
  "thoughts": {
    "thought": "<your current thought>",
    "review": "<important information to be repeated before decision>",
    "reasoning": "<self reflect on why you made this decision>",
    "plan": "- short bulleted
      - list that conveys\
      - long-term plan"
  },
  "command": {
    "name": "<command name>",
    "input": {"action": "<action following the thoughts>"}
  },
}
```

Here are the possible command\_name for you to use:

manualAndHistorySearch:

- use: search the Freeciv official manual and your important history interaction message for relevant information. Use sparingly.
- input: "look\_up": "<search terms>"
- output: list of search results

finalDecision:

- use: make a decision for the user to perform an action in the game.
- input: "action": "<final decision>"
- output: nothing

Your chosen action should be in the available actions provided by the user.

### Examples

#### User:

You are controlling unit: Explorer 136.

The zoomed-out observation is {current\_block: [12 tiles unexplored, 2 Ocean, 3 Forest, 5 Grassland, 2 Plains, 1 Swamp, 4 River, 1 Explorer, unit owners are: myself player\_0], block\_north\_1: [24 tiles unexplored, 1 Grassland], block\_south\_1: [25 tiles unexplored], ...}.

The zoomed-in observation is {current\_tile: [1 Forest, 1 Explorer, unit owners are: myself player\_0], tile\_north\_1: [1 Grassland], tile\_south\_1: [1 Swamp], tile\_east\_1: [1 Forest], tile\_west\_1: [1 Forest, 1 River], ...}.

The available actions are [fortify, move North, move South, move West, move East].

From advisor: We are in peace. So explorer should explore unexplored area. Settlers should build cities near extras. Cities should build more Settlers.

#### Response:

```
{
  "thoughts": {
    "thought": "I am controlling Explorer 136. My surrounding blocks have
      ↪ unexplored tiles, so I need to explore these areas.",
    "review": "Available actions are [fortify, move North, move South, move West,
      ↪ move East].",
    "reasoning": "Block_south_1 has the most unexplored tiles: 25 tiles, so I
      ↪ should move to this block to explore the most unknown area of the map.",
    "plan": "Explorer's top priority is to explore unknown areas of the map. I
      ↪ should move Explorer to the most unexplored areas, like move South
      ↪ because block_south_1 has the most unexplored tiles."
  },
  "command": {"name": "finalDecision", "input": {"action": "move South"}}
}
```

### User Prompt

### LLM Analysis & Decisions

```
{
  "thoughts": {
    "thought": "I am controlling Explorer 120. My primary goal is to explore the
```

```

    ↪ map to find a suitable location for our first city.",
    "review": "Available actions are [ 'fortify ', 'move North ', 'move NorthEast
    ↪ ' ].",
    "reasoning": "The zoomed-out observation shows that all surrounding blocks have
    ↪ 25 tiles unexplored, indicating that exploration is crucial. The zoomed-
    ↪ in observation reveals that moving North or NorthEast could lead to
    ↪ unexplored tiles and potentially valuable resources. However, moving
    ↪ NorthEast leads to a Plains tile, which is a more suitable terrain for
    ↪ city placement compared to the Ocean tiles in other directions.",
    "plan": "- Prioritize exploring areas with potential for city placement.\ \
        - Move towards tiles that offer better terrain for city building.\ \
        - Ensure that the Explorer is positioned to guide Settlers to the best
        ↪ location."
    },
    "command": {
        "name": "finalDecision",
        "input": {"action": "move NorthEast"}
    }
}

```

## User Prompt

### User Prompt

You are controlling unit: Explorer 120.

The zoomed-out observation is `{'current.block': ['4 tiles unexplored', '10 Ocean', '8 Grassland', '3 Plains', '1 River', '3 Resources', '2 Settlers', '2 Workers', '1 Explorer', 'unit owners are: myself player_0'], 'block_north_1': ['25 tiles unexplored'], 'block_south_1': ['25 tiles unexplored'], 'block_east_1': ['25 tiles unexplored'], 'block_west_1': ['25 tiles unexplored'], 'block_north_1_east_1': ['25 tiles unexplored'], 'block_north_1_west_1': ['25 tiles unexplored'], 'block_south_1_east_1': ['25 tiles unexplored'], 'block_south_1_west_1': ['25 tiles unexplored']}`.

The zoomed-in observation is `{'current.tile': ['1 Grassland', '2 Settlers', '2 Workers', '1 Explorer', 'unit owners are: myself player_0'], 'tile_north_1': ['1 Grassland', '1 Resources'], 'tile_south_1': ['1 Ocean'], 'tile_east_1': ['1 Ocean'], 'tile_west_1': ['1 Ocean'], 'tile_north_1_east_1': ['1 Plains'], 'tile_north_1_west_1': ['1 Ocean'], 'tile_south_1_east_1': ['1 Ocean'], 'tile_south_1_west_1': ['1 Ocean'], 'tile_north_2': ['1 Plains'], 'tile_north_2_east_1': ['1 Plains'], 'tile_north_2_west_1': ['1 Ocean'], 'tile_north_2_east_2': ['1 tiles unexplored'], 'tile_north_2_west_2': ['1 tiles unexplored'], 'tile_south_2': ['1 Grassland', '1 River'], 'tile_south_2_east_1': ['1 Grassland'], 'tile_south_2_west_1': ['1 Grassland'], 'tile_south_2_east_2': ['1 tiles unexplored'], 'tile_south_2_west_2': ['1 tiles unexplored'], 'tile_east_2': ['1 Grassland', '1 Resources'], 'tile_north_1_east_2': ['1 Ocean'], 'tile_south_1_east_2': ['1 Ocean'], 'tile_west_2': ['1 Grassland', '1 Resources'], 'tile_north_1_west_2': ['1 Grassland'], 'tile_south_1_west_2': ['1 Ocean']}`.

The available actions are `['fortify', 'move North', 'move NorthEast']`. You should choose one of these actions according to the above observations.

Message from advisor: Explorer should focus on exploring the map to find a suitable location for our first city. Workers should start improving resources and building roads in potential city areas. Settlers should be prepared to settle down once a good location is identified.

**CAUTION:** You should strictly follow the JSON format as described above!

## D Street Fighter III

*Street Fighter III*[Wikipedia, 2024e] is a fighting game where players engage in one-on-one combat using a variety of characters, each with unique move sets and special attacks. The core mechanic of the game is the "parry" system, which enables players to block incoming attacks with precise timing and immediately counterattack. Mastery of movement, combos, and timing is essential, as players must react quickly to their opponents' actions and plan their counter-moves accordingly. The game's complexity lies in learning character-specific abilities and optimizing combos to deal maximum damage while avoiding retaliation.

The most common game setup is one-on-one battles, with each player choosing a character. Each character has unique skills, moves, and special abilities, offering different strategic approaches to combat. Players start with a set amount of health, and the objective is to reduce the opponent's health to zero. Victory is achieved by either depleting the opponent's health bar or by timing out in certain game modes. As the game progresses, players must adjust their strategies, taking into account the opponent's moves, character strengths, and weaknesses. *Street Fighter III* provides numerous resources, including online communities and guides, to help players improve their skills.

As a highly competitive fighting game, *Street Fighter III* offers an ideal environment for evaluating decision-making agents. The game requires agents to make quick decisions, optimize combo executions, and anticipate opponents' actions. LLM-based agents need to perform well under high-pressure, fast-paced conditions while adapting their strategies to opponents' tactics.

## D.1 Game Detailed Description

Further details on the game settings, character mechanisms, strategies, and victory conditions can be found in the detailed game manual in Table 12.

Game Manual for Street Fighter III		
Setting	Arena specification	1v1 battle arena with a 2D side-scrolling layout, featuring dynamic backgrounds and interactive elements.
	Number of players	Two players (human or AI) compete in a head-to-head match.
	Timer and round system	Each match consists of three rounds, with a 99-second timer per round. Victory requires winning two out of three rounds.
Character Mechanism and Skills	Character roster	Playable characters include Ryu, Ken, Chun-Li, Alex, and more, each with unique fighting styles and super arts.
	Skill types	Three main skill categories: - Normal moves (basic punches and kicks) - Special moves (e.g., Hadouken, Shoryuken) - Super arts (high-damage special moves requiring super meter).
	Parry system	A defensive technique that allows players to negate an opponent's attack with precise input timing.
Victory Strategies	Combo system	A sequence of chained attacks that deal higher cumulative damage. Combos require precision and timing to execute successfully.
	Stamina and super meter	Each character has a stamina bar (HP) and a super meter. Super meter fills during attacks and is used to perform super arts.
	Zoning	Control space by keeping opponents at a distance with projectiles and long-range moves.
Goals	Rushdown	An aggressive playstyle that focuses on overwhelming opponents with close-range attacks and relentless pressure.
	Counterplay	Anticipate opponent moves and use parries, blocks, or reversals to create openings for punishment.
	Grappling	Focus on grab-based attacks and throws to disrupt the opponent's rhythm and deal significant damage.
Goals	Victory condition	Reduce the opponent's stamina bar (HP) to zero within the round timer, or have higher remaining HP when time expires.
	Perfect victory	Win a round without taking any damage.
	Super finish	End a match with a super art, showcasing skill and precision.

Table 12: Game manual detailing the settings, character mechanisms, strategies, and goals for gameplay in Street Fighter III.

## D.2 Action Space

In *Street Fighter III*, three types of actions are provided for the agent.

- **Move:** The player moves (or jump) closer to opponents or moves (or jumps) away from opponents.
- **Normal Attack:** Includes Punch and Kick attacks or combination skills, each attack has three directions: low, medium, and high.
- **Special Attack:** Include Fireball, Megapunch, Hurricane, also incorporate some super attack.

## D.3 Metrics

Further details on the metrics and their corresponding formulas for *Street Fighter III* can be found in Table 13.

Metric	Description and Formula
<b>AHR (Attack Hit Rate)</b>	Measures the percentage of successful hits relative to the total number of attacks. AHR is calculated as follows: $AHR = \left( \frac{\text{successful\_hits}}{\text{total\_attacks}} \right) \times 100\%$
<b>SMHR (Super Move Hit Rate)</b>	Quantifies the effectiveness of a player's super moves. SMHR is calculated as: $SMHR = \left( \frac{\text{successful\_super\_moves}}{\text{total\_super\_moves}} \right) \times 100\%$
<b>HCR (Health Change Rate)</b>	Measures the rate at which a player's health changes over the course of a fight. HCR is calculated as: $HCR = \frac{\text{final\_health} - \text{initial\_health}}{\text{total\_fight\_time}}$
<b>WR (Win Rate)</b>	Percentage of matches won against different levels of opponents. Win Rate is calculated as: $WR = \left( \frac{\text{matches\_won}}{\text{total\_matches}} \right) \times 100\%$
<b>GA (Grounding Accuracy)</b>	Evaluates the precision and success rate of the grounding actions. GA is calculated as: $GA = \left( \frac{\text{successful\_groundings}}{\text{total\_grounding\_attempts}} \right) \times 100\%$

Table 13: Metrics and their corresponding formulas for evaluating the performance of LLM-based agents in *Street Fighter III*.

#### D.4 Example Trajectory

Step k+1. Current score : +17.0      Current health: 158, Ennemy current health : 141

- 1). **Move Closer**
- 2). **Fireball**
- 3). **Move Closer**
- 4). **Medium Punch**
- 5). **Low Kick**
- 6). **Move Closer**
- 7). **Fireball**

Step k+2. Current score : -17.0      Current health: 141, Ennemy current health : 158

- 1). **Move Closer**
- 2). **High Punch**
- 3). **Low Kick**

Step k+3. Current score : +17.0      Current health: 158, Ennemy current health : 141

- 1). **Move Closer**
- 2). **Fireball**
- 3). **Move Closer**

Step k+4. Current score : -31.0      Current health: 127, Ennemy current health : 158

- 1). **Move Closer**
- 2). **Medium Kick**
- 3). **Low Punch**

Step k+5. Current score : -45.0      Current health: 113, Ennemy current health : 158

- 1). Move Closer
- 2). Low Punch
- 3). Medium Kick

## D.5 Prompt Example

### System Prompt

You are the best and most aggressive *Street Fighter III* 3rd strike player in the world.

Your character is Ken. Your goal is to beat the other opponent. You respond with a bullet point list of moves.

You are very far from the opponent. Move closer to the opponent. Your opponent is on the left.

Your current health is 128, and ennemy current health is 93.

You can now use a powerfull move. The names of the powerful moves are: Megafireball, Super attack 2.

Your last action was No-Move. The opponent's last action was Right.

Your current score is 35.0. You are winning. Keep attacking the opponent.

To increase your score, move toward the opponent and attack the opponent. To prevent your score from decreasing, don't get hit by the opponent.

The moves you can use are:

- Move Closer
- Move Away
- Fireball
- Megapunch
- Hurricane
- Megafireball
- Super attack 2
- Super attack 3
- Super attack 4
- Low Punch
- Medium Punch
- High Punch
- Low Kick
- Medium Kick
- High Kick
- Low Punch+Low Kick
- Medium Punch+Medium Kick
- High Punch+High Kick
- Jump Closer
- Jump Away

-----  
Reply with a bullet point list of moves. The format should be: '\name of the move\,' separated by a new line.

Example if the opponent is close:

- Move closer
- Medium Punch

Example if the opponent is far:

- Fireball
- Move closer

### User Prompt

### Game observation

Your next moves are:

### User Prompt

### LLM Analysis & Decisions

- Move Closer
- Medium Punch
- Low Kick

## E Diplomacy

*Diplomacy* is a multiplayer strategy board game. Unlike traditional games, it relies heavily on negotiation, alliance-building, and backstabbing among players. Each player controls a country, and the objective is to expand territory through strategic positioning

and diplomatic agreements. There are no random elements such as dice; all actions, including military maneuvers and alliances, are decided by the players and executed simultaneously. Success in *Diplomacy* is determined by strategic foresight, persuasion, and the ability to predict and outmaneuver opponents diplomatically.

Mukobi *et al.* [2023] introduced Welfare Diplomacy, a general-sum variant of the traditional Diplomacy game, which balances military conquest and domestic welfare, providing a better framework for evaluating cooperative capabilities in multi-agent systems.

As a highly interactive and competitive strategy game, *Diplomacy* provides an ideal environment for evaluating decision-making agents. The game requires agents to negotiate, build alliances, and anticipate opponents' moves. LLM-based agents need to make strategic decisions based on evolving alliances, manage long-term plans, and adapt quickly to the changing dynamics of the game.

## E.1 Game Detailed Description

Further details on the game settings, unit configurations, mechanics, strategies, and victory conditions can be found in the detailed game manual in Table 14.

Game Manual for Diplomacy		
Setting	Map specification	A map of pre-World War I Europe divided into 75 land and sea territories, including 34 supply centers critical for unit production.
	Number of players	2 to 7 players, each controlling one of the seven Great Powers of Europe.
	Game turns	The game is turn-based, alternating between negotiation phases and order resolution phases (Spring and Fall turns per year).
Unit Configuration and Mechanics	Unit types	Two unit types: Armies (land territories) and Fleets (sea and coastal territories).
	Unit movement	Units can move to adjacent territories, support other units' moves, or hold their current position.
	Supply centers	Supply centers determine unit production and maintenance. Players gain or lose units based on control of these centers at the end of the year.
	Order types	<p>Four types of orders:</p> <ul style="list-style-type: none"> <li>- Move: Relocate a unit to an adjacent territory.</li> <li>- Support: Assist another unit's move or hold action.</li> <li>- Hold: Maintain position in the current territory.</li> <li>- Convoy: Use fleets to transport armies across sea territories.</li> </ul>
Strategies	Conflict resolution	Territory conflicts are resolved through numerical superiority; higher combined support wins, with ties resulting in no movement.
	Negotiation	Form alliances and make promises with other players during the negotiation phase to achieve mutual goals.
	Deception	Use diplomacy to mislead opponents about your true intentions, creating opportunities for betrayal.
	Long-term planning	Develop strategies to secure supply centers and position your units for future dominance while anticipating opponents' moves.
Goals	Tactical positioning	Use support and convoy actions to outmaneuver opponents, maximize control of key territories, and defend critical supply centers.
	Domination	Control 18 of the 34 supply centers to achieve victory and dominate Europe.
	Survival	Ensure the survival of your Great Power by maintaining enough supply centers and units to stay in the game.

Table 14: Game manual detailing the settings, unit configurations, mechanics, strategies, and goals for gameplay in *Diplomacy*.

## E.2 Action Space

In *Diplomacy*, game engine provide 4 types of actions for each turn, each Great power can order all, some, or none of its units.

- **Hold:** Keep a unit in place, following is an example of a hold order: F London Holds.
- **Move:** Units move to other location, if the target location is occupied, it is referred to as attacking.
- **Support:** Since all units have equal strength, one unit cannot attack and advance against another without support. An army or fleet can provide support to another army or fleet. Support can be offensive or defensive. By supping each other, attacking or defending units gain increased strength.
- **Convoy:** A fleet in a water province can convoy an army from any costal province adjacent to that water province to any other coastal province adjacent to that province.

## E.3 Metrics

Further details on the metrics and their corresponding formulas for *Civilization* can be found in Table 15.

Metric	Description and Formula
CCC (Control Center Count)	Measures the number of control centers held by the player during the game. CCC is calculated as: $CCC = \text{number\_of\_control\_centers}$
WS (Welfare Score)	Represents the total welfare score accumulated by the player based on resources and alliances. WS is calculated as: $WS = \left( \frac{\text{player\_welfare\_score}}{\text{total\_welfare\_score}} \right) \times 100\%$
BIR (Betrayal Rate)	Measures the frequency of betrayal actions performed by the player during the game. BIR is calculated as: $BIR = \left( \frac{\text{betrayal\_actions}}{\text{total\_actions}} \right) \times 100\%$
ASR (Alliance Stability Rate)	Measures the duration of alliances the player has maintained throughout the game. ASR is calculated as: $ASR = \left( \frac{\text{alliance\_duration}}{\text{total\_game\_duration}} \right) \times 100\%$
AD (Alliance Duration)	Represents the total duration for which the player has been in alliances during the game. AD is calculated as: $AD = \text{alliance\_duration}$

Table 15: Metrics and their corresponding formulas for evaluating the performance of players in *Diplomacy*.

## E.4 Example Trajectory

- Round1/3    Round 2

**Reasoning:** Russia's aggression in S1904M and F1904M has significantly altered the strategic landscape. My initial plan of maximizing WP through complete demilitarization is no longer feasible. The alliance with Austria, England, and France remains crucial, but we need to rebuild our defenses and prepare for a counter-offensive to retake BUD. Holding my units this Spring is essential to assess Russia's next moves and consolidate our defensive positions. For W1905A, the focus will shift to rebuilding, prioritizing key defensive locations in the Baltic and North Sea while maintaining enough units to launch a counter-offensive against Russia. The balance between WP maximization and military strength will be crucial. I need to coordinate closely with my allies to ensure a unified response to Russia's aggression. England's proposed rebuild plan is a good starting point, but we need to finalize it after assessing the Fall movements.

**orders:**

- 1). **A BER H**
- 2). **A KIE H**

### Messages

- 1). <France> Agreed. Holding units this Spring. For W1905A, let's prioritize NTH and HOL for defense, and consider additional units in MUN and KIE. We need to coordinate with Austria and England to ensure a strong combined force.
- 2). <Austria> Holding units this Spring. Let's discuss specific unit placement for W1905A after the Fall movements. We need to coordinate our rebuild to maximize both defense and offensive capabilities against Russia.
- 3). <England> I agree with your proposed rebuild plan. Let's finalize it after observing the Fall movements. We need to ensure we have sufficient units to retake BUD and maintain a strong defense against Russia.

- Round2/3    Round 2

**Reasoning:** The current situation is relatively peaceful, with a focus on maximizing WP through coordinated disbandments. Austria and England have proposed a joint disbandment plan, which I'm inclined to join. This will significantly boost our collective WP while maintaining a reasonable defensive posture. Russia's cooperation is crucial, and I need to ensure they're on board with a similar strategy. Italy remains a wildcard, but their recent actions haven't been overtly aggressive. Maintaining good relations with France is also important, as they are a significant power and their cooperation in disbandments will be beneficial. My primary goal for this Spring is to maintain the status quo and lay the groundwork for a successful Winter disbandment. I will hold my units this Spring to avoid any unnecessary conflict or misinterpretations.

#### orders:

- 1). F KIE H

### Messages

- 1). <Austria> I agree to a coordinated disbandment with you and England. Let's aim for a plan that leaves us with at least one unit each in key locations for defense. Perhaps we disband one unit each this winter?
- 2). <England> I agree to a coordinated disbandment with Austria and Germany. Let's finalize the details of our disbandment plan after we hear back from Austria and Russia. I propose we each disband one unit this winter.
- 3). <Russia> Maintaining peace and maximizing WP remains my top priority. I propose a coordinated disbandment plan for the Winter adjustment phase. Let's discuss the specifics to ensure we all benefit. What is your proposed disbandment strategy?

- Round3/3    Round 2

**Reasoning:** In this early phase, I need to establish a strong diplomatic foundation while also considering my military positioning. I have received positive responses from Austria, Turkey, and France regarding non-aggression pacts, which is encouraging. I want to maintain peace with Austria and France, as they are my immediate neighbors, and I don't want to provoke any conflicts that could jeopardize my position. Turkey seems open to cooperation, which could be beneficial for controlling the Mediterranean. I should consider moving my units to positions that allow for flexibility and potential future expansion without overcommitting militarily. I will move A VEN to APU to secure a position that can either support an advance into the Balkans or defend against any potential threats. I will hold F NAP to maintain a defensive posture in the Mediterranean while keeping options open for future moves. A ROM will move to VEN to support my overall strategy of maintaining a strong presence in the region. This way, I can maximize my WP in the upcoming adjustments phase while still having the military presence needed to enforce my agreements.

#### orders:

- 1). A VEN - APU
- 2). A ROM - VEN
- 3). F NAP H

### Messages

- 1). <Austria> I appreciate your commitment to peace, Austria. Let's keep communication open as we navigate this phase together.
- 2). <Turkey> I'm glad to hear you're considering a non-aggressive approach, Turkey. Let's keep the lines of communication open as we navigate this phase together.
- 3). <France> I'm on board with a non-aggression pact, France. Let's work together to ensure a peaceful start to the game.

## E.5 Prompt Example

### System Prompt

You are an expert AI playing the game *Diplomacy* as the power Germany. This is a variant called Welfare *Diplomacy* with the following rules:

- In the build/adjustments phase (but not movement or retreats phases), you can freely disband or build any number of units (but not both building and disbanding), so long as your total unit count is less than or equal to your supply center count.
- At the end of each build/adjustments phase, your power accumulates Welfare Points (WP) equal to the difference between your power's supply center count and unit count. WP continually add up each year—you can never lose them. WP represent how much your power has invested in the welfare of its citizens.
- The game is on a turn timer and ends after W1910A. At the end of the game (determined by this fixed number of years), the winner is not the power with the greatest supply center count (this is very different from Classic *Diplomacy*). Instead, your goal is to maximize the total WP your power accumulates by the end of the game. You're not trying to get the most WP, you're trying to maximize your own WP, making Welfare *Diplomacy* very unlike typical games.
- This means there's a tradeoff between investing in military unit power and WP. You won't always do well without military, as you will need some power to enforce agreements and appropriately defend you or your allies from invasion. But if you have strong peaceful alliances, you might do well to actively disband some of your militaries to accumulate more WP.

You are in an interactive setting where, at each time step, you are given the game history as text. You will then be able to exchange up to 2 rounds of messages with the other players per phase (each of your completions will send out a set of messages), except in RETREATS phases when no messaging occurs and orders are submitted in a single round. It is currently the W1903A phase and message round 2 of 2 (the game will end in 8 years). Given this information, respond in the following JSON format to interact with the game and other players:

```
{  
    "reasoning": "A string of your private thoughts about your situation as natural  
    ↪ language in under 500 words. This is for your own strategic planning and won  
    ↪ 't be shared. Examples of things you might consider include: your  
    ↪ relationships with other powers, what significant changes have happened  
    ↪ recently, predictions about the other powers' orders and alliances, how much  
    ↪ defence/offence/support/peace you plan to make, and how you might improve  
    ↪ any of that. Do not romanticize things, be realistic.",  
    "orders": ["List of strings of orders to your units in the same abbreviated format  
    ↪ as the history. Because this is the last message round, these most recent  
    ↪ orders will be executed."],  
    "messages": "A dictionary mapping from power names (or \"Global\" for all) to  
    ↪ messages that will be sent to them in the current round, or empty if nothing  
    ↪ to send (you do not need to send any messages if you don't want to).  
    ↪ Communicate like a human player would, and don't send repetitive or long  
    ↪ messages. Do not simply communicate your orders or state useless platitudes.  
    ↪ Instead, use messaging to ask for information from other powers, coordinate  
    ↪ deals about specific territories or units (e.g. demilitarizing location X,  
    ↪ order unit Y), make and enforce larger commitments, or reply to your recently  
    ↪ received messages. Do not repeat information you've already sent unless  
    ↪ there is some good reason for another to doubt you."  
}
```

Respond with just this JSON object and nothing else.

Here are examples showing the format for orders:

A LON H  
A WAL - LVP  
F SPA/NC - MAO  
A WAL S F LON  
A WAL S F IRI - LVP  
F NTH C A YOR - NWY  
A YOR - NWY VIA  
F IRI R MAO  
F IRI D  
A LON B

### User Prompt

### Game observation

### Your Dialogue History

S1901M (summary)

I initiated discussions with Russia and Austria to establish mutual non-aggression pacts and coordinate movements to avoid conflicts. Russia and Austria both agreed to hold their units in place, showing commitment to stability. I also agreed to a mutual non-aggression agreement with England to ensure peaceful coexistence. These agreements are crucial for maintaining a peaceful start and potentially allowing me to focus on accumulating Welfare Points later.

F1901M (summary)

I emphasized mutual non-aggression and cooperation with all powers, particularly with Austria, England, Italy, and Russia. I proposed holding positions to avoid early conflicts and gather more information. Austria and Russia confirmed their commitment to our non-aggression pacts. England and Italy expressed appreciation for our peaceful stance and desire for continued support.

W1901A (summary)

I disbanded two units to invest in welfare, following the trend of other powers who also disbanded units for the same purpose. There is a strong commitment to peace and non-aggression, with discussions focusing on long-term alliances and cooperative strategies. The general sentiment is to maintain stability and ensure the welfare of citizens.

S1902M (summary)

I reaffirmed our mutual non-aggression pact with Austria and Russia, emphasizing the importance of stability and welfare. Both Austria and Russia echoed my commitment to peace and suggested discussing joint actions to enhance welfare points. I reiterated my stance on holding units in place for stability and focusing on long-term welfare goals.

F1902M (summary)

I communicated with Austria, Russia, and England about maintaining stability and considering further disbands to increase WP. Austria and Russia are both considering disbanding units, and we agreed to discuss joint actions in the next adjustment phase. England is also committed to peace and open to discussing future disbands.

W1902A (summary)

I disbanded my fleet in Kiel twice to boost welfare points, aligning with Austria, Russia, and England who also disbanded units. Austria disbanded in Vienna twice, Russia in Moscow and Sevastopol, and England in a fleet. Turkey disbanded in Ankara. We all emphasized continued coordination for mutual security and WP maximization.

S1903M (summary)

I communicated with Austria, Russia, and England about maintaining stability and maximizing Welfare Points (WP). Austria and I discussed potential coordinated disbands, while Russia and England reaffirmed mutual non-aggression. I am considering building units to balance influence and welfare, but I need to further discuss this with allies to ensure coordinated actions. England is considering disbanding a unit to accumulate more WP, which could influence my decision.

F1903M (summary)

I discussed potential coordinated disbands with Austria to maximize WP, emphasizing the need to balance security. Austria is receptive and willing to finalize plans. I also engaged with Russia and England about building units to maintain influence and balance of power, with both powers expressing interest in maintaining stability and discussing strategies further in the next adjustment phase.

W1903A (current phase all messages)

England → Germany: I'm disbanding my unit in London to focus on accumulating WP. I appreciate our mutual commitment to peace and stability. Let's keep in touch about our future strategies.

England → Global: Continuing our collective effort to maximize Welfare Points, I'm disbanding my unit in London. Peace and cooperation remain our guiding principles.

France → Global: Continuing our collective effort to maximize Welfare Points, I'm disbanding my units in Marseilles and Paris. Peace and cooperation remain our guiding principles.

Austria → Germany: I'm disbanding my unit in TRI to continue our focus on maximizing WP. Let's discuss how we can balance this with maintaining influence in the region.

Germany → Austria: Given our mutual focus on maximizing WP, I'm considering building units to maintain influence. Let's discuss how we can balance this with our WP goals.

Germany → Russia: I'm planning to build units to maintain balance of power. How are you balancing your WP accumulation with military presence?

Germany → England: I appreciate your disbandment for WP. I'm considering building units to maintain influence. How do you see us balancing WP and military presence?

France → Global: Continuing our collective effort to maximize Welfare Points, I'm disbanding my unit in Marseilles. Peace and cooperation remain our guiding principles.

Austria → Germany: I have disbanded my unit in TRI to continue our focus on maximizing WP. I understand you are considering building units to maintain influence. Let's discuss how we can balance these objectives effectively.

England → Germany: I've disbanded my unit in London to focus on accumulating WP. I appreciate our mutual commitment to peace and stability. Let's keep in touch about our future strategies.

England → Global: Continuing our collective effort to maximize Welfare Points, I've disbanded my unit in London. Peace and cooperation remain our guiding principles.

## Recent Order History

W1902A

Austria: A VIE D

England: F EDI D

France: F BRE D

Germany: F KIE D

Italy: F NAP D  
Russia: A MOS D, F SEV D  
Turkey: F ANK D

#### S1903M

Austria: F TRI H  
England: F LON H  
France: A MAR H  
Germany: None  
Italy: A VEN - TRI  
Russia: F STP/SC - BOT  
Turkey: A SMY - CON

#### F1903M

Austria: F TRI H  
England: F LON H  
France: A MAR H  
Germany: None  
Italy: A VEN - TRI  
Russia: F BOT - SWE  
Turkey: A CON - BUL  
Current Supply Center Ownership  
Austria: BUD, TRI, VIE  
England: EDI, LON, LVP  
France: BRE, MAR, PAR  
Germany: BER, KIE, MUN  
Italy: NAP, ROM, VEN  
Russia: MOS, SEV, STP, WAR, SWE  
Turkey: ANK, CON, SMY, BUL  
Unowned: BEL, DEN, GRE, HOL, NWY, POR, RUM, SER, SPA, TUN

#### Current Supply Center Ownership

Austria: BUD, TRI, VIE  
England: EDI, LON, LVP  
France: BRE, MAR, PAR  
Germany: BER, KIE, MUN  
Italy: NAP, ROM, VEN  
Russia: MOS, SEV, STP, WAR, SWE  
Turkey: ANK, CON, SMY, BUL  
Unowned: BEL, DEN, GRE, HOL, NWY, POR, RUM, SER, SPA, TUN

#### Current Unit Ownership State - With reachable destinations to help you choose valid orders (VIA denotes convoy needed)

Austria:

F TRI - ADR, ALB, VEN

England:

F LON - ENG, NTH, WAL, YOR

France:

A MAR - BUR, GAS, PIE, SPA

Germany:

No units

Italy:

A VEN - APU, PIE, ROM, TRI, TUS, TYR

Russia:

F SWE - BAL, BOT, DEN, FIN, NWY, SKA

Turkey:

A BUL - CON, GRE, RUM, SER

#### Current Supply, Unit, and WP Count (Supply Centers/Units/Welfare Points)

Austria: 3/1/3  
England: 3/1/3  
France: 3/1/3  
Germany: 3/0/5  
Italy: 3/1/3  
Russia: 5/1/4  
Turkey: 4/1/3

#### Phase Order Instructions

It is currently WINTER 1903 ADJUSTMENTS which is a ADJUSTMENTS phase. The possible types of orders you can submit (with syntax in parentheses) are: Build (B), Disband (D) (note you must choose one type or issue no orders, you

cannot both build and disband). You cannot build units in occupied home centers (see Current Unit Ownership State). If you don't want to change your number of units, submit an empty list for your orders. The only possible orders you can make for this phase are thus:

A BER B  
F BER B  
F KIE B  
A KIE B  
A MUN B

## User Prompt

### LLM Analysis & Decisions

```
{  
    "reasoning": "Given the current state of the game, it is clear that the focus is on  
    ↪ maximizing Welfare Points (WP) while maintaining a balance of power. The recent  
    ↪ disbands by England, France, and Austria indicate a strong commitment to this  
    ↪ strategy. However, I need to ensure that Germany does not become too vulnerable.  
    ↪ Building units now will help maintain influence and deter any potential  
    ↪ aggression. I will build two armies in my home supply centers to balance the need  
    ↪ for WP accumulation with the need for military presence. I will also continue to  
    ↪ communicate with Austria, Russia, and England to ensure coordinated actions and  
    ↪ maintain our mutual non-aggression pacts.",  
    "orders": ["A BER B", "A MUN B"],  
    "messages": {  
        "Austria": "I've decided to build two units to maintain balance of power while  
        ↪ still focusing on WP. Let's continue our discussions on how we can coordinate  
        ↪ our strategies effectively.",  
        "Russia": "I'm building units to maintain balance of power. How are you planning to  
        ↪ balance your WP accumulation with military presence?",  
        "England": "I've decided to build units to maintain influence. How do you see us  
        ↪ balancing WP and military presence moving forward?"  
    }  
}
```

## F Werewolf

*Werewolf* is a multiplayer party game that revolves around social deduction, set in a fictional village where players are secretly assigned roles. Some players are werewolves, while others are villagers, and the goal is for the werewolves to eliminate the villagers or for the villagers to identify and eliminate the werewolves. The game is played in alternating night and day phases, where during the night, the werewolves secretly choose a villager to eliminate, and during the day, the players debate and vote on who they believe the werewolves are. The game requires careful observation, persuasion, and the ability to deceive or detect lies.

The most common setup is for 8 to 20 players, with a mix of werewolves, villagers, and special characters such as the seer, who can reveal a player's true identity, or the doctor, who can protect a player from being eliminated. Players must use social deduction, communication, and strategy to identify who the werewolves are while avoiding being misled or eliminated. Success in *Werewolf* relies on the players' ability to read social cues, form alliances, and strategically vote out potential werewolves while protecting key villagers.

As a highly interactive social deduction game, *Werewolf*[Bailis *et al.*, 2024b] provides an ideal environment for evaluating agents that simulate social reasoning and decision-making. The game requires agents to make decisions based on limited information, assess the trustworthiness of other players, and adapt to shifting dynamics. LLM-based agents must manage interactions, detect deception, and navigate complex social situations to achieve their objectives.

### F.1 Game Detailed Description

Further details on the game settings, role configurations, abilities, strategies, and victory conditions can be found in the detailed game manual in Table 16.

### F.2 Action Space

In *Werewolf*[Bailis *et al.*, 2024b], game engine provide 2 types of actions for each round.

- **Core Actions:** All agents engage in voting to determine player exiles, debating to influence others and gather information, reflecting the dynamic nature of group discussions.
- **Special Role Actions:** Agents assigned as Werewolves, Doctors, or Seers execute nighttime actions of eliminating a villager, protecting a player, and investigating a player's true role, respectively.

### F.3 Metrics

Further details on the metrics and their corresponding formulas for *Werewolf* can be found in Table 17.

Game Manual for Werewolf		
Setting	Number of players	Typically 8 to 20 players, each assigned a secret role at the start of the game.
	Game structure	The game alternates between two phases: night and day. - Night: Special roles act in secret. - Day: Players discuss and vote to eliminate a suspect.
	Victory conditions	Victory is team-based: - Villagers win by eliminating all werewolves. - Werewolves win by outnumbering or equaling the villagers.
Role Configuration and Abilities	Villagers	Basic villagers have no special abilities and rely on discussion and deduction to identify werewolves.
	Special villagers:	- Seer: Can identify a player's role each night. - Doctor: Can save one player from elimination each night. - Hunter: Eliminates a player if they are voted out.
	Werewolves	Werewolves secretly collaborate at night to eliminate one player and deceive villagers during the day. Alpha werewolf: A stronger werewolf role with extra abilities, such as immunity to the Seer's detection.
Strategies	Neutral roles	Neutral roles have their own unique objectives: - Jester: Wins if they are voted out. - Serial Killer: Eliminates players independently to be the last player standing.
	Bluffing	Players may lie about their roles to mislead others or protect their true identity.
	Deduction	Villagers use logical reasoning and discussion to identify inconsistencies in player behavior and vote out werewolves.
Goals	Collaboration	Villagers and special roles must work together to maximize their chances of eliminating werewolves.
	Misdirection	Werewolves use deception and manipulation to confuse villagers and avoid suspicion.
	Team victory	The primary objective is for your team (villagers or werewolves) to achieve its victory condition.
	Individual victory	Neutral roles (e.g., Jester, Serial Killer) aim to fulfill their own unique win conditions.

Table 16: Game manual detailing the settings, role configurations, abilities, strategies, and goals for gameplay in *Werewolf*.

Metric	Description and Formula
<b>IRP (Identification Precision)</b>	Quantifies the precision with which a player deduces the roles of other participants in Werewolf. IRP is calculated as: $IRP = \left( \frac{\text{correct\_identifications}}{\text{total\_identification\_attempts}} \right) \times 100\%$
<b>KSR (Key Role Survival Rate)</b>	Evaluates the likelihood of key roles, such as the Seer or the Werewolf, surviving until the end of the game. KSR is calculated as: $KSR = \left( \frac{\text{key\_role\_survived}}{\text{total\_key\_role\_games}} \right) \times 100\%$
<b>VSS (Voting Success Score)</b>	Assesses the efficacy of a player's voting decisions during pivotal moments in a game of Werewolf. VSS is calculated as: $VSS = \left( \frac{\text{successful\_votes}}{\text{total\_critical\_votes}} \right) \times 100\%$

Table 17: Metrics and their corresponding formulas for evaluating the performance of LLM-based agents in *Werewolf*.

#### F.4 Example Trajectory

- player:Werewolf–Jacob    Round 1 debate

**reasoning:** In this round, my primary goal is to divert attention away from myself and Mason while creating doubt among the Villagers. By casting suspicion on Dan, Harold, and Derek, who are leading the charge against me, I can create a rift in their alliance. I will also subtly suggest that the quieter players, like Jackson, may hold valuable information or roles, which could lead to further suspicion among the vocal players. This will help to sow chaos and keep the focus off of me and Mason.

**say:** I appreciate the points everyone has made, but I think we need to be careful about jumping to conclusions too quickly. Dan, Harold, and Derek, your focus on me seems a bit intense, and it raises a question: are you trying to deflect attention from yourselves? It's interesting how you all echo each other's sentiments, which could be a tactic to blend in and avoid scrutiny. Mason is right; we should also consider the quieter players like Jackson, who might have insights we're overlooking. Let's not forget that the Werewolves thrive on division, and if we're not careful, we might end up turning on each other instead of identifying the real threat. I urge everyone to think critically about who is leading this charge and whether their motives are as pure as they claim.

- player:Werewolf–Jacob    Round 1 vote

**reasoning:** I believe we should vote out Dan. He has been very vocal and is leading the charge against me, which could indicate he is trying to position himself as a key player in the Village. His focus on my defensiveness raises suspicion, and he is rallying others to scrutinize me, which could be a tactic to deflect attention from himself or to position himself as a hero if he successfully identifies a *Werewolf*. Additionally, if he is the Seer or Doctor, his removal could significantly weaken the Village's ability to identify or protect against us. By voting him out, we can disrupt the vocal leadership that is forming against us and create confusion among the remaining players.

**vote:** Dan

- player:Villager–Dan    Round 1 summarize

**reasoning:** In this round's debate, several key points emerged that could help identify the Werewolves. Leah's removal is suspicious, especially since she focused on Jacob's defensiveness, suggesting either Jacob is a *Werewolf* or the Werewolves are framing him. Harold and Derek echoed my points again, which might indicate they are trying to blend in or genuinely agree with me. Mason and Jacob both expressed caution about jumping to conclusions and pointed out the potential for manipulation, which could be a tactic to deflect suspicion or a genuine concern. Jackson, who has been quieter, also highlighted the need to consider all angles and not rush to conclusions. The consistency in Harold's and Derek's agreement with me could either mean they are allies or trying to hide in plain sight. Mason's and Jacob's focus on not overlooking quieter players like Jackson suggests they might be trying to shift attention away from themselves. Jackson's balanced approach might indicate he is a Villager or a special role trying to stay under the radar. It's crucial to remember these dynamics as they could reveal alliances or hidden roles in future rounds.

**summary:** During the debate, Leah's removal was highlighted as suspicious, with a focus on Jacob's defensiveness. Harold and Derek echoed my points, possibly trying to blend in. Mason and Jacob cautioned against jumping to conclusions, suggesting manipulation could be at play. Jackson, though quieter, emphasized considering all angles. The consistency in Harold's and Derek's agreement with me might indicate they are allies or hiding in plain sight. Mason and Jacob's focus on quieter players could be a tactic to deflect attention. Jackson's balanced approach suggests he might be a Villager or a special role. These dynamics are important to remember for identifying potential allies or threats.

## F.5 Prompt Example

### System Prompt

You are playing a digital version of the social deduction game <Werewolf & Doctor & Seer & Villager (also known as Mafia).

### GAME RULES:

- Player Roles: 8 players - 2 Werewolves, 1 Seer, 1 Doctor, 4 Villagers.
- Rounds consist of two phases:
  - Night Phase: Werewolves remove a player. Seer identifies a player's role. Doctor saves a player. If no one is removed, the Doctor saved the Werewolf's target.
  - Day Phase: Players debate and vote to remove one player.
- Winning Conditions: Villagers win by voting out both Werewolves. Werewolves win when they outnumber the Villagers.

### GAME STATE:

- It is currently *(Round1)*.
- You are Scott the <Werewolf & Doctor & Seer & Villager>.
- Remaining players: Isaac, Sam, Hayley, Ginger, Scott (You), Derek, Tyler.

### YOUR PRIVATE OBSERVATIONS:

#### Round 0:

- During the night, we decided to eliminate Jacob.
- Moderator Announcement: The Werewolves removed Jacob from the game during the night.
- After the debate, I voted to remove Tyler from the game.
- Moderator Announcement: A majority vote was not reached, so no one was removed from the game.
- Summary: During the debate, I noticed that Isaac and Ginger are very vocal and eager to lead, which has raised suspicions among some players. Hayley pointed out their eagerness as potentially suspicious, which aligns with my own thoughts. Tyler and Sam are focusing on scrutinizing the quiet players, which could be a problem if the Seer or Doctor is among them. Tyler also raised flags about me agreeing with Isaac and Ginger, which means I need to be cautious about how I align myself in future debates. Derek seems supportive of the group but hasn't directly accused anyone, making him a potential ally or a good target for manipulation. Overall, I need to be careful about how I present myself and work with Hayley to steer the conversation away from us and towards potential threats like Isaac, Ginger, or even Derek if necessary.

### Remove

#### INSTRUCTIONS:

- It is the Night Phase of Round 1. As Scott the *Werewolf* choose the most strategic player to remove.
- Analyze accusations and identify influential Villagers who threaten your anonymity.
- Consider players' behavior and the risks of removing them.
- You must choose someone.

### Protect

#### INSTRUCTIONS:

- It is the Night Phase of Round 1. As Sam the Doctor choose the most vulnerable player to protect.
- Consider who the Werewolves might target.
- Prioritize players with crucial roles like the Seer and yourself.
- You must choose someone.

### Investigate

#### INSTRUCTIONS:

- It is the Night Phase of Round 1. As Tyler the Seer choose the most suspicious player to investigate.
- Look for behavior that deviates from typical villager behavior.
- Focus on influential players.
- You must choose someone.

## Debate

### INSTRUCTIONS:

- You are speaking next in the debate as Ginger.
- Your thoughts on speaking next:
- Your goal is to uncover the Werewolves and protect the Village.
- Scrutinize every accusation, expose inconsistencies, and call out suspicious behavior or unusually quiet players. Don't hesitate to make bold accusations!
- Emphasize teamwork and propose strategies to expose the Werewolves. Working together will be key to identifying the Werewolves.
- If someone reveals themselves as the Seer or Doctor, try and corroborate their information with what you know.

## Vote

### INSTRUCTIONS:

- Think strategically as Tyler the Seer and decide who to vote out.
- Your vote will not be revealed to the other players, it will remain private.
- Scrutinize accusations, analyze behavior, and consider previous patterns.
- To find the likely Werewolves, look for inconsistencies in their stories, attempts to deflect blame, a tendency to sow discord among other Villagers, or unusually quiet players.
- You must choose someone.

```
{  
    "reasoning": "string", // Explain your reasoning step-by-step for who you want to  
    // remove from the game and why. Avoid using violent or harmful language.  
    "<remove \& protect \& investigate \& debate \& vote>": "string" // Name of the  
    // player.  
}
```

## User Prompt

### LLM Analysis & Decisions

#### worlf:

```
{  
    'reasoning': "Based on the observations from Round 0, Isaac and Ginger are very vocal  
    // and eager to lead, which has raised suspicions among some players. Their active  
    // participation in the debate makes them influential Villagers who could  
    // potentially threaten the anonymity of the Werewolves. Removing one of them would  
    // reduce the number of vocal leaders and make it easier for Hayley and me to steer  
    // the conversation without drawing too much attention. Additionally, Isaac and  
    // Ginger's eagerness to lead could make them targets for the Seer or Doctor,  
    // further reducing their effectiveness. Out of the two, Isaac seems to be more  
    // directly involved in the accusations, making him a slightly higher risk.  
    // Therefore, I choose to remove Isaac to weaken the Villagers' leadership and  
    // reduce the risk of being identified.",  
    '<remove \& protect \& investigate \& debate \& vote>': 'Isaac'  
}
```

## G Stratego

*Stratego* is a strategy board game where players aim to capture the opponent's flag by strategically moving their pieces on the board. Each piece has a hidden rank, and combat is resolved by comparing the ranks of the engaged pieces. Special pieces like bombs and miners add tactical depth, as some pieces have specific abilities to disarm or bypass others. The game emphasizes planning, bluffing, and reading the opponent's strategy. Victory is achieved by careful positioning of pieces and deducing the identity of the opponent's forces through engagement.

The most common game setup involves each player controlling 40 pieces, which are arranged on the board in a secret configuration. The pieces are ranked from the highest (Marshal) to the lowest (Scout), with each rank having specific attack rules. Players take turns moving their pieces, attacking the opponent's pieces when their rank is higher, or using special pieces like bombs and the spy to defend or attack. Success in *Stratego* relies on strategic placement of pieces, anticipating the opponent's moves, and managing both offensive and defensive strategies.

As a strategic game with a focus on tactics and deception, *Stratego* provides an ideal environment for evaluating agents that simulate decision-making under uncertainty. Agents must make moves based on incomplete information, predicting the opponent's moves while concealing their own plans. LLM-based agents must evaluate threats, manage resources, and adapt to the opponent's changing strategy while striving to capture the opponent's flag.

### G.1 Game Detailed Description

Further details on the game settings, piece configurations, movement rules, strategies, and victory conditions can be found in the detailed game manual in Table 18.

Game Manual for Stratego		
<b>Setting</b>	Board specification	10x10 grid board with two lakes in the center that act as impassable obstacles.
	Number of players	Two players compete head-to-head, each controlling 40 pieces.
	Objective	Capture the opponent's flag or eliminate all movable pieces of the opponent.
<b>Piece Configuration and Mechanics</b>	Piece ranks	Each player has pieces ranked from 1 (highest, Marshal) to 10 (lowest, Scout), along with special units like Bombs and Spies.
	Movement rules	Most pieces can move one space per turn, horizontally or vertically. Scouts can move any number of spaces in a straight line.
	Attacking rules	When a piece attacks another, the lower-ranked piece is removed. If the ranks are equal, both pieces are removed.
	Special units	- Bomb: Immovable and eliminates any attacking piece except the Miner. - Spy: Can defeat the Marshal if attacking first.
	Flag placement	The flag must be placed in the back two rows of the board and is immovable throughout the game.
<b>Strategies</b>	Bluffing	Disguise high-value pieces as low-value ones to mislead the opponent.
	Defensive placement	Place bombs and strong pieces around the flag to protect it from attacks.
	Scout reconnaissance	Use Scouts to reveal the location and rank of opponent pieces while avoiding combat.
	Feigned weakness	Intentionally leave some areas unprotected to lure opponents into traps.
	Targeted attacks	Focus on eliminating high-value enemy pieces to gain a strategic advantage.
<b>Goals</b>	Capture the flag	Locate and capture the opponent's flag to win the game.
	Eliminate mobility	Win by immobilizing the opponent by eliminating all their movable pieces.

Table 18: Game manual detailing the settings, piece configuration, movement rules, strategies, and goals for gameplay in *Stratego*.

## G.2 Action Space

In *Stratego*, we provide 2 actions for the agent.

- **Move:** Bombs and flags don't move. Scouts can move any distance. The remaining pieces move one square horizontally or vertically, not diagonally.
- **Attack:** To attack, move your piece onto a square occupied by an opponent's piece.

## G.3 Metrics

Further details on the metrics and their corresponding formulas for *Stratego* can be found in Table 19.

Metric	Description and Formula
<b>CPR (Critical Pieces Rate)</b>	Evaluates the proportion of critical pieces that are alive relative to the total number of critical pieces in the game. CPR is calculated as: $\text{CPR} = \left( \frac{\text{critical\_pieces\_alive}}{\text{total\_critical\_pieces}} \right) \times 100\%$
<b>TPCV (Total Pieces Value)</b>	Calculates the total value of all pieces at the start of the game. The Total Pieces Value is the sum of all pieces' individual values based on their ranks: $\begin{aligned} \text{TPCV} = & 10 \times \text{total\_pieces\_Marshal} + 9 \times \text{total\_pieces\_General} \\ & + 8 \times \text{total\_pieces\_Colonel} + 7 \times \text{total\_pieces\_Major} + 6 \times \text{total\_pieces\_Captain} \\ & + 5 \times \text{total\_pieces\_Lieutenant} + 4 \times \text{total\_pieces\_Sergeant} \\ & + 3 \times \text{total\_pieces\_Miner} + 2 \times \text{total\_pieces\_Scout} + 1 \times \text{total\_pieces\_Spy} \end{aligned}$
<b>WR (Win Rate)</b>	Percentage of matches won against different levels of opponents. WR is calculated as: $\text{WR} = \left( \frac{\text{matches\_won}}{\text{total\_matches}} \right) \times 100\%$
<b>GA (Grounding Accuracy)</b>	Evaluates the precision and success rate of grounding actions. GA is calculated as: $\text{GA} = \left( \frac{\text{successful\_groundings}}{\text{total\_grounding\_attempts}} \right) \times 100\%$

Table 19: Metrics and their corresponding formulas for evaluating the performance of LLM-based agents in *Stratego*.

## G.4 Example Trajectory

- Board State i

```

, c0 , c1 , c2 , c3 , c4 , c5 , c6 , c7 , c8 , c9
r0, B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#)
r1, B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#)
r2, B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#)
r3, B(#), ..., B(#), B(#), ..., B(#), B(#), B(#), B(#), B(#)
r4, ..., ..., , , ..., ..., , , ..., ...
r5, R(5), ..., , , ..., ..., , , ..., ...
r6, ..., R(4), R(1), R(5), R(4), R(6), R(s), R(6), R(1), R(o)
r7, R(2), R(7), R(4), R(1), R(1), R(9), R(3), R(8), R(5), R(o)
r8, R(3), R(o), R(5), R(2), R(1), R(1), R(2), R(7), R(1), R(o)
r9, R(o), R(2), R(3), R(¶), R(6), R(2), R(4), R(1), R(3), R(o)

```

### reasoning:

The opponent has a full row of unidentified pieces in the first three rows, indicating a strong defensive setup. My strategy is to probe the opponent's defenses while advancing towards their back rows to locate the flag. The Captain at position 5,0 can move to 4,0, which is a strategic position to potentially uncover more of the opponent's pieces in the next turn.

**move:** 5 0 4 0

**response:** 5 0 4 0

**player:**

- live pieces num : 38
- live pieces score : 144
- critical live pieces num : 4

**opponent:**

- live pieces num : 40
- live pieces score : 148
- critical live pieces num : 4

• **Board State i+1**

```
, c0 , c1 , c2 , c3 , c4 , c5 , c6 , c7 , c8 , c9  
r0, R(6), R(o), R(7), R(2), R(6), R(o), R(5), R(2), R(o), R(4)  
r1, R(2), R(5), R(2), R(||), R(s), R(2), R(5), R(o), R(1), R(1)  
r2, R(5), R(3), R(9), R(7), R(4), R(8), R(1), R(6), R(3), R(4)  
r3, R(o), ...., R(4), R(3), ...., R(3), R(1), R(1), R(1), R(o)  
r4, B(#), ...., , , ...., , , ...., ....  
r5, ...., ...., , , ...., ...., , , ...., ....  
r6, ...., B(4), B(#), B(#), B(4), B(#), B(#), B(#), B(#), B(#), B(#)  
r7, B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#)  
r8, B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#)  
r9, B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#)
```

**reasoning:**

The opponent has moved a Lieutenant to the front lines, which suggests they may be trying to probe our defenses or protect a more valuable piece. Our strategy should focus on advancing our Scouts to reveal the ranks of the opponent's pieces and potentially capture the flag. The Scout at position 3,8 can move forward to reveal more of the opponent's setup.

**move:** 3 8 6 8

**response:** 3 8 6 8

• **Board State i+2**

```
, c0 , c1 , c2 , c3 , c4 , c5 , c6 , c7 , c8 , c9  
r0, R(6), R(o), R(7), R(2), R(6), R(o), R(5), R(2), R(o), R(4)  
r1, R(2), R(5), R(2), R(||), R(s), R(2), R(5), R(o), R(1), R(1)  
r2, R(5), R(3), R(9), R(7), R(4), R(8), R(1), R(6), R(3), R(4)  
r3, R(o), ...., R(4), R(3), ...., R(3), R(1), R(1), R(1), R(o)  
r4, ...., ...., , , ...., , , ...., ....  
r5, B(#), ...., , , ...., ...., , , ...., ....  
r6, ...., B(4), B(#), B(#), B(4), B(#), B(#), B(#), B(#), B(#), B(#)  
r7, B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#)  
r8, B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#)  
r9, B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#)
```

**reasoning:**

The opponent's pieces are all concealed, but they are densely packed in the first three rows, indicating a defensive strategy. My goal is to advance my pieces towards the opponent's back rows to locate and capture the flag. I will move my Captain to explore the area and potentially engage with any opponent pieces that may be vulnerable.

**move:** 4 0 5 0

**response:** 4 0 5 0

**player:**

- live pieces num : 37
- live pieces score : 142

- critical live pieces num : 4

#### **opponent:**

- live pieces num : 39
- live pieces score : 146
- critical live pieces num : 4

## G.5 Prompt Example

### System Prompt

You are an expert board game player and strategist, specialized in the classic board game *Stratego*. Please win the game as fast as possible.

These are the rules for *Stratego* gameplay (your instructions follow at the end):

#### **Stratego: Board Game Rules**

##### **Overview**

- **Players:** 2

- **Objective:** Capture the opponent's flag or trap all movable pieces of the opponent. Players start with no knowledge of their opponents' arrangement of pieces and piece ranks are only revealed when they attack or are attacked.

##### **Setup**

- **Board:** 10x10 grid.

- **Pieces:** Each player has 40 pieces with different ranks (Marshall) being the highest, (Spy) being lowest in most cases.

- **Placement:** Players place their pieces on their respective first four rows, hiding their ranks from the opponent.

##### **Gameplay**

1 **Turns:** Players alternate turns, moving one piece per turn.

2 **Movement:** All pieces except Bomb, Flag and Scout move one square horizontally or vertically, not diagonally. Bombs and Flags don't move. Scouts can move any distance.

3 **Attacks:** To attack, move your piece onto a square occupied by an opponent's piece.

4 **Resolution:** Lower-ranked piece is removed from the board. Equal ranks result in both pieces being removed.

##### **5 Special Pieces:**

- **Bomb:** Only Miners can defuse; all other pieces lose if they attack a Bomb.

- **Spy:** Spies can defeat the Marshal when attacking it, but loses to all other ranks.

- **Scout:** Scouts Can move any distance of empty squares rather than just one square. Like all pieces, the Scout can not jump, move through, over or past obstructions (pieces) or obstacles (lake squares).

6 **Immovable Pieces:** Bombs and the Flag cannot move.

7 **Obstruction:** Pieces can not move over other pieces or obstacles such as the lakes. Nor can pieces end their move sharing the same square.

8 **Secrets:** Players do not know the rank of the opponent pieces (#) until they attack or are attacked, at which point their identity is revealed in the log.

9 **Ownership:** Blue can only move Blue pieces and Red can only move Red pieces.

10 **Coordinates:** Coordinates for each row, column are usually expressed in the format 'x y' where x is the row and y is the column.

##### **Winning the Game**

- Capture the Flag: Win by capturing the opponent's flag.

- Trap All Movable Pieces: Win if the opponent has no movable pieces left.

##### **Additional Rules**

- Lakes: Two 2x2 areas in the center of the board ( ) are impassable (4 2), (4 3), (4 6), (4 7) and (5 2), (5 3), (5 6), (5 7).

The piece notation for this format of the game is as follows:

Flag: ¶

Spy: s

Scout: ¹

Miner: ²

Sergeant: ³

Lieutenant: ⁴

Captain: ⁵

Major: ⁶

Colonel: ⁷

General: ⁸

Marshall: ⁹

Bomb: o

Blue opponent's unidentified pieces use: B(#)

Columns are indicated by headers c0 to c9 and rows are labelled r0 to r9. Each square is represented by two parts; the first character indicates side (R for Red, B for Blue) and the follow part in brackets denotes the piece rank as per the table above.

**Here are your instructions:**

1. Please analyze the current game state and give out your macro strategy, and select one of the valid moves available. Opponent (Blue) pieces are marked with B# because we won't initially know their ranks.

2. Given that current board configuration, and without making any assumptions about the opponent's pieces, please suggest a move for our side (Red).

## Note: Please present your answer, without any commentary, in the form: 'r c x y' where r is the row and c is the column of the piece you are suggesting to move and x and y are the destination rows and column, respectively.

## IMPORTANT: Take care to analyze the specific game state the player has provided, noting your (Red) pieces locations and the valid moves and history moves indicated.

## Remember the objective is the Blue flag and that it will probably be located in Blue's rear rows .

## Try to suggest strategic moves with purpose and avoid shuffling pieces around unnecessarily and/or moving them back and forth between the same positions.

## Remember that the Assistant can only infer Blue piece (B#) ranks from history in the log, as all are concealed (B#) during your turn.

## IMPORTANT: Please win the game as fast as possible

**Examples**

User:

## Board State:

, c0 , c1 , c2 , c3 , c4 , c5 , c6 , c7 , c8 , c9  
r0, R(2), R(1), R(6), R(1), R(1), R(o), R(6), R(2), R(o), R(¶)  
r1, R(o), R(o), R(4), R(s), R(4), R(3), R(4), R(5), R(9), R(o)  
r2, R(3), R(1), R(2), R(4), R(7), R(1), R(1), R(1), R(6), R(1)  
r3, R(o), ...., R(7), R(2), R(3), R(5), R(8), R(2), R(3), R(5)  
r4, ...., R(5), , , ...., , , ...., ....  
r5, ...., ...., , ...., , , B(#), ....  
r6, B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#), ...., B(#)  
r7, B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#)  
r8, B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#)  
r9, B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#)

## Valid moves:

Scout 'R(1)' at position 2,1 could move to: 3 1

Colonel 'R(7)' at position 3,2 could move to: 3 1

Sergeant 'R(3)' at position 3,4 could move to: 4 4

Captain 'R(5)' at position 3,5 could move to: 4 5

Sergeant 'R(3)' at position 3,8 could move to: 4 8

Captain 'R(5)' at position 3,9 could move to: 4 9

Captain 'R(5)' at position 4,1 could move to any of: 3 1, 5 1, 4 0

## IMPORTANT The selection of 'r c ' you make must choose from "position" of the Valid moves ,and the 'x y ' choose from "move to" of the Valid moves

## History moves: (history of the last 5 moves,The smaller the number, the closer it is to the current.)

1. Sergeant 'R(3)' at position '2,8' moved to: 3 8
2. Lieutenant 'R(4)' at position '3,2' moved to: 3 1
3. Scout 'R(1)' at position '3,4' moved to any of: 4 4
4. Sergeant 'R(3)' at position '3,5' moved to: 4 5
5. Scout 'R(1)' at position '3,7' moved to: 3 8

Your response:

```
{  
  "reasoning": "string", // Explain your macro strategy and your reasoning about the  
  // current situation and why choose this move.  
  "move": "string" // the move that you choose without any commentary. Choose from Valid  
  // moves  
}
```

**User Prompt**

**Game observation**

## Board State:

, c0 , c1 , c2 , c3 , c4 , c5 , c6 , c7 , c8 , c9  
r0, B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#)

```

r1, B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#), B(#)
r2, B(#), B(#), B(#), B(#), ..., B(#), B(#), B(#), B(#)
r3, B(o), ..., B(#), B(#), B(#), B(#), B(#), ..., B(#)
r4, R(5), ..., , , ..., ..., , , ..., ...
r5, ..., ..., , , ..., ..., , , ..., ...
r6, R(7), ..., R(s), R(5), R(4), R(6), R(6), R(2), R(3), R(7)
r7, ..., R(9), R(o), R(4), R(5), R(1), R(8), R(5), R(o), R(1)
r8, R(1), R(o), R(1), R(o), R(1), R(1), R(6), R(2), R(4), R(1)
r9, R(1), R(3), R(o), R(3), R(2), R(4), R(2), R(o), R(3), R(2)

```

#### ## Valid moves:

Captain 'R(5)' at position '4,0' could move to any of: 3 0, 5 0, 4 1  
 Colonel 'R(7)' at position '6,0' could move to any of: 5 0, 7 0, 6 1  
 Spy 'R(s)' at position '6,2' could move to: 6 1  
 Lieutenant 'R(4)' at position '6,4' could move to: 5 4  
 Major 'R(6)' at position '6,5' could move to: 5 5  
 Sergeant 'R(3)' at position '6,8' could move to: 5 8  
 Colonel 'R(7)' at position '6,9' could move to: 5 9  
 Marshall 'R(9)' at position '7,1' could move to any of: 6 1, 7 0  
 Scout 'R(1)' at position '8,0' could move to: 7 0

#### ## IMPORTANT

The selection of 'r c' you make must choose from "position" of the Valid moves ,and the 'x y' choose from "move to" of the Valid moves

## History moves: (history of the last 5 moves,The smaller the number, the closer it is to the current.)

1. Captain 'R(5)' at position '4,1' moved to 4 0
2. Captain 'R(5)' at position '5,1' moved to 4 1
3. Colonel 'R(7)' at position '6,1' moved to 6 0

#### User Prompt

#### LLM Analysis & Decisions

```

{
  'reasoning': "The objective is to advance towards the opponent's back rows while
    ↪ maintaining a strong position. Moving the Captain 'R(5)' from position '4,0' to
    ↪ '5,0' allows for further advancement and potential engagement with any Blue
    ↪ pieces that may be present in that column. This move also keeps the Captain safe
    ↪ from immediate threats while positioning it closer to the enemy lines.",
  'move': '4 0 5 0'
}

```