CRADLE: EMPOWERING FOUNDATION AGENTS TOWARDS GENERAL COMPUTER CONTROL

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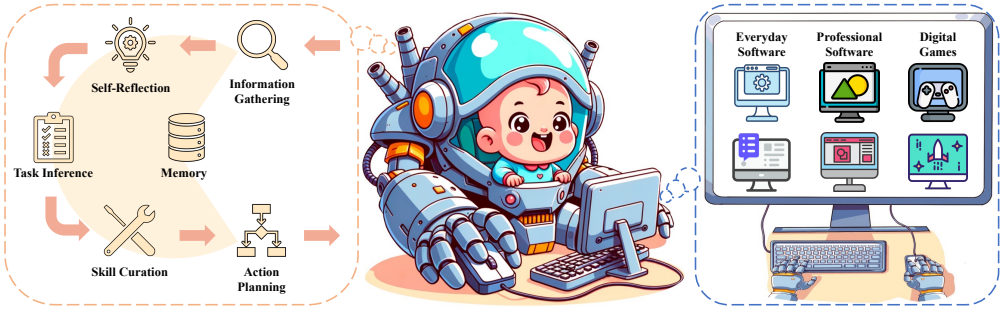

Figure 1: The **CRADLE** framework empowers nascent foundation models to perform complex computer tasks via the same unified interface humans use, *i.e.,* screenshots as input and keyboard & mouse operations as output.

ABSTRACT

Despite the success in specific scenarios, existing foundation agents still struggle to generalize across various virtual scenarios, mainly due to the dramatically different encapsulations of environments with manually designed observation and action spaces. To handle this issue, we propose the **General Computer Control** (GCC) setting to restrict foundation agents to interact with software through the most unified and standardized interface, *i.e.,* using screenshots as input and keyboard and mouse actions as output. We introduce **CRADLE**, a modular and flexible LMM-powered framework, as a preliminary attempt towards GCC. Enhanced by six key modules: Information Gathering, Self-Reflection, Task Inference, Skill Curation, Action Planning, and Memory, **CRADLE** is able to understand input screenshots and output executable code for low-level keyboard and mouse control after high-level planning, so that **CRADLE** can interact with any software and complete long-horizon complex tasks without relying on any built-in APIs. Experimental results show that **CRADLE** exhibits remarkable generalizability and impressive performance across four previously unexplored commercial video games, five software applications, and a comprehensive benchmark, OS-World. To our best knowledge, **CRADLE** is the first to enable foundation agents to follow the main storyline and complete one-hour-long real missions in the complex AAA game Red Dead Redemption 2 (RDR2). **CRADLE** can also create a city with nearly a thousand people in Cities: Skylines, farm and harvest parsnips in Stardew Valley, and trade and bargain with a maximum weekly total profit of 87% in Dealer's Life 2. **CRADLE** can not only operate daily software, like Chrome, Outlook, and Feishu, but also edit images and videos using Meitu and CapCut. With a unified interface to interact with any software, **CRADLE** greatly extends the reach of foundation agents by enabling the easy conversion of any software, especially complex games, into benchmarks to evaluate agents' various abilities and facilitate further data collection, thus paving the way for generalist agents. Video demos and code can be found at https://cradle2024acc.github.io/Cradle.

1 INTRODUCTION

Artificial General Intelligence (AGI) has long been a north-star goal for the AI community (Morris et al., 2023). The recent success of foundation agents, *i.e.,* agents empowered by large multimodal models (LMMs) and advanced tools, in various environments, *e.g.,* web browsing (Zhou et al., 2023; Deng et al., 2023; Gur et al., 2023; Zheng et al., 2024b;a; He et al., 2024), operating mobile applications (Yang et al., 2023b; Wang et al., 2024b) and desktop software (Zhang et al., 2024; Wu et al., 2024), crafting and exploration in Minecraft (Wang et al., 2023b; 2024a; 2023a),

and some robotics scenarios (Huang et al., 2022; Brohan et al., 2023b; Driess et al., 2023; Brohan et al., 2023a), have shown promise. However, current foundation agents still struggle to generalize across different scenarios, primarily due to the dramatic differences in the encapsulation of environments with human-designed observation and action space. Therefore, developing foundation agents applicable to various environments remains extremely challenging.

Computers, as the most important and universal interface that connects humans and the increasing digital world, provide countless rich software, including applications and realistic video games for agents to interact with, while avoiding the challenges of robots in reality, such as hardware requirements, constraints of practicability, and possible catastrophic failures (Raad et al., 2024). Mastering these virtual environments is a promising path for foundation agents to achieve generalizability. Therefore, we propose the **General Computer Control** (GCC) setting [1]:

> *Building **foundation agents** that can master **ANY** computer task via the universal human-style interface by receiving input from screens and audio and outputting keyboard and mouse actions.*

There are many challenges to achieving GCC: i) good alignment across multi-modalities for better understanding and decision-making; ii) precise control of keyboard and mouse to interact with the computer, which has a large hybrid action space, including not only which key to press and where the mouse to move, but also the duration of the press and the speed of the mouse movement; iii) long-horizontal reasoning due to the partial observability of complex GCC tasks, which also leads to the demand for long-term memory to maintain past useful experiences; and iv) efficient exploration in a structured manner to discover better strategies and solutions autonomously, *i.e.,* self-improving, which can allow agents to generalize across the various tasks in the digital world.

As shown in Figure 1, we introduce **CRADLE**, a novel modular LMM-powered framework that empowers foundation agents towards GCC. **CRADLE** consists of six key modules: 1) information gathering, to extract the relevant information from multimodal observations; 2) self-reflection, to rethink past experiences about whether the actions and tasks are successfully completed and reasons for possible failures; 3) task inference, to determine whether to continue current tasks or propose a new task given the current situation; 4) skill curation, to generate, update, and retrieve useful skills for the current task; 5) action planning, to generate specific executable operations for keyboard and mouse control via skills; and 6) memory, for storage, summary, and retrieval of past experiences.

As illustrated in Figure 2, tasks in GCC can be broadly divided into two categories: video game playing and software application manipulation. Video games offer the most challenging tasks in GCC due to several key factors. First, the complexity of game environments requires sophisticated problem-solving and adaptive strategies. Second, long-term reasoning is essential to navigate and succeed in these intricate virtual worlds. Third, understanding and mastering new, complex mechanics within games demand rapid learning and cognitive flexibility. Finally, video games test a player's ability to react quickly and perform precise control and operations, which together create a unique and demanding computational challenge. In addition to the typical embodied control, classical UI manipulation, like menu use and inventory management, is also common during gameplay, which is similar to the other software applications (Raad et al., 2024). Therefore, video games provide rich comprehensive and challenging testbeds to evaluate and improve agents' various abilities.

In this work, we conduct extensive experiments to demonstrate the generalizability of **CRADLE** in such complex environments, while also mastering diverse everyday software applications in distinct domains. We managed to prove that commercial software is out-of-box testbeds under our framework. The four selected representative games are: epic AAA 3D role-playing game, **RDR2**, 2D pixel-art farming simulation game, **Stardew Valley**, pawn shop simulation game, Dealer's Life 2, and 3D, top-down view, city-building game, **Cities: Skylines**. The target set of diverse software applications for evaluation includes: **Chrome**, **Outlook**, **CapCut**, **Meitu**, and **Feishu**, as well as one comprehensive software benchmark, **OSWorld** (Xie et al., 2024). We provide a brief introduction to these games in Appendix A, and representative designed tasks for measuring the various abilities of the agent comprehensively in both games and software applications in Appendix Figure 9.

Experimental results show that **CRADLE** exhibits remarkable generalization ability and impressive performance across the four previously unexplored commercial video games, the five target software applications, and the comprehensive contemporaneous OSWorld benchmark. To our best knowledge, **CRADLE** is the first to enable LMM-based agents to follow the main storyline and complete one-hour-long real missions in a complex AAA game, RDR2. **CRADLE** also manages to create a

[1] This setting can be seamlessly extended to other digital devices, *i.e.,* mobile phones, game controllers, and virtual reality headsets with standard input and output.

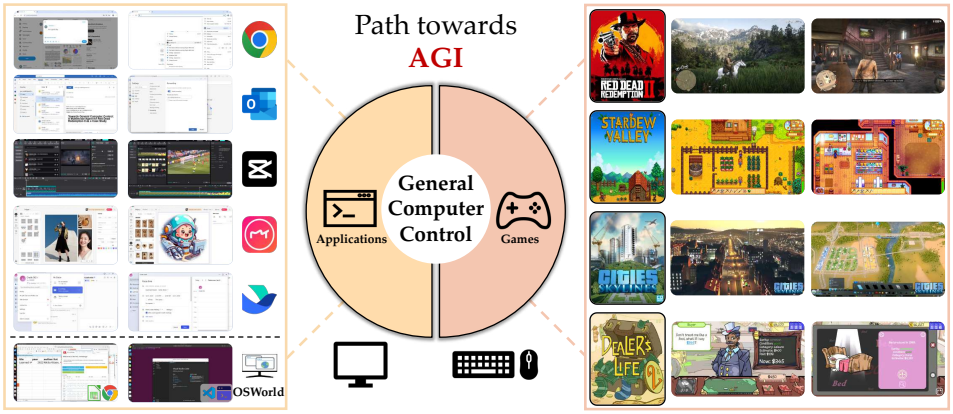

Figure 2: Taxonomy of GCC and the games and software investigated in this work.

city with nearly a thousand people in Cities: Skylines, farm and harvest parsnips in Stardew Valley, trade and bargain with a maximal weekly total profit of 87% in Dealer's Life 2. Besides, **CRADLE** can not only operate daily software, like Chrome and Outlook, but also edit images and videos using Meitu and CapCut, and perform office tasks in Feishu. Able to interact with software in a unified manner, **CRADLE** greatly extends the reach of AI agents by making it easy to convert any software, especially complex games, into benchmarks to evaluate agents' various abilities and facilitate further data collection, paving the way for generalism. We hope **CRADLE** can accelerate the development of more powerful foundation agents, thereby advancing the path towards AGI.

2 Related Work

In this section, we provide a concise review of research related to this work in two lines, *i.e.,* foundation agents for software applications and video games. Due to the space limitation, we provide a detailed discussion of the related work in Appendix B.

Agents for Software Applications. Agents for software applications are developed to complete tasks such as web navigation (Zhou et al., 2023; Deng et al., 2023; Mialon et al., 2023) and software application control (Rawles et al., 2023; Yang et al., 2023b; Kapoor et al., 2024). While previous LLM-based web agents (Deng et al., 2023; Zhou et al., 2023; Gur et al., 2023; Zheng et al., 2024b) show some promising results in effectively interacting with content on webpages, they usually use raw HTML code and DOM tree as input and interact with the available element IDs, ignoring the rich visual patterns with key information, like icons, images, and spatial relations. Multimodal web agents (Hong et al., 2023; Furuta et al., 2023; Yan et al., 2023; He et al., 2024; Zheng et al., 2024a) and mobile app agents (Yang et al., 2023b; Wang et al., 2024b) have also been explored. Though using screenshots as input, they still need to use built-in APIs to get the available interactive element IDs to execute corresponding actions. Several recent works (Gao et al., 2023; Cheng et al., 2024; Niu et al., 2024; Zhang et al., 2024; Wu et al., 2024; Kapoor et al., 2024) aim to apply web agents to more applications by using keyboard and mouse for control. However, they primarily focus on the static websites and lack the generalizability to other tasks such as game playing.

Agents for Video Games. Several attempts try to develop foundation agents for complex video games, such as Minecraft (Wang et al., 2023b;a; 2024a), Starcraft II (Ma et al., 2023) and Civilization-like game (Qi et al., 2024) with textual observations obtained from internal APIs and pre-defined semantic actions. Although JARVIS-1 (Wang et al., 2023a) claims to interact with the environment in a human-like manner with the screenshots as input and mouse and keyboard for control, its action space is predefined as a hybrid space composed of keyboard, mouse, and API. The game-specific observation and action spaces prohibit the generalization of them to other novel games. SIMA(Raad et al., 2024) trained embodied agents to complete 10-second-long basic tasks over ten 3D video games, and the results are promising to be scaled up.

3 The CRADLE Framework

To pursue GCC, we propose **CRADLE**, illustrated in Figure 3, a modular and flexible LMM-powered framework that can properly handle the challenges GCC presents. The framework should have the ability to understand and interpret computer screens and dynamic changes between consecutive frames from arbitrary software and be able to generate reasonable computer control actions for precise execution. This suggests that a multimodal model with powerful vision and reasoning capabilities, in addition to rich knowledge of computer UI and control, is a requirement. In this work, we leverage GPT-4o (OpenAI, 2024b) as the framework's backbone model.

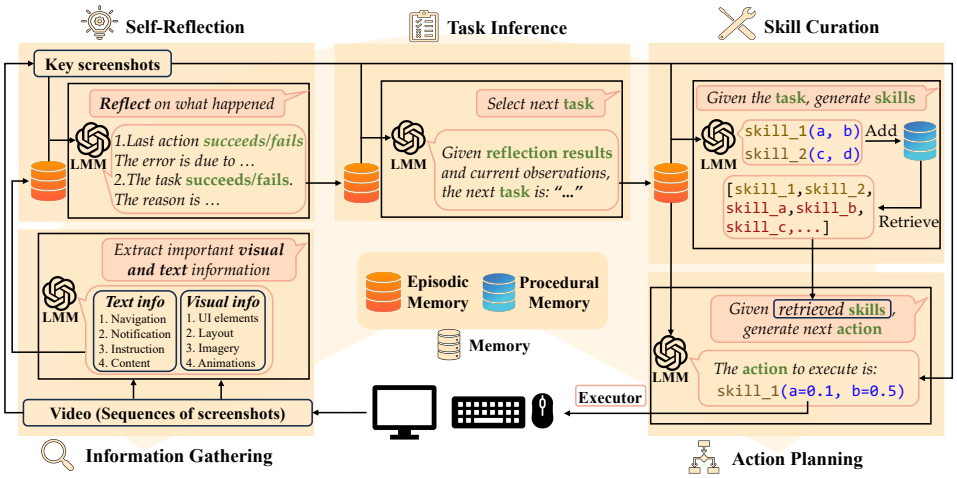

Figure 3: An overview of the CRADLE framework. CRADLE takes video from the computer screen as input and outputs computer keyboard and mouse control determined through inner reasoning.

3.1 ENVIRONMENT IO

Observation and Action Space. CRADLE only takes a video clip, recording the execution of the last action, as input and outputs keyboard and mouse operations to interact with environments. The observation space is made up of complete screen videos with different lengths. For the action space, it includes all possible keyboard and mouse operations, including `key_press`, `key_hold`, `key_release`, `mouse_move`, and `wheel_scroll`, where keys include both keyboard keys and mouse buttons. These operations can be combined in various ways to form combos and shortcuts, execute rapid key sequences, or coordinate timings. We choose to use Python code to simulate these operations and encapsulate them into an `io_env` class. Seldom previous work takes `key_hold`, `key_release` and mouse moving speed into consideration, which are critical in games (*e.g.,* opening weapon wheel and changing view in RDR2). The asynchronization brought by these temporal-extended actions introduces additional challenges for the control.

Information Gathering. Provided with a video clip as input, it is critical for CRADLE to capture and extract all useful visual and textual information to understand the recent situation and perform further reasoning. Visual information includes layout, imagery, animations, and UI elements which pose high spatial perception and visual understanding requirements for LMM models. Moreover, we depend on their OCR capabilities to extract textual information in images, which usually includes content (headings and paragraphs), navigation labels (menus and links), notifications, and instructions to convey messages and guide users. For each environment, we enhance LMMs' abilities with different tools such as template matching (Brunelli, 2009), Grounding DINO (Liu et al., 2023), and SAM (Kirillov et al., 2023) to provide additional grounding for object detection and localization.

Skill and Action Generation As shown in Figure 4, to bridge the gap between semantic actions generated by LMMs and OS-level executable actions, CRADLE uses LMMs to generate code functions as semantic-level skills, which encapsulate lower-level keyboard and mouse control. Similar to how humans improve while playing, these skills can be developed from scratch according to in-game tutorials and guidance, game manuals and settings, or through self-exploration as the game progresses. These skills can also be pre-defined or composited to solve more complex tasks. An action usually consists of a single or multiple skills instantiated with any necessary parametric as-

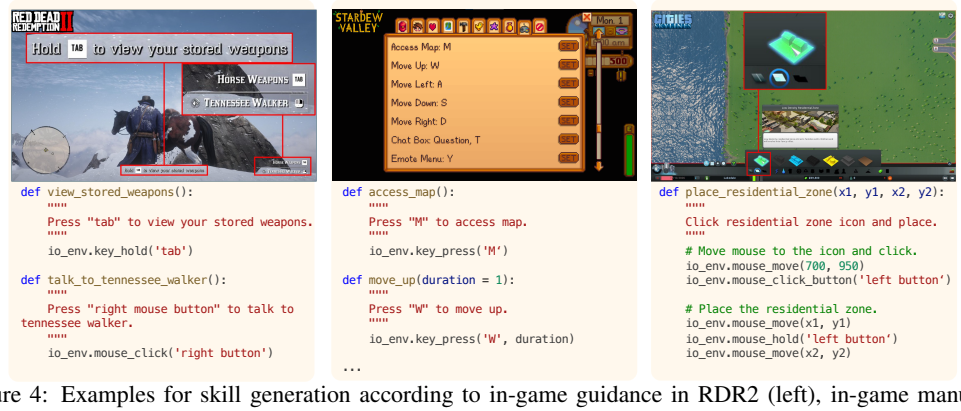

Figure 4: Examples for skill generation according to in-game guidance in RDR2 (left), in-game manual in Stardew Valley (middle), self-exploration in Cities: Skylines (right). Code and comments are shown in brevity.

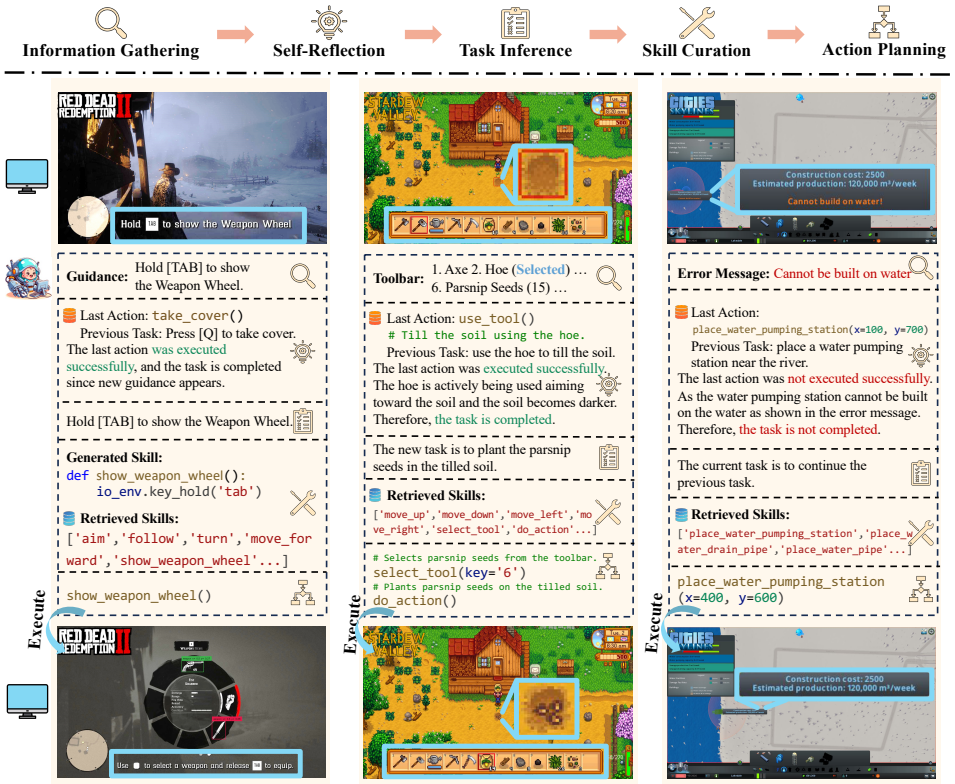

Figure 5: Illustrative examples of **CRADLE**'s complete workflow in RDR2 (left), Stardew Valley (middle) and Cities: Skylines (right). Prompts are shown partially for brevity.

pects, such as duration, position, and speed. After **CRADLE** determines actions to be executed in the environment, an ***Executor*** is then triggered to map these semantic actions to the OS-level keyboard and mouse commands to interact with the environment.

3.2 MEMORY

CRADLE stores and maintains all the useful information from the environment or outputted by each module through a memory mechanism, consisting of episodic memory and procedural memory.

Episodic Memory. Episodic memory is used to maintain current and past experiences, including key screenshots from each video observation, and everything useful outputted by LMMs and advanced tools, *e.g.,* textual and visual information, actions, tasks, and reasoning from each module. To facilitate retrieval and storage, periodical summarization is conducted to abstract recently added multimodal information into long-term summaries. The incorporation of episodic memory enables **CRADLE** to effectively retain crucial information over extended periods.

Procedural Memory. This memory is specific to storing and retrieving skills in code form, which can be learned from scratch as shown in Figure 4, or pre-defined in procedural memory. Skills can be added, updated, or composed to the procedural memory in the skill curation module. Same as Voyager (Wang et al., 2024a), skills are retrieved according to the similarities between their corresponding embedding and task description.

3.3 REASONING

Based on the extracted information from the video observations and relevant information from its memory, **CRADLE** needs to do high-level reasoning and then make the next decision. This process is analogous to "**reflect on the past, summarize the present, and plan for the future**", which is broken down into the following modules.

Self-Reflection. The reflection module initially evaluates whether the last executed action was successfully carried out and whether the task was completed. Sequential key screenshots from the last video observation, along with the previous context for action planning and task inference are fed to the LMM for reasoning. Additionally, we also request the LMM to provide an analysis of any failure. This valuable information enables **CRADLE** to remedy inappropriate decisions or less-than-ideal actions. Furthermore, reflection can also be leveraged to inform re-planning of the task and bring the agent closer to target task completion, better understand the factors that led to previous successes, or suggest how to update or improve specific skills.

Task Inference. After reflecting on the outcome of the last executed action, **CRADLE** needs to analyze the current situation to infer the most suitable task for the current moment. We let LMMs determine the highest priority task to perform and when to stop an ongoing task and start a new one.

Skill Curation. As the task is specified, **CRADLE** needs to prepare the tactics to accomplish it, by retrieving useful skills from the procedural memory, updating existing skills, or generating new ones. The new skill will be stored in the procedural memory for future utilization.

Action Planning. **CRADLE** needs to select the appropriate skills from the curated skill set and instantiate these skills into a sequence of executable actions by specifying any necessary parametric aspects (*e.g.,* duration, position, and target) according to the current task and history information. The generated action is then fed to the ***Executor*** for interaction with the environment.

Through these six modules, the input video is processed in stages: first into reasoning, then into semantic skills and actions, and finally into low-level keyboard and mouse operations. This comprehensive conversion covers all essential interactive data needed for both high-level planning and low-level control, enabling a unified approach to data collection for further self-improvement.

4 EMPIRICAL STUDIES

In this section, we present the empirical results of deploying **CRADLE** across various challenging environments representative of GCC settings, demonstrating its comprehensive capabilities.

Experimental Settings. If not specifically mentioned, all experiments are conducted in five runs under a maximum step limit, using OpenAI's model, *gpt-4o-2024-05-13* (OpenAI, 2024b). For each video game, we hired five human players, who never played the corresponding game before, to do the evaluation. Before they start the experiments, they will read the prompts used by Cradle agents for fair comparison. Every player played the task once. Similar to SIMA (Raad et al., 2024), we apply human evaluation to all tasks across software and games, except for OSWorld (Xie et al., 2024), which provides automatic evaluation scripts. Due to the dynamism of the RDR2 and Stardew Valley and the LMM inference and communication latency, we need to pause those game environments while waiting for backbone model's responses. Other environments execute continuously. All software and games can be run on regular Windows 10 machines, except for RDR2, which is tested on a machine with an NVIDIA RTX-4090 GPU. We also provide estimated experimental cost of the time and API usage in Appendix C, implementation details, environment introduction, task description, case study and prompts in Appendices D to K.

Task Introduction. As shown in Figure 6 and 7, for **RDR2**, we mainly focus on evaluating agents on the first two complete missions of the main storyline in Chapter I, which can be divided into 13 tasks according to the in-game checkpoints, including but not limited to navigation, NPC interaction, inventory management, house exploration, and combat. It usually takes a human player about an hour to complete these missions. Few previous studies tackle such long-duration tasks and rich semantic environments. It is an ideal scenario to emulate a novice player learning to play the game from scratch according to the rich in-game tutorials and hints. For **Stardew Valley**, we propose three essential tasks at the stage of the game, *i.e., Farm Clearup*: Clear the obstacles on the farm, such as weeds, stones, and trees, as much as possible to prepare for farming; 2) *Cultivation*: Plant the parsnip seed, water every day and harvest at least one mutual parsnip; 3) *Shopping*: Go to the general store in the town, which is out of the scope of the current map, to buy more seeds and return home. For **Dealer's Life**, the agent is tasked with managing a pawn shop for a week, appraising item values and haggling with the customers to secure deals. For **Cities: Skylines**, the task is to build a reasonable city ending in as much population as possible, with the initial starting funds of ₡70,000, and basic road, water and electricity facilities. Moreover, we define five representative domain-specific tasks for each of the five **Software Applications** in our diverse target set. We provide an overview of all the tasks for both games and software applications in Appendix Figure 9.

4.1 PERFORMANCE ACROSS ENVIRONMENTS

Red Dead Red Redemption 2. Figure 6 shows that **CRADLE** can efficiently complete simple navigation tasks with a few steps like following an NPC or going to specific locations on the ground (*e.g., Follow Dutch*, *Go to Town* and *Go to Barn*). Another following task, *Follow Javier*, and the searching task, *Search John*, are dangerous for the rugged and winding path up to the snow mountain with cliffs. Note that Cradle is able to retry the checkpoint automatically according to the game guidance if the task fails. Therefore, **CRADLE** takes more steps for retrying the task in these dangerous areas. In addition, Cradle spends about one-fourth of the total steps in the task of *Protect Dutch*, which is a long-horizontal task with nighttime combat. Many key skills are generated in this task for weapon management and shooting movement. The visibility is very poor due to the

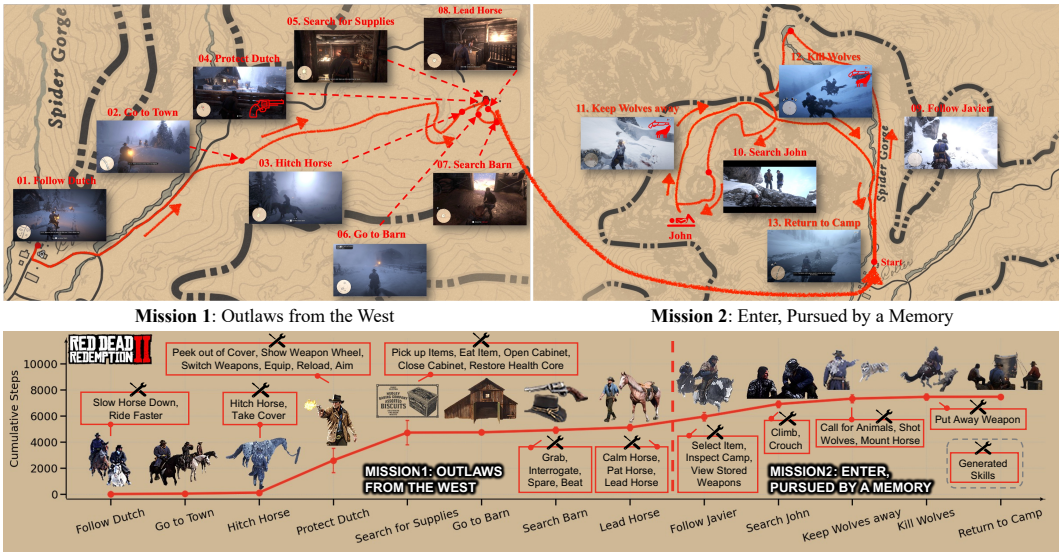

Figure 6: The first row demonstrates the trajectory of 13 sequential tasks in the two main storyline missions. The second row shows the cumulative steps **CRADLE** takes to complete each task in the two missions, starting from the beginning of the game. If a task fails, **CRADLE** can select the 'retry checkpoint' option to retry the task. Skills generated during the task completion are also illustrated in the figure. We only provide key skills for brevity. Error bars represent the standard deviation of steps needed to complete each task separately.

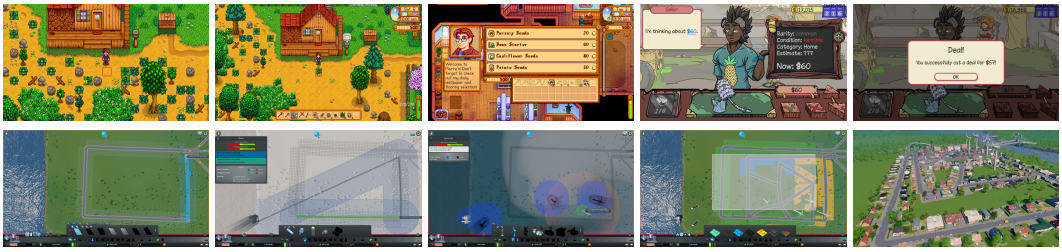

Figure 7: The first row sequentially shows farm clearup, cultivation and shopping in Stardwe Valley and haggling and deal in Dealer's Life 2. The second row sequentially shows road construction, water pipe laying, wind turbine building, zoning and the display of the city built by **CRADLE** in Cities: Skylines.

snow falling in the dark, which prevents GPT-4o from accurately recognizing and locating enemies or objects and precisely timing decisions, even equipped with Grounding DINO (Liu et al., 2023) as an additional detection tool. More times of retry, combined with the need for frequent interactions during combat and the long horizon of the task, lead to this task requiring a large number of steps to complete. The success rate of the combat has significantly improved during the day with much fewer steps for completion, as shown by tasks like *Keep Wolves away*. Additionally, indoor tasks like *Search for Supplies* are also challenging due to GPT4-o's limited spatial perception, which finds it difficult to locate target objects and ends up circling aimlessly around the house. Moreover, the room contains numerous interactive items unrelated to the task, resulting in much more steps for the agent to complete the task. Overall, **CRADLE** requires approximately 8,000 steps to complete both missions, taking around 98 minutes of in-game time, compared to the average of 67 minutes for human players. It is the first time for LMM-powered AI agents to exhibit comparable performance in complex AAA games. Despite the missions in the main storyline, in Appendix E, we also provide **CRADLE**'s performance in an open-ended task, *Buy Supply*, in the open-ended world, Chapter II, where seldom in-game guidance will appear. The agent needs to analyze and propose feasible solutions to complete the mission.

Stardew Valley. As shown in Table 1, we surprisingly find that GPT-4o struggles with accurately recognizing and locating objects near the player in this pixel-art game. This leads to difficulties for the agent to interact with objects or people, as it requires the player to stand precisely in front of them in the grid (*e.g.,* when entering doors, using a pickaxe to break stones). It explains the inefficiency in the farming task though the agent manages to clear up most of the obstacles in front of the house within 100 steps and poor performance in the shopping task. On the other hand, relying on episodic summarization and task inference, **CRADLE** manages to obtain the parsnip by watering the seed for four days and harvesting. Given GPT-4's limited visual capabilities in this game, there is still room for improvement in narrowing the gap between **CRADLE** and human players.

Dealer's Life 2. Table 1 shows that **CRADLE** demonstrates robust performance and efficient profit-making on the *Weekly Shop Management* task, successfully finalizing 93.6% of potential transactions, with an average of 2 negotiation rounds per customer, and generally aiming for a profit rate of over 50% at the initial offer. It consistently generates profit across all runs, maintaining a total profit rate of +39.6%, peaking at +87.4% in a single run. In this game, **CRADLE** significantly outperforms human players. The achievements are mainly attributed to its cautious strategy, by bargaining within a smaller range of price variation but haggling more frequently, resulting in a significantly higher turnover rate. In contrast, human players usually fail the deal due to their aggressive strategy by proposing an unreasonable price and sometimes confusing buying and selling.

Cities: Skylines. Table 1 shows that **CRADLE** is able to complete most of the city design with the averaged maximal population of 450 and the highest single population exceeding 860. **CRADLE** manages to build the roads in a closed loop to ensure smooth traffic flow, place multiple wind turbines to provide sufficient electricity supply and cover more than 90% of available area with residential, commercial and industrial zones, but fails to provide sufficient water supply for all the regions reliably. The most common failure arises from the missing of water pipes. **CRADLE** often fail to connect them with each other to cover all zones, resulting in localized water shortages in the city, and preventing new residents from moving in. The issue also arises from GPT-4o's limited visual understanding, making it difficult to accurately recognize which areas are already covered by the water pipes. We empirically observed that these mistakes usually could be fixed within three unit operations (building or removing a road/facility/a place of zones is counted as one unit operation). Then cities built by **CRADLE** can eventually reach a population of more than one thousand. We provide a detailed case study in Appendix H.5.2. Overall, as shown in Table 1, without the manual fixes, **CRADLE** still beats human players even though it suffers from local water storage. Human players typically pay insufficient attention to budget management and tend to allocate a disproportionate amount of funds to the construction of wind turbines for electricity, resulting in limited road construction and residential areas to attract residents.

Table 1: **CRADLE**'s and human players' performance in Stardew Valley, Dealer's Life 2 and Cites: Skylines with each trial run for at most 100, 500, 1000 steps respectively. $^1/_5$ indicates one successful run out of five runs.

Stardew Valley		
Task	Cradle	Human
Farm Clearup (Grids Num.)	14.8 ± 5.0	**35.2** ± 14.5
Cultivation	$^4/_5$	$^5/_5$
Shopping	$^1/_5$	$^5/_5$
Dealer's Life 2		
Metrics	Cradle	Human
Avg. Haggling Count	**1.95** ± 0.43	1.63 ± 0.53
Turnover Rate (%)	**93.6** ± 6.9	68.4 ± 22.2
Item Profit Rate (%)	**37.8** ± 19.1	21.1 ± 13.6
Total Profit Rate (%)	**39.6** ± 27.3	17.3 ± 15.1
Cities: Skylines		
Metrics	Cradle	Human
Closed-loop Road	$^4/_5$	$^5/_5$
Water Supply	$^1/_5$	$^3/_5$
Power Supply	$^5/_5$	$^5/_5$
Zoning Coverage	$^4/_5$	$^4/_5$
Population	**450** ±224	415 ±416

Software Applications. Figure 8 shows **CRADLE**'s performance across tasks on five applications. Multiple tasks remain challenging. Even with a well-known GUI, like Chrome and Outlook, GPT-4o still cannot recognize specific UI items to interact with and also struggles with visual context. For example, forgetting to press the Save button in an open dialog, or not distinguishing between a nearby enabled button vs. a distant and disabled one (*e.g.,* when posting on Twitter). The phenomenon is more severe in the UI with non-standard layouts, like CapCut, Meitu, and Feishu. Lacking prior knowledge by GPT-4o leads to the failure of task inference and selecting the correct skills.

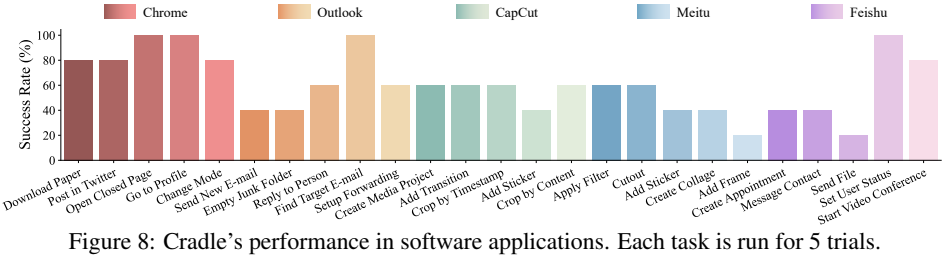

Figure 8: Cradle's performance in software applications. Each task is run for 5 trials.

OSWorld. Table 2 shows that **CRADLE** achieves the overall highest success rate in OSWorld, compared to the baselines without relying on any internal APIs to provide extra grounding labels, *e.g.,* Set-of-Mark (SoM) (Yang et al., 2023a). The information gathering module improves ground-

Table 2: Success rates (%) of different methods in OSWorld.

Method	Office (117)	OS (24)	Daily (78)	Workflow(101)	Professional (49)	All (369)
GPT-4o	**3.58**	8.33	6.07	**5.58**	4.08	5.03
GPT-4o+SoM	**3.58**	**20.83**	3.99	3.60	2.04	4.59
CRADLE	**3.58**	16.67	**6.55**	5.48	**20.41**	**7.81**

ing for more precise action execution, increasing the performance. The self-reflection module enables Cradle to predict infeasible tasks and subsequently fix mistakes, shown in the Professional domain results, where it achieves a 20.41% success rate, significantly surpassing the baselines.

4.2 BASELINE COMPARISON

Since no existing methods are fully applicable to the GCC setting, we select several representative methods with necessary adaptions to make them applicable to GCC, labeling them as "like" in Table 3. Compared to **CRADLE**, React (Yao et al., 2023)-like method only has gather information, skill curation, action planning and procedural memory module, while Reflextion (Shinn et al., 2023)-like method adds a self-reflection and episodic memory, compared to React-like. To show the necessity of multimodal input without access to APIs, we let GPT-4o describe the image and then feed the textual description to Voyager (Wang et al., 2024a)-like as input. Additionally, experiments with GPT-4o and Claude 3 Opus (Anthropic, 2024) as backbone are conducted. Due to the limitation of requests per minute, other prompting methods like self-consistency (Wang et al., 2022) and TOT (Yao et al., 2024) are not considered. Note that methods here refer to the agents initialized by the corresponding framework with game-specific implementations.

Table 3: Baseline comparison for five task in RDR2 and one task in Stardew Valley (*Cultivation*). Numbers before the brackets are average steps for completion. N/A indicates failure for all trials. Every task is run 5 times. Each trial is run for at most 500 steps in RDR2 and 100 steps in Stardew Valley.

Method	Follow Dutch	Follow Micah	Hitch Horse	Protect Dutch	Search for Supplies	Cultivation
React-like (GPT-4o)	15 ± 2 ($5/5$)	74 ± 0 ($1/5$)	N/A	N/A	N/A	N/A
Reflextion-like (GPT-4o)	19 ± 4 ($5/5$)	58 ± 14 ($2/5$)	N/A	N/A	N/A	N/A
Voyager-like (GPT-4o)	32 ± 12 ($3/5$)	N/A	N/A	N/A	N/A	N/A
CRADLE (Claude 3 Opus)	30 ± 7 ($5/5$)	52 ± 17 ($4/5$)	N/A	N/A	N/A	N/A
CRADLE (GPT-4o) (Ours)	$\mathbf{13 \pm 3}$ ($5/5$)	$\mathbf{33 \pm 3}$ ($5/5$)	$\mathbf{26 \pm 5}$ ($4/5$)	$\mathbf{461 \pm 0}$ ($1/5$)	$\mathbf{134 \pm 0}$ ($1/5$)	$\mathbf{24 \pm 4}$ ($4/5$)

As shwon in Table 3, all the baseline methods can only complete simple and straightforward tasks without complex targets and time delays. Compared to React-like method, Reflextion-like method has better performance in the task of *Follow Micah* and still fails to complete more complex tasks, emphasizing the importance of task inference and procedural memory. Voyager-like method that loses vision suffers to accomplish tasks and are the worst of all comparison methods. **CRADLE** with GPT-4o always has the best performance across all tasks. **CRADLE** with GPT-4o has the best performance, while Claude 3 Opus fails frequently due to unreliable OCR ability of the guidance, leading to incorrect skill generation and failures of complex tasks.

Figure 4 provides the detailed performance of each baseline method in the *Cultivation* task in Stardew Valley. Without task inference and episodic memory for summarization, even React-like and Reflexion-like methods sometimes managed to get the parsnip to sprout from the ground, they failed to harvest it because GPT-4o failed to recognize the mature parsnip. Episodic memory can help **CRADLE** record the days of watering and know when the crop can be harvested. Voyager-like method struggles with getting out of the house and returning home due to the lack of visual input. Claude 3 Opus also has difficulties in localizing the position of the character and the crop. Moreover, it prefers moving characters much more frequently than GPT-4, resulting in the failure to position the character in front of the crop.

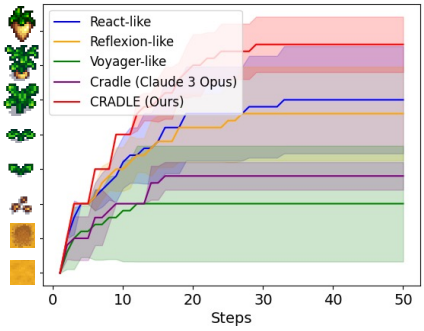

Table 4: Performance of each method in task *Cultivation*. The Y-axis shows the stage of parsnip. Only if the mutual parsnip (shown on the top of the y-axis) is obtained will this trial be counted as a success.

4.3 ABLATION STUDY

Besides comparing with other baseline methods, we provide a complete ablation study by systematically removing each module of Cradle to show the effectiveness in Table 5. We mainly show the results of 6 consecutive subtasks at the beginning of the main storyline, separated from the tasks of *Follow Micah*, *Hitch Horse* and *Protect Dutch* in RDR2. Note that the combination of skill curation, action planning and procedural memory is the minimal unit of our framework. Without any of them, the agent cannot generate and execute valid actions successfully. So these modules are not ablated.

The most significant decline in agent capabilities arises from the absence of the information gathering module. Without this module, the agent is unable to extract key information in the observation,

which is critical for all other modules to function effectively. The second largest impact comes from the lack of the self-reflection module, which is instrumental in correcting mistakes and recognizing when the agent is stuck, such as in the subtask of *Go to Shed*. Third, the task inference module is vital for tasks that require strict adherence to guidance, like *Switch Weapon*. In these cases, the in-game instructions appear only at the beginning of the task, as seen in *Follow Micah* and *Go to Shed*. Lastly, episodic memory becomes increasingly important as tasks grow more complex, requiring more steps to complete, such as in *Go to Shed* and *Combat*, which involve far more steps than other subtasks. Overall, each module plays a crucial and distinct role in the Cradle framework. Removing or isolating any of them significantly reduces the agent's effectiveness, underscoring the importance of their integrated function.

Table 5: Success rates of each variant by systematically removing Cradle's module on six consecutive subtasks in RDR2. Every subtask is run 5 times. Each of subtasks are run for at most 500 steps.

Subtask	w/o Information Gathering	w/o Self-Reflection	w/o Task Inference	w/o Episodic Memory	CRADLE
Follow Micah	0%	0%	40%	80%	**100%**
Hitch Horse	0%	**100%**	**100%**	**100%**	**100%**
Go to Shed	0%	20%	40%	20%	**80%**
Peek out of Cover	60%	**100%**	80%	**100%**	**100%**
Switch Weapon	0%	80%	60%	80%	**100%**
Combat	0%	0%	0%	0%	**20%**

5 Limitations and Future Work

Despite **CRADLE**'s encouraging performance across games and software, several limitations remain. i) Due to the limited ability of current LMM models, **CRADLE** struggles in recognizing out-of-distribution (OOD) icons and completing OOD tasks, such as games with non-realistic styles, *i.e.,* Stardew Valley. As LMMs evolve, they can further improve **CRADLE**'s performance. ii) Another general bottleneck for LMM-based agents is the latency caused by the limited inference speed of LMMs, which can also be alleviated as LMMs evolve (*e.g.,* Realtime API (OpenAI, 2024a)). iii) Audio, as an important modality, often plays an important role in games and software; which has not been considered in this work. The future work will be enabling **CRADLE** to process the audio and graphical input simultaneously. iv) Most **CRADLE**'s modules need to call LMM explicitly to process the input for best performance, resulting in frequent interactions with LMM and potentially high costs and long delays. The six modules represent a problem-solving mindset; as LMM capabilities improve, some or even all of these modules may be combined into a single request. v) In this work, we mainly focus on enabling foundation agents to interact with various software in a unified manner without taking training into consideration. As SIMA (Raad et al., 2024) has already shown promising results in a similar setting with the trained agents, we will let **CRADLE** autonomously explore and improve over environments through RL (Tan et al., 2023) or collect expert demonstrations for supervised learning (Raad et al., 2024). vi) Though **CRADLE** is broadly applicable to any computer task, only a few selected tasks are investigated in this work. We plan to expand its application to a wider range of targets, delve deeper into complex games, and enhance its adaptability for users. vii) Due to the large scope of the experiments conducted in this work, the number of runs for each task and human participants are limited. A more comprehensive evaluation can be beneficial. **CRADLE** holds great potential to improve effective general computer task completion and boost research and deployment of foundation agents. However, there is also a risk of unintended or unsuitable usage, including developing game cheats, incorrect operations of software with harmful failures, or other negative agent behavior. Therefore, additional regulations or safeguards are required for secure and responsible deployments across digital and physical environments.

6 Conclusion

We introduce GCC, a general and challenging setting to control diverse video games and software with a unified and standard interface, paving the way towards general foundation agents across all digital world tasks. To properly address the challenges GCC presents, we propose a novel framework, **CRADLE**, which exhibits strong performance in reasoning and performing actions to accomplish various missions in a set of complex video games and common software applications. To the best of our knowledge, **CRADLE** is the first framework that enables foundation agents to succeed in such a diverse set of environments without relying on any built-in APIs. The success of **CRADLE** greatly extends the reach of foundation agents and demonstrates the feasibility of converting any software, especially complex games, into benchmarks to evaluate agents' general intelligence and facilitate further data collection for self-improvement. Although **CRADLE** still faces difficulties in certain tasks, it serves as a pioneering work to develop more powerful LMM-based agents towards GCC, combining both further framework enhancements and new advances in LMMs.

REFERENCES

Anthropic. The claude 3 model family: Opus, sonnet, haiku, 2024. URL https://www-cdn.anthropic.com/de8ba9b01c9ab7cbabf5c33b80b7bbc618857627/Model_Card_Claude_3.pdf.

Bowen Baker, Ilge Akkaya, Peter Zhokov, Joost Huizinga, Jie Tang, Adrien Ecoffet, Brandon Houghton, Raul Sampedro, and Jeff Clune. Video pretraining (VPT): Learning to act by watching unlabeled online videos. *Advances in Neural Information Processing Systems*, 35:24639–24654, 2022.

Anton Bakhtin, Noam Brown, Emily Dinan, Gabriele Farina, Colin Flaherty, Daniel Fried, Andrew Goff, Jonathan Gray, Hengyuan Hu, et al. Human-level play in the game of diplomacy by combining language models with strategic reasoning. *Science*, 378(6624):1067–1074, 2022.

Marc G Bellemare, Yavar Naddaf, Joel Veness, and Michael Bowling. The Arcade learning environment: An evaluation platform for general agents. *Journal of Artificial Intelligence Research*, 47:253–279, 2013.

Christopher Berner, Greg Brockman, Brooke Chan, Vicki Cheung, Przemysław Dębiak, Christy Dennison, David Farhi, Quirin Fischer, Shariq Hashme, Chris Hesse, et al. Dota 2 with large scale deep reinforcement learning. *arXiv preprint arXiv:1912.06680*, 2019.

Anthony Brohan, Noah Brown, Justice Carbajal, Yevgen Chebotar, Xi Chen, Krzysztof Choromanski, Tianli Ding, Danny Driess, Avinava Dubey, Chelsea Finn, et al. RT-2: Vision-language-action models transfer web knowledge to robotic control. *arXiv preprint arXiv:2307.15818*, 2023a.

Anthony Brohan, Yevgen Chebotar, Chelsea Finn, Karol Hausman, Alexander Herzog, Daniel Ho, Julian Ibarz, Alex Irpan, Eric Jang, Ryan Julian, et al. Do as I can, not as I say: Grounding language in robotic affordances. In *Conference on Robot Learning*, pp. 287–318. PMLR, 2023b.

Roberto Brunelli. *Template matching techniques in computer vision: theory and practice*. John Wiley & Sons, 2009.

Micah Carroll, Rohin Shah, Mark K Ho, Tom Griffiths, Sanjit Seshia, Pieter Abbeel, and Anca Dragan. On the utility of learning about humans for human-ai coordination. *Advances in neural information processing systems*, 32, 2019.

Kanzhi Cheng, Qiushi Sun, Yougang Chu, Fangzhi Xu, Yantao Li, Jianbing Zhang, and Zhiyong Wu. SeeClick: Harnessing GUI grounding for advanced visual GUI agents. *arXiv preprint arXiv:2401.10935*, 2024.

Maxime Chevalier-Boisvert, Dzmitry Bahdanau, Salem Lahlou, Lucas Willems, Chitwan Saharia, Thien Huu Nguyen, and Yoshua Bengio. BabyAI: First steps towards grounded language learning with a human in the loop. In *International Conference on Learning Representations*, 2019. URL https://openreview.net/forum?id=rJeXCo0cYX.

Matt Deitke, Eli VanderBilt, Alvaro Herrasti, Luca Weihs, Kiana Ehsani, Jordi Salvador, Winson Han, Eric Kolve, Aniruddha Kembhavi, and Roozbeh Mottaghi. Procthor: Large-scale embodied ai using procedural generation. *Advances in Neural Information Processing Systems*, 35:5982–5994, 2022.

Xiang Deng, Yu Gu, Boyuan Zheng, Shijie Chen, Samuel Stevens, Boshi Wang, Huan Sun, and Yu Su. Mind2Web: Towards a generalist agent for the web. *arXiv preprint arXiv:2306.06070*, 2023.

Danny Driess, Fei Xia, Mehdi SM Sajjadi, Corey Lynch, Aakanksha Chowdhery, Brian Ichter, Ayzaan Wahid, Jonathan Tompson, Quan Vuong, Tianhe Yu, et al. Palm-e: An embodied multimodal language model. *arXiv preprint arXiv:2303.03378*, 2023.

Benjamin Ellis, Jonathan Cook, Skander Moalla, Mikayel Samvelyan, Mingfei Sun, Anuj Mahajan, Jakob Nicolaus Foerster, and Shimon Whiteson. SMACv2: An improved benchmark for cooperative multi-agent reinforcement learning. In *Thirty-seventh Conference on Neural Information Processing Systems Datasets and Benchmarks Track*, 2023. URL https://openreview.net/forum?id=5OjLGiJW3u.

Linxi Fan, Guanzhi Wang, Yunfan Jiang, Ajay Mandlekar, Yuncong Yang, Haoyi Zhu, Andrew Tang, De-An Huang, Yuke Zhu, and Anima Anandkumar. Minedojo: Building open-ended embodied agents with internet-scale knowledge. *Advances in Neural Information Processing Systems*, 35: 18343–18362, 2022.

Hiroki Furuta, Ofir Nachum, Kuang-Huei Lee, Yutaka Matsuo, Shixiang Shane Gu, and Izzeddin Gur. Multimodal web navigation with instruction-finetuned foundation models. *arXiv preprint arXiv:2305.11854*, 2023.

Difei Gao, Lei Ji, Zechen Bai, Mingyu Ouyang, Peiran Li, Dongxing Mao, Qinchen Wu, Weichen Zhang, Peiyi Wang, Xiangwu Guo, et al. ASSISTGUI: Task-oriented desktop graphical user interface automation. *arXiv preprint arXiv:2312.13108*, 2023.

Xiaofeng Gao, Ran Gong, Tianmin Shu, Xu Xie, Shu Wang, and Song-Chun Zhu. Vrkitchen: an interactive 3d virtual environment for task-oriented learning. *arXiv preprint arXiv:1903.05757*, 2019.

Izzeddin Gur, Hiroki Furuta, Austin Huang, Mustafa Safdari, Yutaka Matsuo, Douglas Eck, and Aleksandra Faust. A real-world webagent with planning, long context understanding, and program synthesis. *arXiv preprint arXiv:2307.12856*, 2023.

William H Guss, Brandon Houghton, Nicholay Topin, Phillip Wang, Cayden Codel, Manuela Veloso, and Ruslan Salakhutdinov. Minerl: A large-scale dataset of Minecraft demonstrations. *arXiv preprint arXiv:1907.13440*, 2019.

Hongliang He, Wenlin Yao, Kaixin Ma, Wenhao Yu, Yong Dai, Hongming Zhang, Zhenzhong Lan, and Dong Yu. WebVoyager: Building an end-to-end web agent with large multimodal models. *arXiv preprint arXiv:2401.13919*, 2024.

Wenyi Hong, Weihan Wang, Qingsong Lv, Jiazheng Xu, Wenmeng Yu, Junhui Ji, Yan Wang, Zihan Wang, Yuxiao Dong, Ming Ding, et al. CogAgent: A visual language model for GUI agents. *arXiv preprint arXiv:2312.08914*, 2023.

Wenlong Huang, Fei Xia, Ted Xiao, Harris Chan, Jacky Liang, Pete Florence, Andy Zeng, Jonathan Tompson, Igor Mordatch, Yevgen Chebotar, et al. Inner monologue: Embodied reasoning through planning with language models. *arXiv preprint arXiv:2207.05608*, 2022.

Max Jaderberg, Wojciech M Czarnecki, Iain Dunning, Luke Marris, Guy Lever, Antonio Garcia Castaneda, Charles Beattie, Neil C Rabinowitz, Ari S Morcos, Avraham Ruderman, et al. Human-level performance in 3D multiplayer games with population-based reinforcement learning. *Science*, 364(6443):859–865, 2019.

Matthew Johnson, Katja Hofmann, Tim Hutton, and David Bignell. The Malmo platform for artificial intelligence experimentation. In *Ijcai*, pp. 4246–4247, 2016.

Raghav Kapoor, Yash Parag Butala, Melisa Russak, Jing Yu Koh, Kiran Kamble, Waseem Alshikh, and Ruslan Salakhutdinov. OmniACT: A dataset and benchmark for enabling multimodal generalist autonomous agents for desktop and web, 2024.

Christian Kauten. Super Mario Bros for OpenAI Gym. GitHub, 2018. URL https://github.com/Kautenja/gym-super-mario-bros.

Alexander Kirillov, Eric Mintun, Nikhila Ravi, Hanzi Mao, Chloe Rolland, Laura Gustafson, Tete Xiao, Spencer Whitehead, Alexander C Berg, Wan-Yen Lo, et al. Segment anything. In *Proceedings of the IEEE/CVF International Conference on Computer Vision*, pp. 4015–4026, 2023.

Jing Yu Koh, Robert Lo, Lawrence Jang, Vikram Duvvur, Ming Chong Lim, Po-Yu Huang, Graham Neubig, Shuyan Zhou, Ruslan Salakhutdinov, and Daniel Fried. VisualWebArena: Evaluating multimodal agents on realistic visual web tasks. *arXiv preprint arXiv:2401.13649*, 2024.

Karol Kurach, Anton Raichuk, Piotr Stańczyk, Michał Zając, Olivier Bachem, Lasse Espeholt, Carlos Riquelme, Damien Vincent, Marcin Michalski, Olivier Bousquet, et al. Google research football: A novel reinforcement learning environment. In *Proceedings of the AAAI conference on artificial intelligence*, pp. 4501–4510, 2020.

Joel Z Leibo, Edgar A Dueñez-Guzman, Alexander Vezhnevets, John P Agapiou, Peter Sunehag, Raphael Koster, Jayd Matyas, Charlie Beattie, Igor Mordatch, and Thore Graepel. Scalable evaluation of multi-agent reinforcement learning with melting pot. In *International conference on machine learning*, pp. 6187–6199. PMLR, 2021.

Chengshu Li, Fei Xia, Roberto Martín-Martín, Michael Lingelbach, Sanjana Srivastava, Bokui Shen, Kent Vainio, Cem Gokmen, Gokul Dharan, Tanish Jain, et al. igibson 2.0: Object-centric simulation for robot learning of everyday household tasks. *arXiv preprint arXiv:2108.03272*, 2021.

Evan Zheran Liu, Kelvin Guu, Panupong Pasupat, Tianlin Shi, and Percy Liang. Reinforcement learning on web interfaces using workflow-guided exploration. In *International Conference on Learning Representations (ICLR)*, 2018. URL https://arxiv.org/abs/1802.08802.

Shilong Liu, Zhaoyang Zeng, Tianhe Ren, Feng Li, Hao Zhang, Jie Yang, Chunyuan Li, Jianwei Yang, Hang Su, Jun Zhu, et al. Grounding Dino: Marrying dino with grounded pre-training for open-set object detection. *arXiv preprint arXiv:2303.05499*, 2023.

Weiyu Ma, Qirui Mi, Xue Yan, Yuqiao Wu, Runji Lin, Haifeng Zhang, and Jun Wang. Large language models play StarCraft II: Benchmarks and a chain of summarization approach. *arXiv preprint arXiv:2312.11865*, 2023.

Manolis Savva*, Abhishek Kadian*, Oleksandr Maksymets*, Yili Zhao, Erik Wijmans, Bhavana Jain, Julian Straub, Jia Liu, Vladlen Koltun, Jitendra Malik, Devi Parikh, and Dhruv Batra. Habitat: A Platform for Embodied AI Research. In *Proceedings of the IEEE/CVF International Conference on Computer Vision (ICCV)*, 2019.

Grégoire Mialon, Clémentine Fourrier, Craig Swift, Thomas Wolf, Yann LeCun, and Thomas Scialom. GAIA: a benchmark for general AI assistants. *arXiv preprint arXiv:2311.12983*, 2023.

Meredith Ringel Morris, Jascha Sohl-dickstein, Noah Fiedel, Tris Warkentin, Allan Dafoe, Aleksandra Faust, Clement Farabet, and Shane Legg. Levels of AGI: Operationalizing progress on the path to AGI. *arXiv preprint arXiv:2311.02462*, 2023.

Runliang Niu, Jindong Li, Shiqi Wang, Yali Fu, Xiyu Hu, Xueyuan Leng, He Kong, Yi Chang, and Qi Wang. ScreenAgent: A vision language model-driven computer control agent. *arXiv preprint arXiv:2402.07945*, 2024.

OpenAI. Universe, 2016. URL https://openai.com/index/universe/.

OpenAI. New and improved embedding model, 2022. URL https://openai.com/index/new-and-improved-embedding-model/.

OpenAI. Introducing the realtime api, 2024a. URL https://openai.com/index/introducing-the-realtime-api/.

OpenAI. Hello gpt-4o, 2024b. URL https://openai.com/index/hello-gpt-4o/.

Joon Sung Park, Joseph O'Brien, Carrie Jun Cai, Meredith Ringel Morris, Percy Liang, and Michael S Bernstein. Generative agents: Interactive simulacra of human behavior. In *Proceedings of the 36th Annual ACM Symposium on User Interface Software and Technology*, pp. 1–22, 2023.

Xavier Puig, Kevin Ra, Marko Boben, Jiaman Li, Tingwu Wang, Sanja Fidler, and Antonio Torralba. Virtualhome: Simulating household activities via programs. In *Proceedings of the IEEE conference on computer vision and pattern recognition*, pp. 8494–8502, 2018.

Xavier Puig, Eric Undersander, Andrew Szot, Mikael Dallaire Cote, Tsung-Yen Yang, Ruslan Partsey, Ruta Desai, Alexander William Clegg, Michal Hlavac, So Yeon Min, et al. Habitat 3.0: A co-habitat for humans, avatars and robots. *arXiv preprint arXiv:2310.13724*, 2023.

Siyuan Qi, Shuo Chen, Yexin Li, Xiangyu Kong, Junqi Wang, Bangcheng Yang, Pring Wong, Yifan Zhong, Xiaoyuan Zhang, Zhaowei Zhang, et al. CivRealm: A learning and reasoning odyssey in Civilization for decision-making agents. In *ICLR*, 2024.

Maria Abi Raad, Arun Ahuja, Catarina Barros, Frederic Besse, Andrew Bolt, Adrian Bolton, Bethanie Brownfield, Gavin Buttimore, Max Cant, Sarah Chakera, et al. Scaling instructable agents across many simulated worlds. *arXiv preprint arXiv:2404.10179*, 2024.

Christopher Rawles, Alice Li, Daniel Rodriguez, Oriana Riva, and Timothy Lillicrap. Android in the wild: A large-scale dataset for Android device control. *arXiv preprint arXiv:2307.10088*, 2023.

Mikayel Samvelyan, Tabish Rashid, Christian Schroeder De Witt, Gregory Farquhar, Nantas Nardelli, Tim GJ Rudner, Chia-Man Hung, Philip HS Torr, Jakob Foerster, and Shimon Whiteson. The Starcraft multi-agent challenge. *arXiv preprint arXiv:1902.04043*, 2019.

Bokui Shen, Fei Xia, Chengshu Li, Roberto Martín-Martín, Linxi Fan, Guanzhi Wang, Claudia Pérez-D'Arpino, Shyamal Buch, Sanjana Srivastava, Lyne Tchapmi, et al. igibson 1.0: a simulation environment for interactive tasks in large realistic scenes. In *2021 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, pp. 7520–7527. IEEE, 2021.

Tianlin Shi, Andrej Karpathy, Linxi Fan, Jonathan Hernandez, and Percy Liang. World of bits: An open-domain platform for web-based agents. In *International Conference on Machine Learning*, pp. 3135–3144. PMLR, 2017.

Noah Shinn, Federico Cassano, Ashwin Gopinath, Karthik R Narasimhan, and Shunyu Yao. Reflexion: language agents with verbal reinforcement learning. In *Thirty-seventh Conference on Neural Information Processing Systems*, 2023. URL https://openreview.net/forum?id=vAElhFcKW6.

Andrew Szot, Alex Clegg, Eric Undersander, Erik Wijmans, Yili Zhao, John Turner, Noah Maestre, Mustafa Mukadam, Devendra Chaplot, Oleksandr Maksymets, Aaron Gokaslan, Vladimir Vondrus, Sameer Dharur, Franziska Meier, Wojciech Galuba, Angel Chang, Zsolt Kira, Vladlen Koltun, Jitendra Malik, Manolis Savva, and Dhruv Batra. Habitat 2.0: Training home assistants to rearrange their habitat. In *Advances in Neural Information Processing Systems (NeurIPS)*, 2021.

Weihao Tan, Wentao Zhang, Shanqi Liu, Longtao Zheng, Xinrun Wang, and Bo An. True knowledge comes from practice: Aligning large language models with embodied environments via reinforcement learning. In *ICLR*, 2023.

Oriol Vinyals, Igor Babuschkin, Junyoung Chung, Michael Mathieu, Max Jaderberg, Wojciech M Czarnecki, Andrew Dudzik, Aja Huang, Petko Georgiev, Richard Powell, et al. AlphaStar: Mastering the real-time strategy game Starcraft II. *DeepMind blog*, 2:20, 2019.

Guanzhi Wang, Yuqi Xie, Yunfan Jiang, Ajay Mandlekar, Chaowei Xiao, Yuke Zhu, Linxi Fan, and Anima Anandkumar. Voyager: An open-ended embodied agent with large language models. *Transactions on Machine Learning Research*, 2024a. ISSN 2835-8856. URL https://openreview.net/forum?id=ehfRiF0R3a.

Junyang Wang, Haiyang Xu, Jiabo Ye, Ming Yan, Weizhou Shen, Ji Zhang, Fei Huang, and Jitao Sang. Mobile-Agent: Autonomous multi-modal mobile device agent with visual perception. *arXiv preprint arXiv:2401.16158*, 2024b.

Xuezhi Wang, Jason Wei, Dale Schuurmans, Quoc Le, Ed Chi, Sharan Narang, Aakanksha Chowdhery, and Denny Zhou. Self-consistency improves chain of thought reasoning in language models. *arXiv preprint arXiv:2203.11171*, 2022.

Zihao Wang, Shaofei Cai, Anji Liu, Yonggang Jin, Jinbing Hou, Bowei Zhang, Haowei Lin, Zhaofeng He, Zilong Zheng, Yaodong Yang, and Yitao Liang. Jarvis-1: Open-world multi-task agents with memory-augmented multimodal language models. *arXiv preprint arXiv:2311.05997*, 2023a.

Zihao Wang, Shaofei Cai, Anji Liu, Xiaojian Ma, and Yitao Liang. Describe, explain, plan and select: Interactive planning with large language models enables open-world multi-task agents. In *ICML*, 2023b.

Sarah A. Wu, Rose E. Wang, James A. Evans, Joshua B. Tenenbaum, David C. Parkes, and Max Kleiman-Weiner. Too many cooks: Coordinating multi-agent collaboration through inverse planning. *Topics in Cognitive Science*, n/a(n/a), 2021. doi: https://doi.org/10.1111/tops.12525. URL https://onlinelibrary.wiley.com/doi/abs/10.1111/tops.12525.

Zhiyong Wu, Chengcheng Han, Zichen Ding, Zhenmin Weng, Zhoumianze Liu, Shunyu Yao, Tao Yu, and Lingpeng Kong. OS-copilot: Towards generalist computer agents with self-improvement. *arXiv preprint arXiv:2402.07456*, 2024.

Peter R. Wurman, Samuel Barrett, Kenta Kawamoto, James MacGlashan, Kaushik Subramanian, Thomas J. Walsh, Roberto Capobianco, Alisa Devlic, Franziska Eckert, Florian Fuchs, et al. Outracing champion Gran Turismo drivers with deep reinforcement learning. *Nature*, 602(7896): 223–228, 2022.

Yuchen Xiao, Weihao Tan, and Christopher Amato. Asynchronous actor-critic for multi-agent reinforcement learning. *Advances in Neural Information Processing Systems*, 35:4385–4400, 2022.

Tianbao Xie, Danyang Zhang, Jixuan Chen, Xiaochuan Li, Siheng Zhao, Ruisheng Cao, Toh Jing Hua, Zhoujun Cheng, Dongchan Shin, Fangyu Lei, et al. Osworld: Benchmarking multimodal agents for open-ended tasks in real computer environments. *arXiv preprint arXiv:2404.07972*, 2024.

An Yan, Zhengyuan Yang, Wanrong Zhu, Kevin Lin, Linjie Li, Jianfeng Wang, Jianwei Yang, Yiwu Zhong, Julian McAuley, Jianfeng Gao, Zicheng Liu, and Lijuan Wang. GPT-4V in wonderland: Large multimodal models for zero-shot smartphone GUI navigation. *arXiv preprint arXiv:2311.07562*, 2023.

Jianwei Yang, Hao Zhang, Feng Li, Xueyan Zou, Chunyuan Li, and Jianfeng Gao. Set-of-mark prompting unleashes extraordinary visual grounding in gpt-4v, 2023a.

Zhao Yang, Jiaxuan Liu, Yucheng Han, Xin Chen, Zebiao Huang, Bin Fu, and Gang Yu. AppAgent: Multimodal agents as smartphone users. *arXiv preprint arXiv:2312.13771*, 2023b.

Shunyu Yao, Howard Chen, John Yang, and Karthik Narasimhan. Webshop: Towards scalable real-world web interaction with grounded language agents. *Advances in Neural Information Processing Systems*, 35:20744–20757, 2022.

Shunyu Yao, Jeffrey Zhao, Dian Yu, Nan Du, Izhak Shafran, Karthik Narasimhan, and Yuan Cao. ReAct: Synergizing reasoning and acting in language models. In *International Conference on Learning Representations (ICLR)*, 2023.

Shunyu Yao, Dian Yu, Jeffrey Zhao, Izhak Shafran, Tom Griffiths, Yuan Cao, and Karthik Narasimhan. Tree of thoughts: Deliberate problem solving with large language models. *Advances in Neural Information Processing Systems*, 36, 2024.

Chaoyun Zhang, Liqun Li, Shilin He, Xu Zhang, Bo Qiao, Si Qin, Minghua Ma, Yu Kang, Qingwei Lin, Saravan Rajmohan, et al. UFO: A UI-focused agent for Windows OS interaction. *arXiv preprint arXiv:2402.07939*, 2024.

Boyuan Zheng, Boyu Gou, Jihyung Kil, Huan Sun, and Yu Su. GPT-4V(ision) is a generalist web agent, if grounded. *arXiv preprint arXiv:2401.01614*, 2024a.

Longtao Zheng, Rundong Wang, Xinrun Wang, and Bo An. Synapse: Trajectory-as-exemplar prompting with memory for computer control. In *ICLR*, 2024b.

Shuyan Zhou, Frank F. Xu, Hao Zhu, Xuhui Zhou, Robert Lo, Abishek Sridhar, Xianyi Cheng, Yonatan Bisk, Daniel Fried, Uri Alon, et al. WebArena: A realistic web environment for building autonomous agents. *arXiv preprint arXiv:2307.13854*, 2023.

Appendix

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A Game & Task Introduction

The four selected representative games are:

- **Red Dead Redemption 2** (RDR2), an epic AAA 3D role-playing game (RPG) with rich storylines, realistic scenes, and an immersive open-ended world; where players can complete missions by following the instructions, freely explore the world, interact with non-player characters (NPCs) and engage in a variety of activities such as hunting and fishing, in a first- or third-person perspective. This game offers great challenges in 3D embodied navigation and interaction.
- **Stardew Valley**, a 2D pixel-art farming simulation game where players can restore and expand a farm through carefully planned activities such as planting crops, mining, fishing, and crafting. Players can build relationships with the villagers, participate in seasonal events, and uncover the mysteries of the valley. The game encourages strategic planning and time management, as each day brings new opportunities and challenges. Players have to balance their energy and resources to maximize their farm's productivity and profitability.
- **Dealer's Life 2**, a simulation game where players manage a pawn shop. They must assess the value of items, haggle with customers, and make strategic decisions to grow their business. The game offers a dynamic market influenced by trends, customer preferences, and random events, requiring players to adapt and refine their negotiation tactics.
- **Cities: Skylines**, a 3D, top-down view, city-building game where players take on the role of a city mayor, tasked with the development and management of a thriving metropolis, engaging in urban planning by controlling zoning, road placement, taxation, public services, and public transportation in an area. They must balance the needs and desires of the population with the city's budget, addressing issues such as traffic congestion, pollution, and citizen satisfaction. The game provides a sandbox environment where creativity and strategic thinking are key to building efficient and aesthetically pleasing urban landscapes. It also requires highly precise mouse control.

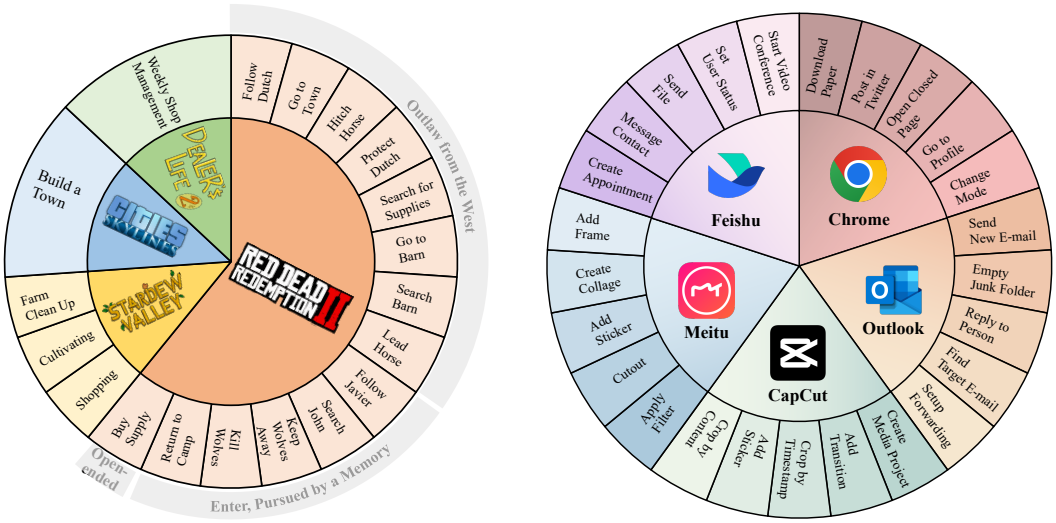


Figure 9: Overview of all game tasks (left) in RDR2, Stardew Valley, Cities: Skylines, and Dealer's Life 2 and application tasks (right) in Chrome, Outlook, CapCut, Meitu, and Feishu.

B Extended Related Work

B.1 Environments and Benchmarks for Computer Control

Environments and Benchmarks on Software Applications. Simulated environments on computers have been popular benchmarks and testbeds for the research community. Earlier computer control environments primarily focused on web navigation tasks (Shi et al., 2017; Liu et al., 2018; Yao et al., 2022; Deng et al., 2023; Zhou et al., 2023; Koh et al., 2024). Recent benchmarks start to include various common software (Kapoor et al., 2024; Xie et al., 2024), aiming to develop a generalist agent in the digital world. However, none of them takes video games into consideration, missing a key component of computer control.

Environments and Benchmarks on Video Games. On the other side, many research environments are built on top of video games, significantly advancing the study of decision-making, especially, reinforcement learning (RL). Examples include but are not limited to Atari games (Bellemare et al., 2013), Super Mario Bros (Kauten, 2018), Google Research Football (Kurach et al., 2020), Minecraft (Johnson et al., 2016; Guss et al., 2019; Fan et al., 2022), Dota II (Berner et al., 2019), StarCraft II (Vinyals et al., 2019; Samvelyan et al., 2019; Ellis et al., 2023), Quake III (Jaderberg et al., 2019), Gran Turismo (Wurman et al., 2022), Diplomacy (Bakhtin et al., 2022) and Civilization (Qi et al., 2024). Additionally, many custom-built environments, especially grid world and embodied scenarios, are created from scratch in a game-like manner to facilitate agent development, such as BabyAI (Chevalier-Boisvert et al., 2019), Melting Pot (Leibo et al., 2021), Overcooked (Carroll et al., 2019; Wu et al., 2021; Xiao et al., 2022), VRKitchen (Gao et al., 2019), VirtualHome (Puig et al., 2018), iGibson (Shen et al., 2021; Li et al., 2021), ProcTHOR (Deitke et al., 2022), Habitat (Manolis Savva* et al., 2019; Szot et al., 2021; Puig et al., 2023), and Generative agents (Park et al., 2023).

Each of these environments highly relies on the accessibility of the open-source code or provided built-in APIs. Significant human efforts are required for implementation and encapsulation, enabling agent interaction. Therefore, despite the abundance of software and games available for human use, only a limited number are accessible to agents, especially for commercial closed-source games and software applications. Additionally, the lack of consensus on environment standards further complicates the interaction, as each environment has specific observation and action spaces, tailored to its unique requirements. This variation exacerbates the challenge of enabling agents to interact with diverse environments and collect data with a consistent level of fine-grained semantics to improve the agent's capabilities. Few agents can complete tasks across multiple environments so far.

Similar to OpenAI Universe (OpenAI, 2016) and SIMA (Raad et al., 2024), our goal is to explore a unified way that allows agents to interact for measuring and training agents' abilities across a wide range of games, websites, and other applications without heavy human efforts needed. This approach aims to prove that diverse software applications and games can serve as out-of-the-box environments for AI development.

B.2 LMM-based Agents for Computer Tasks

Agents for Software Manipulation. Agents for software applications are developed to complete tasks such as web navigation (Zhou et al., 2023; Deng et al., 2023; Mialon et al., 2023) and software application control (Rawles et al., 2023; Yang et al., 2023b; Kapoor et al., 2024). While previous LLM-based web agents (Deng et al., 2023; Zhou et al., 2023; Gur et al., 2023; Zheng et al., 2024b) show some promising results in effectively interacting with content on webpages, they usually use raw HTML code and DOM tree as input and interact with the available element IDs, ignoring the rich visual patterns with key information, like icons, images, and spatial relations. Recently, multimodal web agents (Yan et al., 2023; Gao et al., 2023; He et al., 2024; Zheng et al., 2024a; Niu et al., 2024; Zhang et al., 2024; Wu et al., 2024) and mobile app agents (Yang et al., 2023b; Wang et al., 2024b) have been explored. Though using screenshots as input, they still rely on built-in APIs and advanced tools to get internal information, like available interactive element IDs, to execute corresponding actions, which greatly limits their applicability. Other train-based agents (Hong et al., 2023; Furuta et al., 2023; Cheng et al., 2024) also suffer from generalizing to unseen software and tasks. Moreover, all of these works primarily focus on static websites and software, which greatly reduces the need for timeliness and simplifies the setting by ignoring the dynamics between adjacent screenshots, *i.e.,* animations, and incomplete action space without considering the duration of the key press and different mouse mode. It results in the failure of deployment to the tasks with rapid graphics changes, *e.g.,* game playing.

Agents for Game Playing. Several attempts try to develop foundation agents for complex video games, such as Minecraft (Wang et al., 2023b;a; 2024a), Starcraft II (Ma et al., 2023) and Civilization-like game (Qi et al., 2024) with textual observations obtained from internal APIs and pre-defined semantic actions. Although JARVIS-1 (Wang et al., 2023a) claims to interact with the environment in a human-like manner with the screenshots as input and mouse and keyboard for control, its action space is predefined as a hybrid space composed of keyboard, mouse, and API. The game-specific observation and action spaces prohibit the generalization of them to other novel games. Pre-trained with videos with action labels, VPT (Baker et al., 2022) manages to output mouse

and keyboard control with raw screenshots as input without any additional information. However, collecting videos with action labels is time-consuming and costly, which is difficult to generalize to multiple environments. Another concurrent work, SIMA (Raad et al., 2024) trained embodied agents to complete 10-second-long tasks over ten 3D video games. Though their results are promising to scale up, they focus on behavior cloning with gameplay data from human experts, resulting in a high expense.

In both targeting complex video games and diverse software applications, **CRADLE** attempts to explore a new way to efficiently interact with different complex environments in a unified manner and facilitate further data collection. In a nutshell, to our best knowledge, there are currently no agents under the GCC setting, reported to show superior performance and generalization in complex video games and across computer tasks. In this work, we make a preliminary attempt to explore and benchmark diverse environments in this setting, applying our framework to diverse challenging environments under GCC and proposing an approach where any software can be used to benchmark agentic capabilities in it.

C EXPERIMENTAL COST

Table 6: Financial and time-related costs of running all the tasks once in each environment or domain.

	RDR2	Cities: Skylines	Stardew Valley	Dealer's Life 2	Software Apps	OSWorld	Total
Tasks Num.	14	1	3	1	25	369	-
Input Tokens	600M	150M	60M	25M	45M	-	-
Output Toekns	20M	7.5M	4M	1M	2.5M	-	-
Cost (USD)	$3300	$862.5	$345	$140	$262.5	$500	$5410
Time	240 hrs	60 hrs	30 hrs	20 hrs	50 hrs	240 hrs	640 hrs

Table 6 shows the approximate cost of experiments in Section 4.1 with gpt-4o-2024-05-13. Baselines comparison and ablation studies are not included. Since all the tasks were run 5 times except for OSWorld once, the total cost of getting all the results shown in Section 4.1 is approximately 5400 USD. claude-3-opus-20240229 will roughly use 3X more money and 2X more time compared to gpt-4o-2024-05-13, due to its higher price and longer latency. We also want to note that with the latest model, gpt-4o-2024-08-06, the cost will be halved. We estimate that costs will decrease by one or two orders of magnitude in the coming few years. Then the cost will be affordable to every researcher and developer.

D GENERAL IMPLEMENTATION

Here we introduce the general implementation details of **CRADLE**. For specialized implementations addressing issues unique to their own environment, please refer to the corresponding section.

Hardware. All software and games can be run on regular Windows 10 machines, except for RDR2, which is tested on two machines with an NVIDIA RTX-3060 GPU and RTX-4090 GPU separately. We observe a slight performance gain due to the stability of RTX-4090 GPU during the gameplay.

Backbone Model. We employ GPT-4o (OpenAI, 2024b), currently one of the most capable LMM models, as the framework's backbone model. If not mentioned explicitly, all the experiments are done with *gpt-4o-2024-05-13*. Temperature is set to 0 to lower the variance of the text generation. Same as Voyager (Wang et al., 2024a), we use OpenAI's *text-embedding-ada-002 model* (OpenAI, 2022) to generate embeddings for each skill, stored in the procedural memory and retrieved according to the similarities.

Evaluation Methods. Unlike conventional research benchmarks, which usually provide grounding signals for evaluation, it is difficult to have a unified and general method to determine whether a task is completed automatically in diverse software, especially in video games. Similarly to SIMA (Raad et al., 2024), we apply human evaluation to all tasks across application software and games. Moreover, to provide more quantitative results and a comparison baseline, we provide results for the

OSWorld (Xie et al., 2024) benchmark, a contemporaneous benchmark that provides evaluation scripts for at least one solution per task.

Observation Space. **CRADLE** only takes a video clip, which records the progress of execution of the last action, as input. To lower the frequency of interaction with backbone models and reduce the strain on the computer, video is recorded at 2 fps (a screenshot every 0.5 seconds), which proves to be sufficient in most cases for information gathering without missing any important information. It is important to note that, due to the dynamism of the RDR2 and Stardew Valley and the LMM inference and communication latency, we must pause those game environments while waiting for backbone model responses. Other environments execute continuously.

Action Space. For the action space, it includes all possible keyboard and mouse operations, including `key_press`, `key_hold`, `key_release`, `mouse_move`, `mouse_click`, `mouse_hold`, `mouse_release`, and `wheel_scroll`, which can be combined in different ways to form combos and shortcuts, use keys in fast sequence, or coordinate timings. We choose to use Python code to simulate these operations and encapsulate them into an `io_env` class. Skill code needs to be generated by the agent in order to utilize such functions and affordances so executed actions take effect. Table 7 illustrates **CRADLE**'s action space.

Table 7: Action space in the **CRADLE** framework, including action attributes. Coordinate system is either *absolute* or *relative*. Actions with durations can be either *synchronous* or *asynchronous*.

Type	Action	Attributes
Keyboard	Key Press	Key name (string), Key press duration (seconds:float)
	Key Hold	Key name (string)
	Key Release	Key name (string)
	Key Combo	Key names (strings), Key combo duration (seconds:float), Wait behaviour (sync/async)
	Hotkey	Key names (strings), Hotkey sequence duration (seconds:float), Wait behaviour (sync/async)
	Text Type	String to type (string), Typing duration (seconds:float)
Mouse	Button Click	Mouse button (left/middle/right), Button click duration (seconds:float)
	Button Hold	Mouse button (left/middle/right)
	Button Release	Mouse button (left/middle/right)
	Move	Mouse position (width:int, height:int), Mouse speed (seconds:float), Coordinate system (relative/absolute), Tween mode (enum) [2]
	Scroll	Orientation (vertical), Distance (pixels:int), Duration (seconds:float)
Wait	Noop	-

It is important to note that, while some works (*e.g.,* AssistantGUI (Gao et al., 2023), OmniACT (Kapoor et al., 2024) and OSWorld (Xie et al., 2024)) use *PyAutoGUI* [3] for keyboard and mouse control, this approach does not work in all applications, particularly in modern video games using DirectX [4]. Moreover, such work chooses to expose a subset of the library functionality in its action space, ignoring dimensions like press duration and movement speed, which are critical in many scenarios (*e.g.,* RDR2, for opening the weapon wheel and changing view).

[3]Python library that provides a cross-platform GUI automation module - https://github.com/asweigart/pyautogui

[4]Microsoft DirectX graphics provides a set of APIs for high-performance multimedia apps - https://learn.microsoft.com/en-us/windows/win32/directx

To ensure wide game and software compatibility and accommodate different operating systems, in our current implementation we use the similar *PyDirectInput* library [5] and *PyAutoGUI* for keyboard control, utilize *AHK* [6] and write our own abstraction (using the *ctypes* library [7]) to send low-level mouse commands to the operating system for mouse control. For increased portability and ease of maintenance, all keyboard and mouse control is encapsulated in a class, called *IO_env*.

Notably, our low-level control wrapper is adapted for both MacOS and Windows systems, making the OS transparent to us. At the software window level, we implemented automatic switching between the target software window and the window running the agent (using Python *ctypes* for Windows and *AppleScript* for MacOS [8]).

Procedure Memory. This memory stores pre-defined basic skills and the generated skills captured from the *Skill Curation*. However, as we continuously obtain new skills during game playing, the number of skills in procedural memory keeps increasing, and it is hard for GPT-4o to precisely select the most suitable skill from the large memory. Thus, similar to Voyager (Wang et al., 2024a), we use OpenAI's *text-embedding-ada-002 model* (OpenAI, 2022) to generate embeddings for each skill and store pre-defined basic skills and any generated skills captured from *Skill Curation*, along with their embeddings in a procedural memory. We retrieve a subset of skills, that are relevant to the given task, and then let GPT-4o select the most suitable one from the subset. In the skill retrieval, we pre-compute the embeddings of the documentations (code, comments and descriptions) of skill functions, which describe the skill functionality, and compute the embedding of the given task. Then we compute the cosine similarities between the skill documentation embeddings and the task embedding. The higher similarity means that the skill's functionality is more relevant to the given task. We select the top K skills with the highest similarities as the subset. Using similarity matching to select a small candidate set simplifies the process of choosing skills.

Episodic Memory. This memory stores all the useful information provided by the environment and LMM, which consists of short-term memory and long-term summary.

The short-term memory stores the screenshots within the recent k interactions in game playing and the corresponding information from other modules, *e.g.,* screenshot descriptions, task guidance, actions, and reasoning. We set k to five, and it can be regarded as the memory length. Information stored over k interactions ago will be forgotten from direct short-term memory. Empirically, we found that recent information is crucial for decision-making, while a too-long memory length would cause hallucinations. In addition, other modules continuously retrieve recent information from short-term memory and update the short-term memory by storing the newest information.

For some long-horizon tasks, short-term memory is not enough. This is because the completion of a long-horizon task might require historical information from a long steps ago. For example, the agent might do a series of short-horizon tasks during a long-horizon task, which makes the original long-horizon task forgotten in short-term memory. To maintain the long-term valuable information while avoiding the long-token burden of GPT-4o, we propose a recurrent information summary as long-term memory, which is the text summarization of experiences in game playing, including the ongoing task, the past entities that the player met, and the past behaviors of the player and NPCs.

In more detail, we provide GPT-4o with the summarization before the current screenshot and the recent screenshots with corresponding descriptions, and GPT-4o will make a new summarization by organizing the tasks, entities, and behaviors in the time order with sentence number restriction. Then we update the summarization to be the newly generated one, which includes the information in the current screenshot. The recurrent summarization update, inspired by RNN, achieves linear-time inference by preserving a hidden state that encapsulates historical input. This method ensures

[5] Python library encapsulating Microsoft's *DirectInput* calls for convenience manipulating keyboard keys - https://github.com/learncodebygaming/pydirectinput

[6] A fully typed Python wrapper around AutoHotkey to keyboard and mouse control - https://github.com/spyoungtech/ahk

[7] Python library that provides C compatible data types, and allows calling functions in DLL/.so binaries - https://docs.python.org/3/library/ctypes.html

[8] AppleScript is a scripting language created by Apple, which allows users to directly control scriptable applications, as well as parts of MacOS - https://developer.apple.com/library/archive/documentation/AppleScript/Conceptual/AppleScriptLangGuide/introduction/ASLR_intro.html

the compactness of summarization token lengths and recent input data. Furthermore, the incorporation of long-term memory enables the agent to effectively retain crucial information over extended periods, thereby enhancing decision-making capabilities.

Information Gathering. Given the video clip as input, we mainly depend on GPT-4o's OCR capabilities to extract textual information in the keyframes, which usually contain critical guidance and notifications for the current situation. We also rely on GPT-4o's visual understanding to analyze the visual information in the frames. Besides, we augment LMMs' visual understanding via some tools, like template matching (Brunelli, 2009), Grounding DINO (Liu et al., 2023), and SAM (Kirillov et al., 2023), to provide additional grounding for object detection and segmentation. Some visual prompting tricks, like drawing axes and colorful directional bands, are also applied to enhance the GPT-4o's visual ability.

Task Inference. After reflecting on the outcome of the last executed action, We let GPT-4o analyze the current situation to infer the most suitable task for the current moment and estimate the highest priority task to perform and when to stop an ongoing task and start a new one.

Skill Curation. GPT-4o is required to strictly follow the provided interfaces and examples to generate the corresponding code for new skills. Moreover, GPT-4o is required to include documentation/comments within the generated code, delineating the functionality of each skill. *Procedural Memory* where skills are stored will then check whether the code is valid, whether the format of documentation is right, and whether any skill with the same name already exists. If all conditions are passed, the newly generated skill is persisted for future utilization.

Action Planning. GPT-4o needs to select the appropriate skills from the curated skill set and instantiate these skills into a sequence of executable actions by specifying any necessary parametric aspects (*e.g.,* duration, position, and target) according to the current task and history information. The generated action is then fed to the ***Executor*** for interaction with the environment.

E Red Dead Redemption II

E.1 Introduction to RDR2

Red Dead Redemption II (RDR2) is an epic AAA Western-themed action-adventure game by Rockstar Games. As one of the most famous and highest-selling games in the world, it is widely acknowledged for its movie-like realistic scenes, rich storylines, and immersive open-ended world. The game applies a typical role-playing game (RPG) control system, played from a first- or third-person perspective, which uses WASD for movement, mouse control for view changing, first- or third-person shooting for combat, and inventory and manipulation.

For most of the game, players need to control the main character, Arthur Morgan, upon choosing to complete mission scenarios following the main storyline. Otherwise, they can freely explore the interactive world, such as going hunting, fishing, chatting with non-player characters (NPCs), training horses, witnessing or partaking in random events, and participating in side quests. As the main storyline progresses, different skills are gradually unlocked. As a close-source commercial game, no APIs are available for obtaining additional game-internal information nor pre-defined automation actions. Following its characteristics, this game serves as a fitting and challenging environment for the GCC setting and a comprehensive benchmark for embodiment.

E.2 Objectives

In Chapter 1 of RDR2, the first two missions of the main storyline are *Outlaws from the West* and *Enter, Pursued by a Memory*. These missions serve as the tutorial content for RDR2, guiding players step-by-step into the role of Arthur. They immerse the player in the story's development while teaching the game's controls and mechanics.

We divided Mission 1 and Mission 2 into 8 and 5 tasks respectively based on the checkpoints within each mission. Each checkpoint may present failure scenarios. For example, in Mission 1, there are six failure scenarios: i) Assaults, kills, or abandons Dutch or Micah; ii) Allows Dutch or Micah to be killed; iii) Abandons the homestead; iv) Assaults, kills, or abandons their horse; v) Assaults, kills,

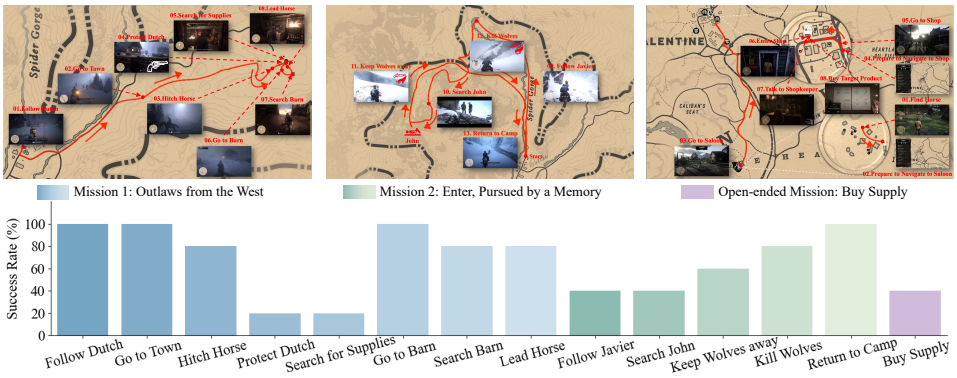


Figure 10: Trajectory and success rates of 13 main storyline tasks and 1 open-world task in RDR2. Each task is run 5 times and each trial is run for at most 500 steps. Long horizontal and challenging tasks like *Protect Dutch* and *Search for Supplies* usually need several times of retry to complete, resulting in the demand for more steps. It explains the low success rate of these tasks within 500 steps.

or abandons the horse in the barn; vi) Dies. We categorized each sub-task as either "Easy" or "Hard" based on the likelihood of failure at each checkpoint and the need to retry the checkpoint.

To evaluate **CRADLE**'s capabilities in an open-world environment, Mission 3 is designed as a hard open-ended task. Unlike the first two tutorial missions, it does not include any checkpoints. Consequently, the entire Mission 3 is treated as a single, comprehensive task. Although we do not subdivide Mission 3 into finer tasks, we aim to identify key points to facilitate a clearer understanding of Mission 3 for the reader.

Tables 8 and 9 provide a brief introduction of each task in the first two missions of the main storyline and an open-ended mission, along with approximate estimates of their difficulty. Due to GPT-4o's poor performance in spatial understanding and fine-manipulation skills, it can be challenging for our agent to perform certain actions, like entering or leaving a building, or going to precise indoor locations to retrieve specific items. Additionally, the high latency of GPT-4o's responses also makes it harder for an agent to deal with time-sensitive events, *e.g.,* during combat.

E.3 Implementation Details

Our experiments are based on the latest version of RDR2, 'Build 1491.50'. As shown in Figure 14, strictly following the GCC setting, our agent takes the video of the screen as input and outputs keyboard and mouse operations to interact with the computer and the game. An observation thread is responsible for the collection of video frames from the screen and each video clip records the whole in-game process since executing the last action.

Information Gathering. To extract keyframes from the video observation, we utilize the VideoSubFinder tool [9], a professional subtitle discovery and extraction tool. These keyframes usually contain rich meaningful textual information in the game, which are highly relevant to the completion of tasks and missions (such as character status, location, dialogues, in-game prompts and tips, etc.) We use GPT-4o to extract and categorize all the meaningful contexts in these keyframes and perform OCR, and call this processing "gathering text information". Then, to save interactions with GPT-4o, we only let GPT-4o provide a detailed description of the last frame of the video.

While GPT-4o exhibits impressive visual understanding abilities across various CV tasks, we find that it struggles with spatial reasoning and recognizing some game-specific icons. To address these limitations, we add a visual augmentation sub-module within our *Information Gathering* module. This augmentation step serves two main purposes: i) utilize Grounding DINO (Liu et al., 2023), an open-set object detector, to output precise bounding boxes of possible targets in an image and serve as spatial clues for GPT-4o; and ii) perform template matching (Brunelli, 2009) to provide icon recognition grounding truth for GPT-4o when interpreting instructions or menus shown on screen. As LMM capabilities mature, it should be possible to disable such augmentation.

[9] VideoSubFinder standalone tool - https://sourceforge.net/projects/videosubfinder/

Table 8: Tasks in the first two missions of RDR2. In the tutorial guide, the prompt text *Start Dialogue* signifies the end of the previous checkpoint and the beginning of the current checkpoint. *Difficulty* refers to how hard to accomplish the corresponding tasks. Figures 11 and 12 showcase snapshots of each task (specific sub-figures marked in parenthesis in the table). The maximal number of steps (agent takes one action) for each task is 500.

Mission 1: Outlaws from the West	Description	Start Dialogue	Difficulty
Follow Dutch (Fig. 11a)	Arthur follows Dutch on horseback into the snow to find their scouting gang members.	Use [W] to Follow Dutch	Easy
Go to Town (Fig. 11b)	Arthur rides his horse, following Micah to the vicinity of a little homestead Micah discovered.	Hold [W] to match speed with Dutch and Micah	Easy
Hitch Horse (Fig. 11c)	Arthur hitches the horse to the hitching post, then goes to the old shed and takes cover.	Hold [E] to hitch your horse	Easy
Protect Dutch (Fig. 11d)	Arthur uses his gun to shoot all of the O'Driscolls inhabiting the house and protect Dutch.	Use [W] to peak out of cover	Hard
Search for Supplies (Fig. 11e)	Arthur follows Dutch to the house to search for supplies.	Hold [R] near items to pick the up while searching house.	Hard
Go to Barn (Fig. 11f)	Arthur follows Dutch's directions and goes to the barn to see if there's anything inside.	Dutch: Micah, Arthur, keep looking for stuff	Easy
Search Barn (Fig. 11g)	Arthur searches the barn and defeats the O'Driscoll hiding inside.	[F] Attack the O'Driscoll	Hard
Lead Horse (Fig. 11h)	Arthur calms the horse and takes it out of the barn.	Hold [Right Mouse Button] to focus on the horse	Easy
Mission 2: Enter, Pursued by a Memory	**Description**	**Start Dialogue**	**Difficulty**
Follow Javier (Fig. 12a)	Arthur rides his horse following Javier up the mountain through the blizzard searching for John's trail.	Follow Javier	Hard
Search John (Fig. 12b)	After dismounting, Arthur followed Javier over slopes and ledges to find John and carry him away.	Javier: Down this way	Hard
Keep Wolves away (Fig. 12c)	Arthur manages to shoot all of the wolves before they can attack Javier and John.	Keep the wolves away from Javier and John	Hard
Kill Wolves (Fig. 12d)	Three people ride horses down the mountain. Arthur eliminate the wolves, protecting Javier and John ahead.	Javier: Come on, let's get back to the others	Hard
Return to Camp (Fig. 12e)	Arthur followed Javier on horseback back to camp.	Yea...c'mon. Let's push hard and get back	Easy

Table 9: Key points in the open-ended mission, *Buy Supply* in RDR2. Figure 13 showcases snapshots of key points (specific sub-figures marked in parenthesis in the table).

Mission 3: Buy Supply	Description
Find Horse (Fig. 13a)	Find and mount the horse in the camp.
Prepare to Navigate to Saloon (Fig. 13b)	Open map, find the saloon and create waypoint.
Go to Saloon (Fig. 13c)	Ride horse to the saloon.
Prepare to Navigate to Shop (Fig. 13d)	Open map, find the general store and create waypoint.
Go to Shop (Fig. 13e)	Ride horse to the shop.
Enter Shop (Fig. 13f)	Dismount the horse and enter the shop.
Talk to Shopkeeper(Fig. 13g)	Approach the shopkeeper and talk.
Buy Target Product (Fig. 13h)	Open the menu, find and buy the target product.

Self-Reflection. The reflection module mainly serves to evaluate whether the previously executed action was successfully carried out and whether the current executing task is finished. To achieve this, we uniformly sample at most 8 sequential frames from the video observation since the execution of the last action and use GPT-4o to estimate the success of its execution. Additionally, we expect GPT-4o can also provide analysis for any failure of the last action (*e.g.,* the move-forward action failed and the cause could be the agent was blocked by an obstacle). With such valuable information as input for *Action Planning*, including the failure/success of the last action and the corresponding analysis, the agent is capable of attempting to remedy an inappropriate decision or action execution.

Moreover, some actions require prolonged durations, such as holding down specific keys, which can coexist or interfere with other actions decided by subsequent decisions. Consequently, the reflection module must also decide whether an ongoing action should continue to be executed. Furthermore, self-reflection can be leveraged to dissect why the last action failed to bring the agent close to the target task completion, better understand the factors that led to the successful completion of the preceding task, and so on.

(a) Follow Dutch (b) Go to Town (c) Hitch Horse

(d) Protect Dutch (e) Search for Supplies (f) Go to Barn

(g) Search Barn (h) Lead Horse

Figure 11: Image examples of tasks in the first mission of *Outlaws from the West*. (The picture has been brightened for easier reading.)

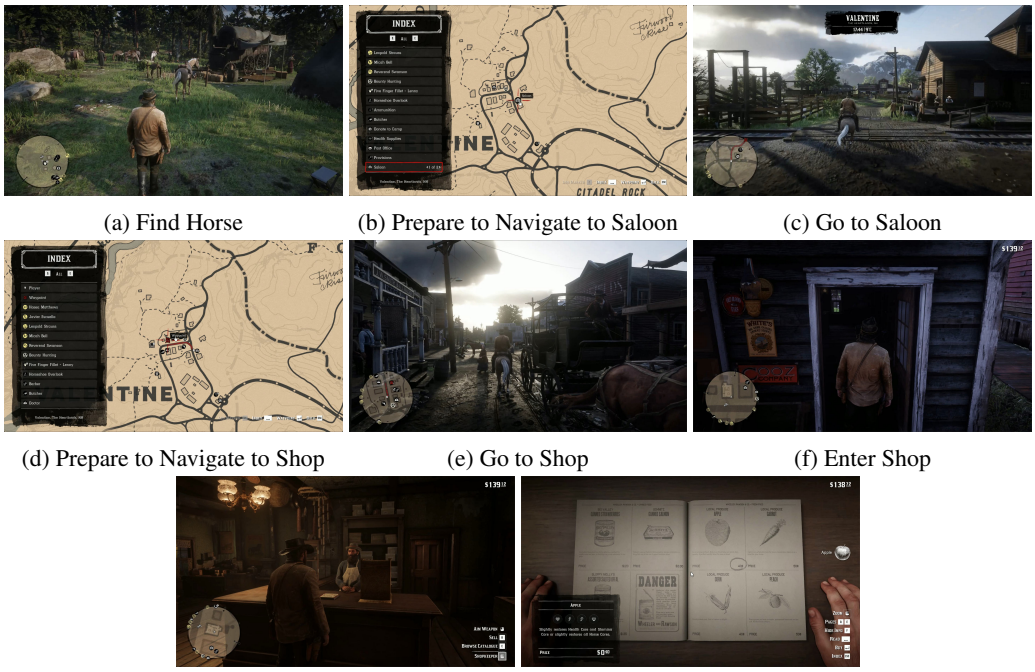
(a) Follow Javier (b) Search John (c) Keep Wolves Away

(d) Kill Wolves (e) Return to Camp

Figure 12: Image examples of tasks in the second mission of *Enter, Pursued by a Memory*.

Besides, we observe that instead of providing GPT-4o with sequential high-resolution images for self-reflection, low-resolution images make it easier for GPT-4o to understand the relation among the sequential screenshots and capture dynamic changes, resulting in a significantly higher success rate of detecting whether the action is executed successfully and take any effect. We hypothesize that since a high-resolution image can cost as many as 2000 tokens, too many high-resolution images make GPT-4o fail to capture the overall changes across screenshots and be caught up in the local details.

Task Inference. During gameplay, we let GPT-4o propose the current task to perform whenever it believes it is time to start a new task. GPT-4o also outputs whether the task is a long- or short-horizon task when proposing a new task. Long-horizon tasks, such as traveling to a location, typically require multiple iterations, whereas short-horizon tasks, like picking up an item or conversing with someone,



(a) Find Horse (b) Prepare to Navigate to Saloon (c) Go to Saloon

(d) Prepare to Navigate to Shop (e) Go to Shop (f) Enter Shop

(g) Talk to Shopkeeper (h) Buy Target Product

Figure 13: Image examples of key points in the open-ended task of *Buy Supply*.

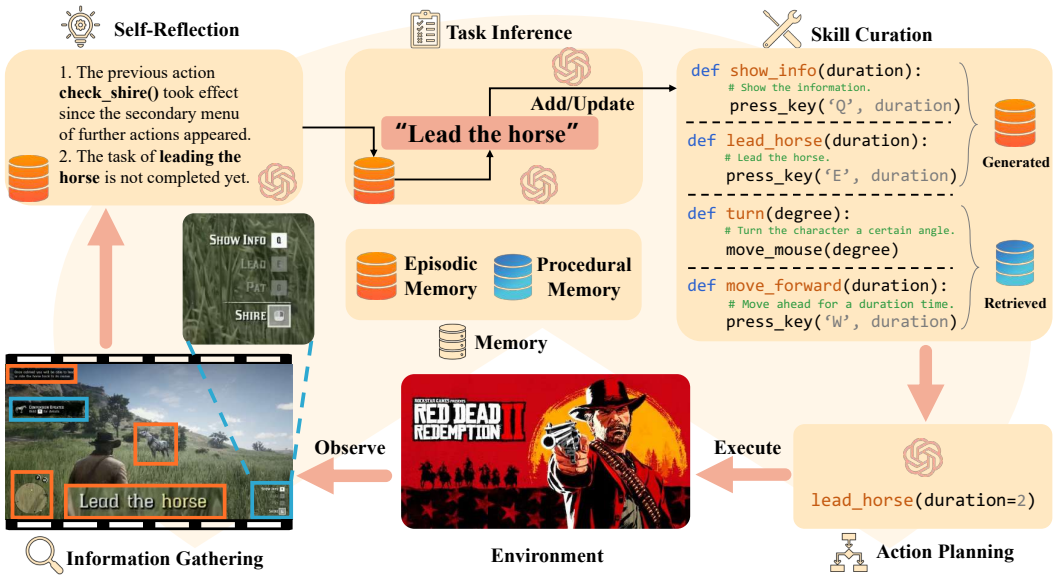


Figure 14: The detailed illustration of how **CRADLE** is instantiated as a game agent to play RDR2.

involve fewer iterations. The agent will follow the newly generated task for the next 3 interactions. After 3 interactions, the agent returns to the last long-horizon task in the stack. Deciding on a binary task horizon is much easier and more robust for GPT-4o, than re-planning at every iteration. Since a long-horizon task frequently includes multiple short-horizon sub-tasks, this implementation also helps avoid forgetting the long-horizon tasks under execution.

Skill Curation. As shown in Figure 16, during gameplay, instructions often appear on the screen, such as "press [Q] to take over" and "hold [TAB] to view your stored weapons", which serve as essential directives for completing current and future tasks proficiently. To save interactions with

GPT-4o, we implement a simple version of this module inside *Information Gathering* to reduce interactions with GPT-4o. When GPT-4o detects and classifies some instructional text in the recent observation, which usually contains key and button hints, it will directly generate the corresponding code and description.

Action Planning. Upon execution of this module, we first retrieve the top k relevant skills for the task from procedural memory, alongside the newly generated skills. We then provide GPT-4o with the current task, the set of retrieved skills, and other information collected in *Information Gathering* that may be helpful for decision-making (*e.g.*, recent screenshots with corresponding descriptions, previous decisions, and examples) and let it suggest which skills should be executed. We also request that GPT-4o provide the reasons for choosing these skills, which increases the accuracy, stability, and explainability of skill selection and thus greatly improves framework performance. While GPT-4o sometimes may generate a sequence of actions, we currently only execute the first one, and perform *Self-Reflection*, since we observe a tendency for the second action to usually suffer from severe hallucinations.

Action Execution. Unlike the conventional mouse operation in standard software, where the cursor is restricted to a 2D grid and remains visible on the screen to navigate and interact with elements, the utilization of the mouse in 3D games like RDR2 introduces a varied control scheme. In menu screens, the mouse behaves traditionally, offering familiar point-and-click functionality. However, during gameplay, the mouse cursor disappears, requiring players to move the mouse according to specific action semantics. For example, to alter the character's viewpoint, the player needs to map the actual mouse movement to in-game direction angle changes, which differ in magnitude in the X and Y axes. Another special transition applies to shooting mode, where the front sight is fixed at the center of the screen, and players must maneuver the mouse to align the sight with target enemies. This nuanced approach to mouse control in different contexts adds an extra layer of challenge to general computer handling, showcasing the adaptability required in game environments, compared to regular software applications.

Procedural Memory. In our target setting, We intend to let the agent learn all skills from scratch, to the extent possible for the main storyline missions. The procedural memory is initialized with only preliminary skills for basic movement, which are not clearly provided by the in-game tutorial and guidance.

- *turn(degree)*, *move_forward(duration)*: Since the game does not precisely introduce how to move in the world through in-game instructions, we provide these two basic actions in advance, so GPT-4o can perform basic mobility, while greatly reducing the number of calls to the model.
- *shoot(x, y)*: RDR2 also does not provide detailed instructions on how to aim and shoot. Moreover, due to limitations with GPT-4o spatial reasoning and the need to sometimes augment images with object bounding boxes, we provide such basic skill for the agent to complete relevant tasks.
- *select_item_at(x, y)*: Similarly to *shoot()*, due to the lack of instructions, we provide such skill for the agent to move the mouse to a certain place to select a given item.

Beyond these basic atomic low-level actions, we introduce a few composite skills to facilitate the game playing progress. The agent should be able to complete tasks using only the basic skills above and the skills it learns, but these composite skills streamline the process by greatly reducing calls to the backend model.

- *turn_and_move_forward(degree, duration)*: This skill is just a simple composition of *turn()* and *move_forward()* to save frequent calls to GPT-4o in a common sequence.
- *follow(duration)* and *navigate_path(duration)*: In RDR2, tasks often guide players to follow NPCs or generated paths (red lines) in the minimap to certain locations. This can be reliably accomplished via the basic movement skills, but requires numerous interactions with GPT-4o. To control both cost and time budgets involving GPT-4o's responses, we leverage the information shown in the minimap to implement a composite skill to follow target NPCs or red lines for a short set of game iterations. The default duration is 20 iterations. Increasing the duration can dramatically improve the performance in task *Follow Dutch*, *Follow Javier* and *Killing Wolves* but significantly decrease the success rate of

Search John since this task requires frequent exchange of the skills between climbing and following.

- *fight()*: As output of an interaction with GPT-4o, the agent will only take one action per step. However, though the action is generated correctly, specifically in fight scenarios, the action frequency may not be high enough to defeat an opponent. In order to allow sub-second punches, we provide a pre-defined action that wraps this multi-action punching, which can be selected by GPT-4o to effectively win fights.

For the open-ended mission, since the agent skips all the tutorials in Chapter I, we provide all the necessary skills in the procedural memory at the beginning of the mission.

Episodic Memory. This module stores all the useful information, *e.g.,* input and output of GPT-4o. In each iteration, after the self-reflection, we will request GPT-4o to summary the event that happened in the last action and the past experiences.

Game Pause. To prevent in-game time from passing in real-time games like RDR2, we have to pause the game while waiting for LMMs' response. The time interval between two consecutive actions can be as long as one minute. In RDR2, after the agent finishes executing outputted actions, *esc* will be automatically pressed to pause the game and when the agent determines the next action, *esc* will be automatically pressed again to unpause the game. Note that there will be an animation lasting up to 0.5 seconds for both pausing and unpausing. During this animation, we can not control the character, but the dynamics of the game world keep changing, *e.g.,* the wolves are still moving. It introduces additional challenges for the tasks that require precise timing, like combat.

E.4 Case Studies

Here we present a few game-specific case studies for more in-depth discussion of the framework capabilities and the challenges of the GCC setting.

E.4.1 Self-Reflection

Self-reflection is an essential component in **CRADLE** as it allows our framework reasoning to correct previous mistakes or address ineffective actions taken in-game. Figure 15 provides an example of the self-reflection module. The task requires the agent to select a weapon to equip, in the context of the "Protect Dutch" task. Initially, the agent selects a knife as its weapon by chance, but since the game requires a gun to be chosen, this is incorrect and the game still prompts the player to re-open the weapon wheel. The self-reflection module is able to determine that the previous action was incorrect and on a subsequent iteration the agent successfully opts for the gun, correctly fulfilling the task requirement and advancing to the next stage in the story.

E.4.2 Skill Curation

For skill curation, we first provide GPT-4o with examples of general mouse and keyboard control APIs, *e.g.*, io_env.key_press and io_env.mouse_click. Figure 16 shows that GPT-4o can capture and understand the prompts appearing on screenshots, *i.e.,* icons and text, and strictly follow the provided skill examples using our IO interface to generate correct skill code. Moreover, GPT-4o also generates comments in the code to demonstrate the functionality of this skill, which are essential for computing similarity and relevance with a given task during skill retrieval. The quality of the generated comment directly determines the results of skill retrieval, and further impacts reasoning to action planning. Curation can also re-generate code for a given skill, which is useful if GPT-4o wrongly recognized a key or mouse button in a previous iteration.

E.4.3 Action Execution and Feedback

Proper reasoning about environment feedback is critical due to the generality of the GCC setting and the level of abstraction to interact with the complex game world. The semantic gaps between the execution of an action, its effects in the game world, and observing the relevant outcomes for further reasoning lead to several potential issues that **CRADLE** needs to deal with. Such issues can be categorized into four major cases:

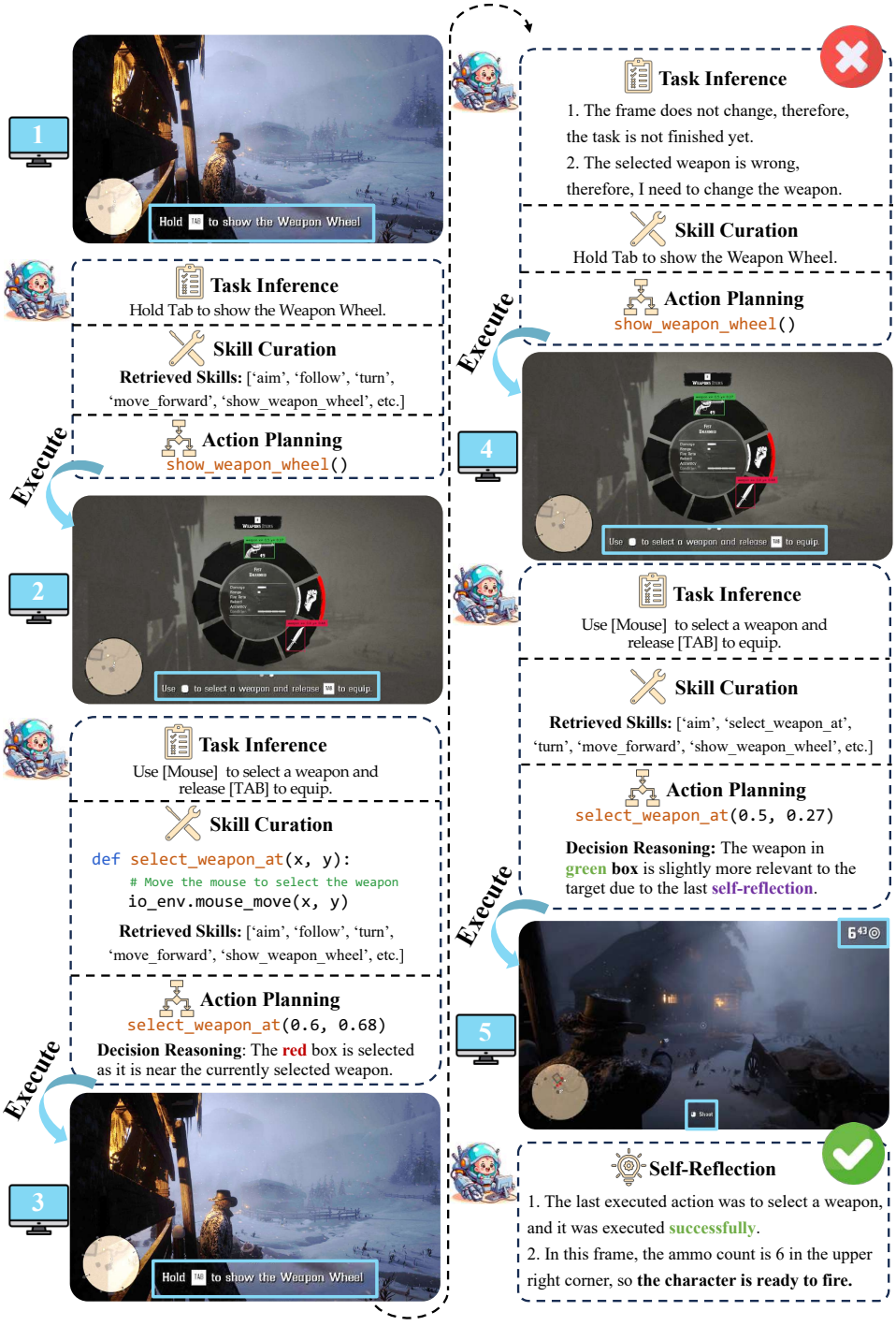


Figure 15: Case study of self-reflection on re-trying a failed task. Task instruction and context require the agent to equip the gun. A wrong weapon (knife) is first selected, but the agent equips the gun after self-reflection. Only relevant modules are shown for better readability, though all modules (Figure 3) are executed per iteration.


```
def take_cover(duration = 2):
    """
    press "Q" to take cover
    """
    io_env.key_press('q', duration)
```

```
def focus_on_horse():
    """
    hold "right mouse button" to focus on horse
    """
    io_env.mouse_hold('right button')
```

```
def view_stored_weapons():
    """
    press "tab" to view your stored weapons
    """
    io_env.key_hold('tab')
```

Figure 16: Skill code generation based on in-game instructions. As the storyline progresses, the game will continually provide prompts on how to use a new skill via keystrokes or utilizing the mouse.

Lack of grounding feedback. In many situations, due to the lack of precise information from the environment, it can be difficult for the system to deduce the applicability or outcome of a given action. For example, when picking an item from the floor, the action may fail due to the distance to the object not yet being close enough. Or, if within pick up range, the chosen action may not exactly apply due to other factors (*e.g.,* character's package is full).

Even if the right action is selected and executed successfully, the agent still needs to figure out its results from the partial visual observation of the game world. If the agent needs to pick or manipulate an object that is occluded from view, the action may execute correctly, but no outcome can be seen.

A representative example in RDR2 happens when the agent tries to pick up its gun from the floor after a fight. Getting to the right distance, without completely occluding the object, can lead to multiple re-trials. Figure 17a showcases a situation where, though the character is already standing near the gun (as seen in the minimap), it's still not possible to pick it up.

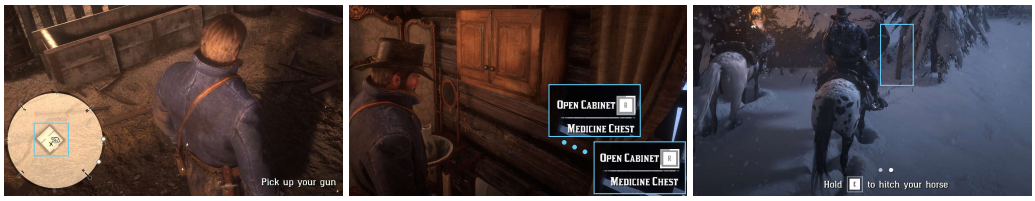
Previous efforts (Wang et al., 2023b; 2024a) that utilize in-game state APIs unreasonably bypass such issues by leveraging internal structured information from the game and the full semantics of responses (data) or failures (error messages).

Imprecise timing in IO-level calls. This issue is caused by the ambiguity in the game instructions or differences in specific in-game action behaviors, where even the execution of a correct action may fail due to minor timing mismatches. For example, when executing an action like 'open cabinet', which requires pressing the [R] key on the keyboard, if the press is too fast, no effect happens in the game world. However, as there is no visual change in the game nor other forms of feedback, it can be difficult for GPT-4o to figure out if an inappropriate action was chosen at this game state or if the minor timing factor was the problem. Pressing the key for longer triggers an animation around the button (only if the helper menu is on screen), but this is easily missed and any key release before the circle completes also results in no effect. Figure 17b illustrates the situation.

The same problem also manifests in other situations in the game, where pressing the same key for longer triggers a completely different action (*e.g.,* lightly pressing the [Left Alt] key vs. holding it for longer).

Change in the semantics of key and button. A somewhat similar situation occurs when the same keyboard key or mouse button gets attributed different semantics in different situations (or even in a multi-step action). GPT-4o may decide to execute a given skill, but the original semantics no longer hold. The lack of in-game effect parallels the previous situations. Worse yet, an undesired effect will confuse the system regarding the correct action being selected or not.

For example, when approaching a farm in the beginning of the game, the agent needs to hitch the horse to a pole to continue. The operation to perform the action consists of pressing the [E] key near a hitching post (as shown in Figure 17c). However, the same [E] key press is the only constituting step in other actions with different semantics, like *dismount the horse* or *open the door*. Wrongly triggering a horse dismount at the situation shown in the figure can lead to undesired side effects, *i.e.,* it may mislead the system about the actual effects of the action or affect the planning of which next actions to perform.



(a) 'Pick gun' unavailable (b) 'Open cabinet' press timing (c) 'Hitch horse' re-use of [E] key

Figure 17: Examples of action execution uncertainty. Lack of environmental feedback to actions and semantic gaps between action intent and game command can lead to challenging situations for agent reasoning.

Interference issues. Lastly, completion of some actions requires the correct execution of multiple steps sequentially, which could be interrupted in many ways not related to the agent's own actions. Without the use of APIs that expose internal states or other forms of feedback, it is much harder for the agent to decide when to repeat sub-actions or try different strategies. For example, if the agents gets shot and loses aim while in combat, or an unrelated in-game animation is triggered mid-action, canceling it.

Since there is no direct environment feedback, the agent needs to carefully analyze the situation and try to infer if any action step needs re-execution.

E.5 Limitations of GPT-4o and GPT-4V

Deploying **Cradle** in a complex game like RDR2 requires the backbone LMM model to handle multimodal input, which revealed several limitations of both GPT-4V and GPT-4o, necessitating external tools to enhance overall framework performance. Initial tests and exploration were performed using GPT-4V, as GPT-4o was not yet available. These tests highlighted significant weaknesses in spatial perception, icon understanding, history processing, and world understanding. Upon the release of GPT-4o, further testing demonstrated some notable improvements in spatial perception. However, enhancements in other areas remained marginal, while some regressions were also observed, all indicating the need for additional tools to aid decision-making.

Spatial Perception. As shown in Figure 18a and 19a, GPT-4V's spatial-visual recognition capability is insufficient for precise fine-grained control, particularly in detecting whether the character is being or going to be blocked and in estimating the accurate relative positions of target objects. In contrast, GPT-4o exhibits a significant enhancement in spatial perception, capable of recognizing obstacles ahead and estimating the approximate relative positions between objects. However, both models require supplementary information, such as bounding boxes of potential target objects, to make fine-grained decisions. These led to the need to augment certain images to provide auxiliary visual clues for decision-making, *i.e.,* bounding boxes of possible target objects.

Icon Understanding. Both GPT-4o and GPT-4V struggle with domain-specific concepts, such as unique icons within the game, which may represent specific targets or refer to certain mouse and key actions. As shown in Figure 18b and 19b, GPT-4V and GPT-4o fail to recognize the left shift, right mouse button, and space icons. Attempts to incorporate few-shot learning to improve image understanding cannot be generalized. Therefore, we match prepared pattern templates, *e.g.,* icon images, against each screenshot to continuously detect and highlight any appearing icons.

Figure 18c and Figure 19c also demonstrate that although GPT-4o performs better than GPT-4V in understanding the mini-map, it still fails to consistently interpret this crucial information regarding the position and direction of the character. This failure in localization leads the agent to sometimes get lost in the town and miss the task target. While the aforementioned issues can be slightly alleviated by providing additional few-shot examples, a significant improvement is only achieved by cropping the image and providing GPT-4o with the exact region containing the icon to be recognized. This dependency on precise input makes the issue challenging and unreliable for decision-making. Although the above issues can be slightly alleviated by providing additional few-shot examples, it can only have an obvious effect if we crop the image and provide the GPT-4o with the region exactly containing the icon to be recognized, which makes the issue intractable.

ChatGPT

There are **no immediate obstacles** directly in front of the character in the image. The character has a **clear path ahead** on a muddy street in what appears to be a Western-style town setting.

ChatGPT

The shopkeeper in the image is on the **right side**, behind the counter.

(a) GPT-4V fails to recognize obstacles in the environment and the position of the shopkeeper.

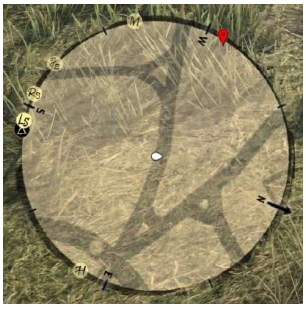
ChatGPT

Based on the provided game screenshot, I've identified the following control prompt:
- "**Hold L** to ride faster"
This control suggests that holding a certain key (which seems to be an **upward arrow key**, often associated with the **'W' key** for forward movement in many games) will make the character ride faster.

ChatGPT

From the provided image screenshot from the game, I can identify the following keyboard and mouse control prompts:
1. "**Toggle View**" - The key for this action is "**V**".
2. "**Zoom**" - The key for this action is "**O**".
3. "**Flip**" - The key for this action is "**L**".
4. "**Back**" - The key for this action is "**ESC**".

(b) GPT-4V struggles to recognize the icons for keys on keyboard and mouse buttons.



ChatGPT

The central white arrow is facing towards the **left**.

ChatGPT

The central white arrow with the white arrowhead is facing towards the **left**.

(c) GPT-4V cannot understand the correct direction of arrow points, *i.e.,* character, towards in the mini-map.

Figure 18: Example situations of GPT-4V's limitations in understanding visual information from the game.

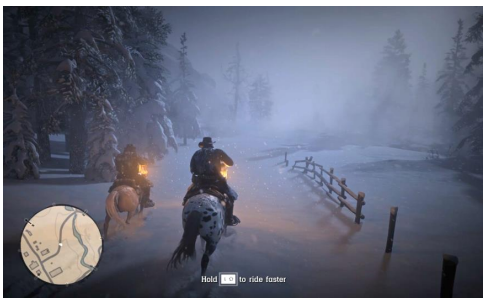
ChatGPT

There is **an obstacle** in front of the character. It appears to be a small wooden railing or barrier along the edge of the platform. The character would need to navigate around it or find a way over it to proceed forward.

ChatGPT

The shopkeeper in the image is on the **left** side

(a) GPT-4o can recognize obstacles in the environment and the position of the shopkeeper.



ChatGPT

Based on the provided image, the control prompt shown is:

- "Hold **L** to ride faster'.

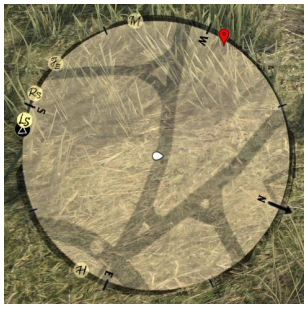
The '**L**' refers to the left analog stick on a **controller**, indicating that the player should hold the left analog stick in a forward position to increase the speed of their character's movement, typically while riding a horse.

ChatGPT

From the provided image screenshot from the game, I can identify the following keyboard and mouse control prompts:

1. Toggle View: **V**
2. Zoom: **Mouse Scroll Wheel**
3. Flip: **R**
4. Back: **Esc**
5. Photograph: (No specific key assigned, just a label)

(b) GPT-4o struggles to recognize the icons for keys on keyboard and mouse buttons.



ChatGPT

The central white arrow in the mini-map is facing to the **right**.

ChatGPT

The central white arrow on the mini-map is facing **down**.

(c) GPT-4o occasionally accurately determines the direction of arrow points, *i.e.,* character, towards in the mini-map.

Figure 19: Example situations of GPT-4o's limitations in understanding visual information from the game.

History Processing. Moreover, both GPT-4o and GPT-4V can easily get distracted by irrelevant information in longer contexts, resulting in hallucinations. For example, when action planning utilizes too many historical screenshots, they may confuse past and present frames. Additionally, performance fluctuates and both model versions frequently generate output not adhering to the rules in the provided prompts. To mitigate the issue of hallucinations, we more strictly control input information by further summarizing long-term memory.

World Understanding. Lastly, the absence of an RDR2 world model limits GPT-4V and GPT-4o's understanding of the consequences of its actions in the game. This often results in inappropriate action selection, such as overestimating the necessary adjustments for aligning targets or misjudging the duration required for certain actions. To alleviate this problem, we introduced extra prompt rules regarding action parameters and more flexibility into the self-reflection module.

F Stardew Valley

F.1 Introduction to Stardew Valley

Stardew Valley is an open-ended country-life RPG game developed by ConcernedApe, which has a 98% positive rating on Steam and is rated as Overwhelmingly Positive. Players take on the role of a character disillusioned with city life who inherits a dilapidated farm from their late grandfather. Initially, the farmland is overrun with boulders, trees, stumps, and weeds, which players must clear to make way for crops, buildings, and placeable items. The main goal is to restore and expand the farm through activities such as planting crops, raising animals, mining, fishing, and crafting. Additionally, players can interact with NPCs in town, forming relationships that can lead to marriage and children. Players complete quests for money or to restore the town's Community Center by completing "bundles," which reward items like seeds and tools and unlock new areas and game mechanics. All activities are balanced against the character's health, energy, and the game's clock. Food provides buffs, health, and energy. The game features a simplified calendar with four 28-day months representing each season, affecting crop growth and activities. Compared to RDR2, this game is more lightweight and easy to control. This game features a wealth of production and social activities, presenting a comprehensive test of an agent's abilities, which is an ideal platform to observe and evaluate agents' comprehensive behaviors and abilities, like in the Generative Agents (Park et al., 2023). We use the latest version (1.6.8) of the game to conduct all the experiments.

F.2 Objectives

We find that GPT-4o surprisingly struggles with accurately recognizing and locating objects near the player in this 2D game. This leads to difficulties for the agent to interact with objects or people, as it requires the player to stand precisely in front of them in the grid (*e.g.,* when entering doors, using a pickaxe to break stones). Even some basic tasks are already challenging enough for current agents in this game. Therefore, as shown in Figure 20, we evaluate three essential tasks in the early stages of the game:

- **Farm Clearup.** Clear the obstacles on the farm, such as weeds, stones, and trees, as much as possible to prepare for farming. This task requires agents to move precisely to be in front of the obstacles, identify the type of obstacles correctly and select corresponding tools to deal with them.
- **Cultivation.** Use the hoe to till the soil, use a parsnip seed packet on the tilled soil to sow a crop, water the crop every day and harvest at least one parsnip. This task requires long-horizontal memory and reasoning.
- **Shopping.** Go to the general store in the town, which is on the other map, to buy more seeds and return home. This task is used to evaluate agents' long-distance navigation ability.

For each task, the maximal steps is 100.

F.3 Implementation Details

Visual Prompting. As a cartoon-style pixel game, the game screen of Stardew is quite different from the real world. Although GPT-4o can observe coarse-grained information from screenshots,

(a) Before *Farm Clear-up* (b) After *Farm Clear-up*

(c) *Cultivation* (d) *Shopping*

Figure 20: Three tasks in Stardew Valley.

more fine-grained information is required to complete tasks. Therefore, as shown in Figure 21, we divide each screenshot into 3×5 grids and require GPT-4o to describe the screenshot in a grid-by-grid format. We empirically find that it can result in a more precise and accurate description. And GPT-4o can also make better control based on the grids. In addition, we also augment the image with two blue and yellow bands on the left and right sides, respectfully, with the prompt, "The blue band represents the left side and the yellow band represents the right side". Our empirical results show that this method significantly improves GPT-4o's ability to accurately distinguish left from right.

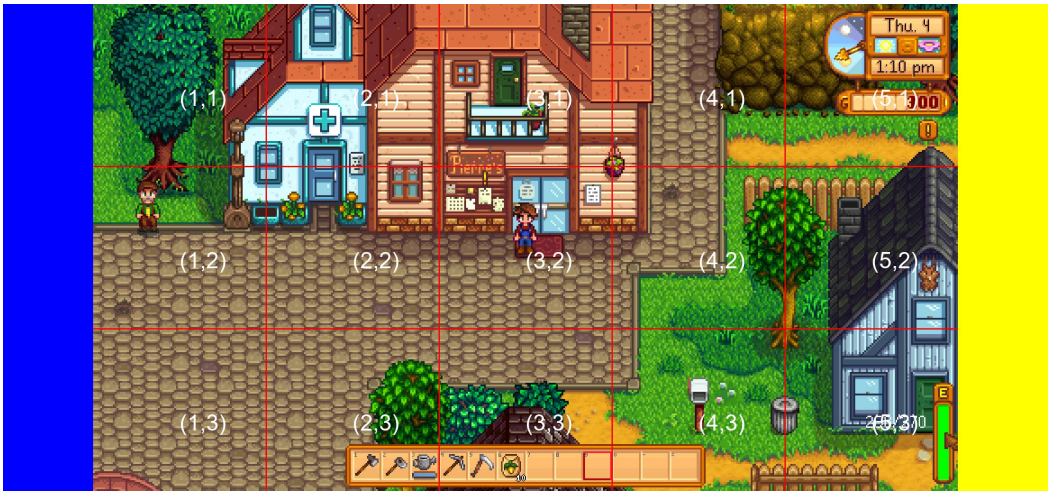


Figure 21: Augmented screenshot via visual prompting. The full screenshot is divided into 3×5 grids and each grid has a unique white coordinate. Additionally, we augment all input images with color bands, with the prompt, "The blue band represents the left side and the yellow band represents the right side", which significantly improves GPT-4o's ability to accurately distinguish left from right.

Information Gathering. As mentioned in the introduction of visual prompting, we let GPT-4o describe the image grid by grid, which is helpful in locating the position of the character, surrounding objects and buildings and facilitates the understanding of the relative positions among them for GPT-4o. Besides, while compared to GPT-4V, GPT-4o is able to recognize most of the icons and their quality in the toolbar shown at the bottom of the screenshot, GPT-4o cannot output the items in the inventory sequentially one by one as it always skips a few in between. We have to clip the box for each item out of the toolbar and feed them to GPT-4o independently, augmented with template matching, for recognition, which turns out to be more accurate. The success of recognition of the tools in the toolbar is critical to tasks like **Farm Clearup** and **Cultivation**.

Self-Reflection. The duration of actions in Stardew is usually much shorter than in RDR2, so we only use the first and last frame from the video observation to reduce the number of tokens used per request. Additionally, we provide some helpful prior information for GPT-4o. For example, a screenshot of the inside of the store is provided to check whether the store was successfully entered. This is useful because there are many other buildings near the store, and sometimes GPT-4o controls the character to enter the wrong one. However, this is not realized if the screenshot is not provided.

Skill Curation. For skill curation, as mentioned in Figure 4, we mainly rely on the in-game manual to generate atomic skills, like *move_up()*, *do_action()* and *use_tool()*. In addition, to handle the challenges of locating objects, especially doors, we have a special set of composite skills specifically for Stardew. *e.g.*, go_through_door, buy_item, get_out_of_house and enter_door_and_sleep. With the restrictions of GPT-4o in fine-grained control, we designed go_through_door composite skills for the agent to control the game character to accurately reach various doors and successfully enter, such as the house and the store door. and in order to buy certain items such as parsnip seeds, we designed the composite skills buy_item to control the game character to interact with the salesman and buy parsnip seeds. similarly, we designed the get_out_of_house and enter_door_and_sleep composite skills to accurately exit the house from the bed and enter the house and walk to the bed.

Action Planning. In this game, we let GPT-4o output at most two skills in a single action every time, which turns out to be efficient. The agent usually needs to select the correct tool first and then use the tool or do action.

Procedure Memory. Procedure Memory is used to store and retrieve skills in code form. In order for agents to quickly get started and complete some special tasks in Stardew, we have predefined skills in Procedure Memory. These skills are divided into atomic and composite skills. atomic skill consists of basic operations such as moving, selecting tools, etc. The description of all the atomic skills is listed as follows:

- *do_action()*: The function to perform a context-specific action on objects or characters.
- *use_tool()*: The function to execute an in-game action commonly assigned to using the character's current selected tool.
- *move_up(duration)*: The function to move the character upward (south) by pressing the 'w' key for the specified duration.
- *move_down(duration)*: The function to move the character downward (north) by pressing the 'w' key for the specified duration.
- *move_left(duration)*: The function to move the character left (west) by pressing the 'w' key for the specified duration.
- *move_right(duration)*: The function to move the character right (east) by pressing the 'w' key for the specified duration.
- *select_tool(key)*: The function to select a specific tool from the in-game toolbar based on the given tool number.

and the composite skills are designed for the agent to complete a variety of special tasks. The description of all the composite skills is listed as follows:

- *buy_item()*: The function to interact with the salesman and buy the item.
- *enter_door_and_sleep()*: The function to enter the house and walk to the bed.
- *get_out_of_house()*: The function to accurately exit the house from the bed

- *go_through_door()*: The function to reach and enter all kinds of doors.

Game Pause. The game will pause automatically when the game window is not focused. So when the character finishes executing actions, we will activate another window, *e.g.,* code window, to pause the game and stop the passage of the time in the game.

F.4 CASE STUDIES

Here we present a few game-specific case studies to further discuss **CRADLE**'s self-reflection and task-inference processes in the GCC setting.

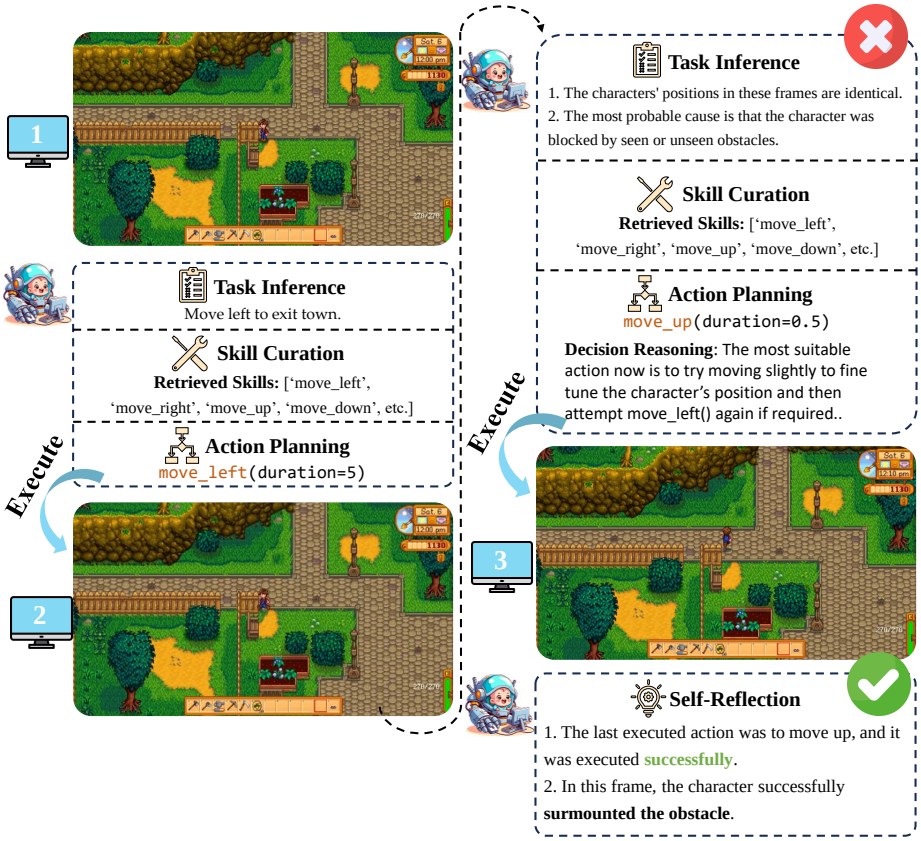


Figure 22: Case study of self-reflection on re-trying a failed task. Task instruction and context require the agent to exit town. A wrong direction is first selected, but the agent moves up after self-reflection. Only relevant modules are shown for better readability, though all modules (Figure 3) are executed per iteration.

F.4.1 SELF-REFLECTION

The Self-reflection module plays an important role in the completion of game missions in Stardew, giving our framework the ability to determine if the actions performed are complete and effective and to correct the errors of invalid actions. In the "Purchasing Seeds" task, the Agent is asked to return home from the store after purchasing items. At the "Home is on the left side of the store" prompt, the Agent controls the character to go left, but there are obstacles to keep going left, and the character must go up to circumnavigate the obstacles. As shown in the Fingure 22, the role will initially be stuck at the obstacle and cannot continue to the left. Through Self-Reflection, the Agent can judge that it is currently in a state of obstruction, and moving to the left cannot be implemented smoothly. Therefore, the agent can adjust the direction upward to bypass the obstacle and enable the role to continue to the left until it returns home.

F.4.2 TASK-INFERENCE

Task Inference is a very effective module for completing game quests in Stardew. Its function is to decompose a vague and grand task into a specific sub-task, which effectively guides the Agent to complete the overall task. For example, in the Farming task, as shown in Figure 23, the task that the character needs to complete is "cultivate and harvest a parsnip." This is a complete but vague task. Through the Task Inference module, the Agent breaks down the task into (1) till the soil with the hoe, (2) plant the parsnip seeds, (3) water the planted seeds once daily for four days, (4) harvest the fully grown parsnip. This enables the Agent to know more clearly the steps needed to complete and finish the task successfully.

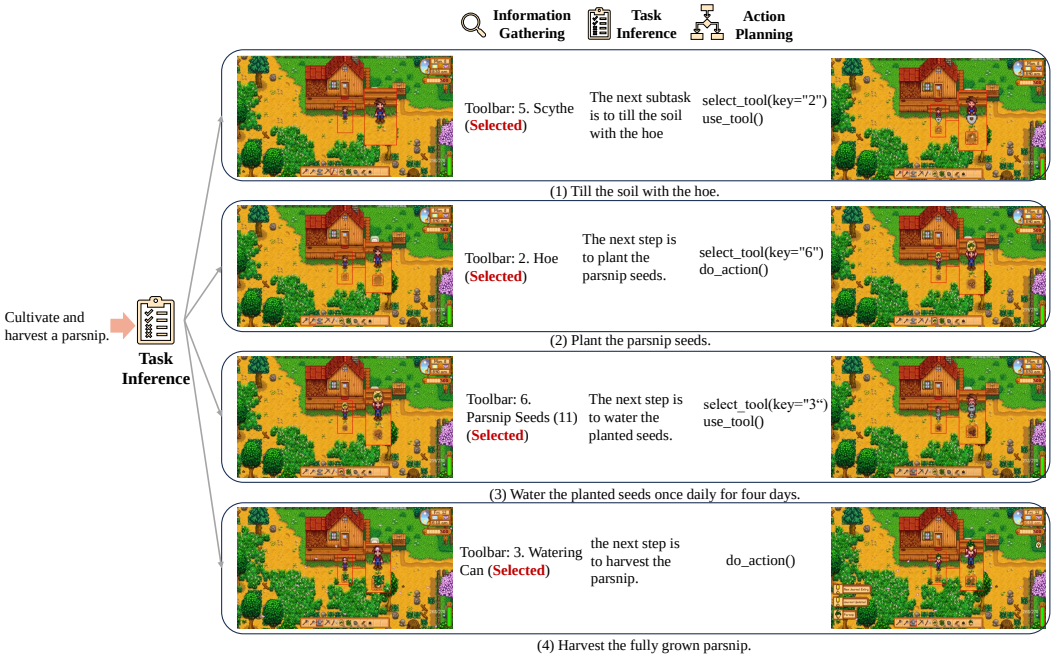


Figure 23: Case study of task inference on decomposing a task into specific sub-tasks. The complete task is to cultivate and harvest a parsnip. **CRADLE** decomposes the task into four sub-tasks by task inference. Only relevant modules are shown for better readability, though all modules (Figure 3) are executed per iteration.

F.5 LIMITATIONS OF GPT-4O

Fine-grained Control. Stardew Valley requires that players are positioned precisely to interact with objects, such as doors and NPCs. However, it is difficult for GPT-4o to take a pixel-level precise action. For example, GPT-4o can not take a precise movement even though the speed at which the figure moves is known. To alleviate this problem, we make some composite skills that use template-matching to complete some complex interaction tasks, such as purchasing items.

Perception in a 2D virtual world . In Stardew Valley, it's common for a character to be blocked by rocks or trees, and GPT-4o fails to tell if a character is blocked by looking at the image once, and can't predict if the next move will be blocked, which is very easy for a human to do by looking at the image. This indicates that GPT-4o is relatively weak in perceiving the virtual world in this game. In order to solve this problem, we compare the successive frames before and after in Self-Reflection to enable GPT-4o to judge the corresponding changes.

G DEALER'S LIFE 2

G.1 INTRODUCTION TO DEALER'S LIFE 2

Dealer's Life 2 is a captivating indie simulation game developed by Abyte Entertainment. Renowned for its intricate negotiation mechanics and humorous portrayal of a pawn shop environment, the game is celebrated for its engaging gameplay that combines strategy with a quirky, cartoonish art style. As a simulation game with role-playing elements, Dealer's Life 2 is played from a first-person perspective, utilizing a mouse for point-and-click interactions and a keyboard for price inputs. This interface facilitates item appraisals, customer interactions, and comprehensive shop management.

In the game, players assume the role of a pawn shop manager, tasked with acquiring and selling various items to make a profit while managing their store's reputation and inventory. Players engage with a wide range of unique non-player characters (NPCs), each with their own distinct behaviors and negotiation styles. Whether bartering over the price of a rare collectible or managing unforeseen shop events, players must hone their haggling and strategic decision-making skills to succeed. Dealer's Life 2 operates in a closed-source format with no APIs available for accessing in-game data or automating gameplay functions. This setup ensures a hands-on experience where players are immersed in the day-to-day challenges of running a pawn shop. This game environment provides a unique and entertaining setting for testifying the GCC's haggling and strategic decision-making abilities. We run our experiments using the latest version, V. 1.013_W96 of the game.

G.2 OBJECTIVES

We concentrate on evaluating the sustained management skills required to maximize profits through buying and selling a diverse range of items from customers. Therefore, the task in this game is defined as *Weekly shop management*, *i.e.*, managing a shop for a week automatically. This game could effectively demonstrate the negotiation ability of the LMM in a trade and bargain. For example, giving an unacceptable price to the customers, *i.e.,* a pretty low price for a seller customer or a very high price for a buyer customer, could cause the deal to fail directly, which brings no profit in this situation. The key is to carefully analyze the description of the item, *e.g.*, the rarity and condition of the item, and more importantly, the response of the customer, *i.e.*, the customer's mood changes.

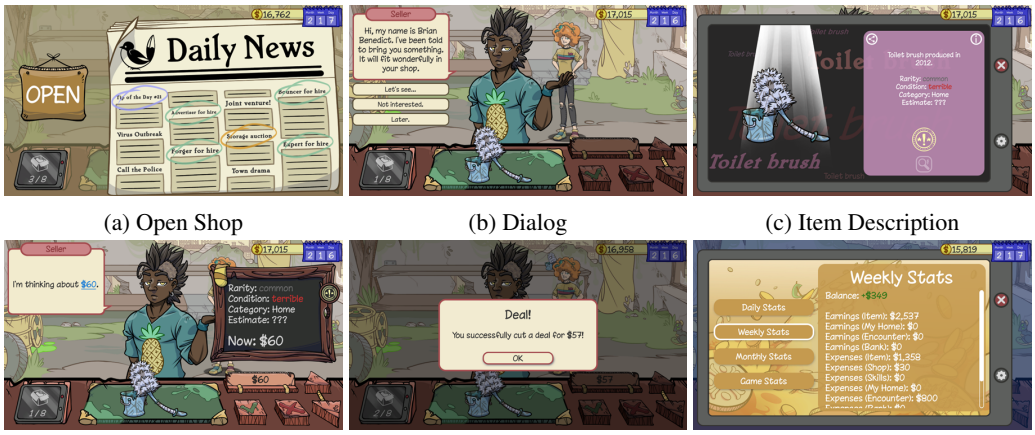
Contrary to many games that feature detailed tutorials highlighting specific operations and objectives through each crucial step, Dealer's Life 2 does not provide such guidance. This absence transforms the game into a zero-shot, hard open-world task, where the LMM must directly apply its prior knowledge of haggling and strategic decision-making to a new and unfamiliar environment. To provide readers with a clear and straightforward understanding of the task, we illustrate the typical flow of a day's shop management through several key steps, presented in Table 10.

Table 10: Key points in the open-ended mission, *Weekly shop management* in Dealer's Life 2. Figure 24 showcases snapshots of key points (specific sub-figures marked in parenthesis in the table).

Task: Weekly shop management	Description
Open shop (Fig. 24a)	Start a new day shop management.
Dialog (Fig. 24b)	Choose an option in a dialog.
Item Description (Fig. 24c)	View the item information
Haggle (Fig. 24d)	Give a price for the item.
Deal Result (Fig. 24e)	View the deal results.
Stats (Fig. 24f)	View shop stats.

G.3 IMPLEMENTATION DETAILS

The implementation of Dealers' Life 2 also strictly follows the GCC framework, which includes Information Gathering, Self-Reflection, Task Inference, Skill Curation, Action Planning, and Action Execution. The details are described in Appendix D. Therefore, we emphasize the specific implementations for Dealers' Life 2.



(a) Open Shop (b) Dialog (c) Item Description

(d) Haggle (e) Deal Result (f) Stats

Figure 24: Image examples of key points in the open-ended task of Dealers' Life 2.

Procedural Memory. Due to the absence of a new-user guide, the LMM cannot directly and accurately know the operation method or effect of an action in the game, *e.g.*, giving the price can only use the keyboard to input an integer in an abstract box in the bottom right of the haggle screen as shown in Figure 24d, by directly observing the screen. Unless the player executes an action and observes what is happening, the player cannot know what its effect is. However, this could easily cause severe errors in an open-world environment. For example, if the player gives a price at $100,000 for an item without knowing what the box is, it could cause the player to lose all the money. Besides, this game is very simplified with finite types of screen content and fixed buttons positions for processing the deal, where we could categorize the screen types and design general atomic skills for them. Thus, with a focus on evaluating the LMM's zero-shot haggling and strategic decision-making ability in managing a shop, we believe it is reasonable to skip the skill curation by directly setting several atomic skills as the initialization of the procedural memory, such as "process_dialog()" for clicking on the option of a dialog screen to keep the deal going on as shown in Figure 24b. The description of all the atomic skills is listed as follows:

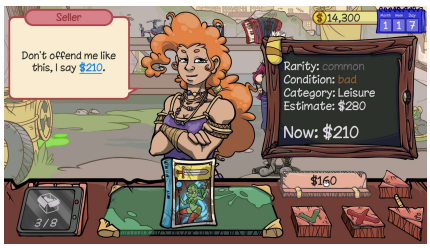
- *open_shop()*: The function to open the dealer's shop to start dealing for today.
- *give_price(price)*: The function to give a price for the item in the deal. The price must be an integer number.
- *process_dialog()*: The function to click on to choose the first option of the dialog to make the game go on.
- *close_description_page()*: The function to close a description page showing information about the item details, daily stats, or the traits of the buyer or seller.
- *accept_deal()*: The function to click on the check mark to accept the deal on the confirmation dialog.
- *reject_deal()*: The function to click on the cross mark to reject the deal on the confirmation dialog.
- *finish_buy()*: The function to click on the ok button to finish the deal on the confirmation dialog.
- *finish_sell()*: The function to click on the ok button to finish the selling on the confirmation dialog.

Self-Reflection. Additionally, as Dealers' Life 2 has no heavy need for a long-term reflection, so we only use the first and last frame of the video as input to reduce the number of tokens used per request. Finally, this self-reflection module could help to keep the game going, instead of sticking to the same point in the game.

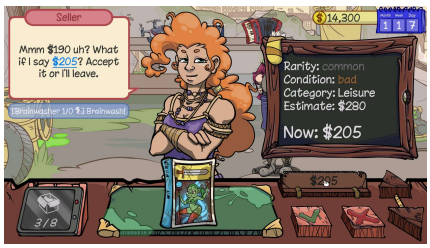
Action Planning. In this game, we restrict GPT-4 to output only one skill per action because it is a round-based game that does not require frequent execution of actions, and the state of the next

(a) Agent: Given that the customer is a seller and the item on offer is in bad condition with an estimated price of $ 280, it would be wise to offer around $150 to leave room for negotiation.

(b) Agent: Given the item's bad condition and $280 estimate, A reasonable starting counteroffer would be 50-60% of its estimated value, and $160 is a reasonable counteroffer.



(c) Agent: A reasonable next offer could be $180 or $190, aiming to reach a middle ground. I would still risk with $160 to see if the offer is cut further.



(d) Agent: The customer is proposing her final offer at $205. It will be necessary to accept the offer as this is still a profitable margin.

Figure 25: The reasoning of **CRADLE** in a successful deal with haggling. The price provided by **CRADLE** is keyed in by keyboard and mouse operations in the digital display box in the bottom-right corner.

time-step after an action is executed is highly uncertain, *e.g.*, the unpredictable mood changes in a customer's response.

G.4 CASE STUDIES

Here we present a few game-specific case studies to further discuss **CRADLE**'s reasoning and decision-making process in the GCC setting.

G.4.1 SUCCESSFUL NEGOTIATION

Figure 25 illustrates a successful negotiation by **CRADLE** with an NPC seller over an item valued at $280. **CRADLE** determines a strategic starting offer by considering both the item's quality and the customer's initial proposal. Throughout subsequent negotiation rounds, **CRADLE** leverages its memory to maintain an offer close to the initially assessed $160, applying pressure on the customer to reduce their expectations. However, **CRADLE** also demonstrates flexibility, adapting its strategy when faced with the customer's final offer—signaled by their incline to leave. This allows **CRADLE** to secure a final agreement that still yields a profitable deal.

G.4.2 UNSUCCESSFUL NEGOTIATION

Figure 26 illustrates a scenario where **CRADLE** engages in an unsuccessful negotiation. The seller consistently demands a price above the estimated value of the item, while **CRADLE**, aiming to secure a profit, steadfastly offers a price below the estimated value. A common price cannot be arrived at after rounds of negotiation. Consequently, the negotiation fails to reach an agreement, resulting in the departure of the high-expectation customer.

(a) Agent: I will offer an initial price of $100 to reflect the poor condition while allowing room for negotiation since the condition is poor.

(b) Agent: The buyer suggests higher than the estimated price.I should offer a price lower than the item's estimated value. I will offer $110.

(c) Agent: The seller has countered several times already, suggesting that further negotiations could result in a mutually acceptable price, possibly just a little bit below $164.

(d) Agent: The negotiation failed. My next step is to acknowledge the failure and continue the game-play to interact with other customers to profit.

Figure 26: The reasoning of **CRADLE** in an unsuccessful deal with haggling. The price provided by **CRADLE** is keyed in by keyboard and mouse operations in the digital display box in the bottom-right corner.

G.4.3 ACQUIRING AND SELLING OF A COUNTERFEIT ITEM

Figure 27 depicts a complete buying and selling cycle involving an item later identified as counterfeit by a buyer. Notably, **CRADLE** initially acquires the item without a known price estimate, basing its purchase solely on the seller's initial offer. In subsequent transactions, although **CRADLE** recognizes the item's potential forgery, it continues to trade the item in pursuit of maximizing profit. This strategy yields a substantial profit margin of 145%. However, it also poses a risk to the in-game character's reputation, highlighting a strategic decision made under the directive to prioritize profit.

G.5 QUANTITATIVE EVALUATION

The effectiveness of **CRADLE** in terms of game performance is evaluated through experiments conducted over a 7-day gaming scenario using nine quantitative financial metrics. A comprehensive description of these metrics is provided in Section G.6.

G.6 EVALUATION METRICS

Assuming the buying price for item i is denoted by B_i, the selling price by S_i, the market valuation by V_i, and the number of successfully traded items is n. To evaluate **CRADLE**'s profitability and performance in Dealer's Life 2, we use the following evaluation metrics:

- **Turnover Rate (TR)** can be calculated as the ratio of the number of successfully traded items to the total number of items considered (both successfully and unsuccessfully traded). It reflects the Agent's ability to successfully complete transactions and can indicate operational efficiency, market competitiveness, and negotiation effectiveness. The calculation formula is $TR = \frac{n}{n+m}$.
- **Gross Profit Margin (GPM)** is the ratio of gross profit to sales revenue, reflecting the dealer's direct profit capability after selling items. The calculation formula is $GPM = \frac{\sum_{i=1}^{n} S_i - B_i}{\sum_{i=1}^{n} S_i}$.

(a) Agent: Given that we do not know the estimated price, I proceed with 70%-80% of the asked price, around $4,200 to $4,480.

(b) Agent: Since the seller is willing to lower the price, the current counteroffer may still be negotiated.

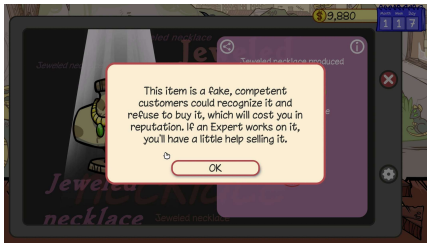
(c) Agent: The counteroffer of $4,900 seems reasonable, but I can go further for the best possible price.

(d) Agent: The response will be final. Given this, accepting the deal is a sensible to secure the item.

(e) Agent: As I am selling the item, I'll try for a higher price for higher profits.

(f) Agent: I note that the customer rejected my counter-offer, calling the item fake.

(g) Agent: The seller is in an urgent need to buy the jeweled necklace.



(h) Agent: From the warning window, I am told that this necklace is fake.

(i) Agent: Though the jeweled necklace is fake, accepting this offer provides substantial profit with the buyer's offer at $11,400.

(j) Agent: Despite the successful sale at a good price, the item is revealed as a fake. The added profit is good (+145%)

Figure 27: Case in acquiring and selling an item for multiple attempts with reasoning, and dealing with unexpected information on the authenticity. The price provided by **CRADLE** is keyed in by keyboard and mouse operations in the digital display box in the bottom-right corner.

- **Return on Investment (ROI)** is the ratio of profit to investment, used to measure the dealer's return on investment for items. The calculation formula is $ROI = \frac{\sum_{i=1}^{n} S_i - B_i}{\sum_{i=1}^{n} B_i}$.
- **Valuation Deviation (VD)** reflects the difference between the selling price and the market valuation, used to evaluate the reasonableness of the pricing strategy. It is denoted as $VD = \frac{\sum_{i=1}^{n} S_i - V_i}{\sum_{i=1}^{n} V_i}$.
- **Buying Price to Valuation Ratio (BPVR)** can help determine whether the buying price is lower than the market valuation, reflecting the success of the procurement. The calculation formula is $BPVR = \frac{\sum_{i=1}^{n} B_i}{\sum_{i=1}^{n} V_i}$.
- **Selling Price to Valuation Ratio (SPVR)** reflects the selling price relative to the market valuation, helping to assess the success of the sales. The calculation formula is $SPVR = \frac{\sum_{i=1}^{n} S_i}{\sum_{i=1}^{n} V_i}$.
- **Average Profit Rate (APR)** reflects the overall profitability of the dealer on items. Assuming the return rate for item i is $\frac{S_i - B_i}{B_i}$, the calculation formula of average return rate is denoted as $APR = \frac{1}{n} \sum_{i=1}^{n} \frac{S_i - B_i}{B_i}$.
- **Maximum Return Rate (MRR)** is the highest return rate among all items. The calculation formula is $MRR = \max(\frac{S_1 - B_1}{B_1}, \frac{S_2 - B_2}{B_2}, \ldots, \frac{S_n - B_n}{B_n})$.
- **Minimum Return Rate (mRR)** is the lowest return rate among all items. The calculation formula is $mRR = \min(\frac{S_1 - B_1}{B_1}, \frac{S_2 - B_2}{B_2}, \ldots, \frac{S_n - B_n}{B_n})$.

Table 11: Performance of **CRADLE** with GPT-4o in Dealer's Life 2 gameplay. "# attempts" represents the total number of all negotiation attempts on items, including both successful and unsuccessful transactions.

Exp	# attempts	TR↑	GPM↑	ROI↑	VD↑	BPVR↓	SPVR↑	APR↑	MRR↑	mRR↑
01	13	92.86	20.38	25.60	13.17	90.10	113.17	42.97	105.56	0.00
02	12	91.67	18.89	23.30	23.30	100.00	123.30	17.98	97.76	0.00
03	12	83.33	26.81	36.63	34.39	98.36	134.39	38.68	127.27	-8.06
04	9	100.00	49.35	87.45	80.69	93.53	165.74	66.45	145.16	0.00
05	12	100.00	20.61	25.25	25.25	100.00	125.25	23.08	44.33	0.00
Avg.	11.6	93.57	27.21	39.65	35.36	96.40	132.37	37.83	104.02	-1.61

H CITIES: SKYLINES

H.1 INTRODUCTION TO CITIES: SKYLINES

Cities: Skylines is a single-player open-ended city-building simulation game developed by Colossal Order. In the game, players assume the role of a city planner, tasked with building and managing various aspects of a city to ensure its growth and prosperity. Players engage with a wide range of urban challenges, from managing traffic flow to balancing the budget, and from providing essential services to fostering a vibrant economy. Each decision impacts the city's development, requiring players to hone their planning and strategic decision-making skills to succeed. Effective city management leads to thriving neighborhoods, a growing economy, and high citizen satisfaction, while mismanagement can result in traffic congestion, service shortages, and a decline in population and reputation. Proper planning and responsive governance are crucial for a city that flourishes and remains appealing to its residents and visitors.

As the city's infrastructure and various supporting resources are well-developed, it can attract more people. And a larger population brings more tax revenue and also brings greater expenses to the city's operations. If operated properly, the increasing population can continuously unlock richer urban facilities; if operated improperly, such as road congestion, insufficient services, housing shortage, water and electricity shortage, noise pollution, water pollution, excessive garbage, disease, fire Situation, etc., will all lead to population decline.

This game could be used to evaluate agents' strategies in managing urban development and resource allocation. By simulating different scenarios, agents can experiment with various policies and infrastructural changes to see their impacts on the city's growth and sustainability. Effective strategies may

involve optimizing public transportation systems to reduce road congestion, investing in renewable energy sources to prevent power shortages, and implementing comprehensive waste management programs to handle excessive garbage. It offers a risk-free environment to test innovative ideas and learn from the consequences of their actions, ultimately promoting a deeper understanding of sustainable urban development.

Though this game is ranked very positive on Steam, it is notorious for its extremely high difficulty for beginners, as it lacks a detailed tutorial in the beginning, which introduces more challenges for **CRADLE** to deal with. On the other side, Although the successor, Cities: Skylines 2, simplified the controls and provided a detailed tutorial for beginners, it became notorious for poor optimization and frequent crashes that caused computer blue screens. As a result, we had to back to using Cities: Skylines 1 instead of 2. And we do not apply any modes to the game. We use the latest version of the game (version 1.17.1-f4).

H.2 OBJECTIVES

Our mission is to build cities so that they can support as many people as possible. Maps in this game are usually very large, which usually costs human players dozens of hours to cover all areas. Besides, the technology tree unlocks as the population grows, which requires multiple turns of planning and building. In this work, we simplified the problem by starting the game near the water and fixing the viewpoint (as shown in Figure 28), so that **CRADLE** can leverage the pixel position in the screenshot to locate the position of placed buildings and facilities. Agents start with a plot of land, which is equipped with an entry and an exit from a major highway, providing crucial access for future traffic flow, and proximity to the water source, which is essential for the city's water supply needs. And we focus on the first turn of planning, i.e., pause the game and stop the passage of the in-game time, use the initial starting funds of ₡70,000 and the most basic road, water, and electricity facilities provided at the beginning of the game, which is enough to achieve the first milestone, *Little Hamlet* with the population of 440 in the game. Then what kind of city can **CRADLE** create? Can this city ensure water and electricity supply to keep functioning normally while reasonably dividing residential, commercial, and industrial zones? A run is terminated when it reaches the maximal steps, 1000, or the budget is used up (less than ₡ 1000).

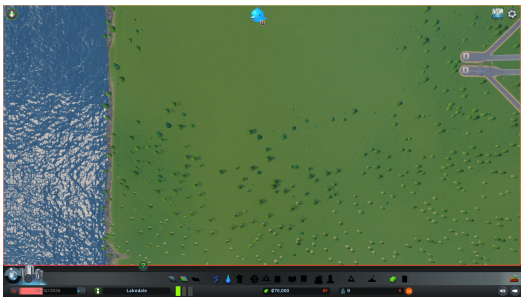


Figure 28: Demonstration for the initialization location of our mission in City: Skylines, which is near the river and contains the entry and exit of the highways.

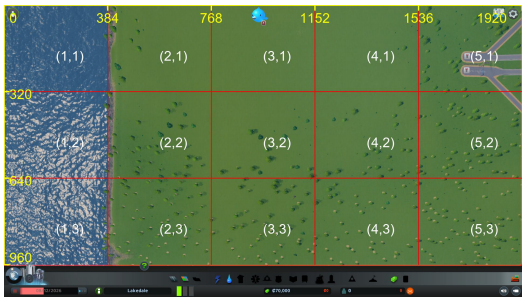


Figure 29: Visual prompting methods used in Cities: Skylines. The full screenshot is divided into 3×5 grids and each grid is assigned a unique white coordinate.

H.3 EVALUATION METRIC

To measure the completeness of the city built by the agent, we design the following preliminary metrics:

- **Roads in closed loop**: Whether the road is a closed loop, which is crucial for ensuring smooth traffic flow and is beneficial for the city's future development.
- **Sufficient water supply**: To ensure a sufficient water supply, the player needs to construct a water pumping station at the shoreline and then use water pipes to cover every district along the roads. To manage the effluent effectively, the other end of the water pipe network must be equipped with the water drain pipe which is also required to be placed near the shoreline.

- **Sufficient electricity supply**: Both zones and water facilities need electricity to power. To provide sufficient electricity supply, the player can build a coal power plant or wind turbine. Considering coal power plants cost too much and will create heavy pollution, wind turbines combined with the power lines are a better choice at the beginning. The electricity area extends automatically based on the presence of buildings and infrastructure that consume electricity.
- **Zones Coverage > 90%**: The built two-lane road will provide empty space for the development of zones, *i.e.,* residential zone, commercial zone and industrial zone. Residential zones provide houses for people to live in, which is the most essential zone to increase the population. Commercial zones provide places for small businesses, shops, and services produced in the industrial zones or imported. Industrial zones provide jobs for the residents and products for commercial buildings, which is also important to attract more people to move to the city. This metric is used to evaluate whether 90% of the available areas are covered by the zones. The agent needs to reasonably allocate the areas and proportions of various zones to achieve better city development and attract a larger population.
- **Maximal population**: After **CRADLE** finishes building, we will unpause the game and start the simulation. Then houses start to be built and residents start to move in. We will record the maximal population during the simulation as the value for this metric.
- **Maximal population with assistance**: We find that cities built by **CRADLE** manage to meet most of the requirements but suffer a significant population loss due to a few easy-to-fix mistakes. So after **CRADLE** finishes the design of the city, we apply human assistance that attempts to address these small mistakes within 3 unit operations (building or removing a road/facility/a place of zones is counted as one unit operation). We will also record the maximum population during the simulation in the city with human assistance.

H.4 Implementation Details

The implementation of Cities: Skylines also strictly follows the GCC framework, which includes Information Gathering, Self-Reflection, Task Inference, Skill Curation, Action Planning and Action Execution. The details are described in Appendix D. Therefore, we emphasize the specific design for Cities: Skylines.

Pause. Since the game is stopped before starting the simulation, there is no need to unpause and pause the game while executing actions.

Visual Prompting. As shown in Figure 29, similar to Stardew Valley, we divide each screenshot into 3×5 grids with an axis based on the resolution of the game screen. Then **CRADLE** can utilize the pixel-level position in the screenshot to locate the building and facility. We empirically find that this visual prompting method can result in a more precise control of GPT-4o.

Information Gathering. In Cities: Skylines, the game's perspective is typically adjustable, allowing players to zoom in and out, rotate, and pan across their cityscape to get a detailed view of their urban development. To ensure consistency and ease of navigation for GPT-4o, we have locked the camera angle and applied a visual prompting method to enhance GPT-4o's visual understanding. Besides, we use GPT-4o to extract key information, such as budget, population, construction information and error messages, in the game.

It is worth noting that in this module, we feed the original screenshot to GPT-4o, rather than the augmented screenshot with axis and coordinates. We find that the numbers and lines may cover some key information and result in wrong OCR recognition. For example, the construction information, "Estimated Production: 120,000m^3/week" may be mistakenly interpreted as "Estimated Production: 000,000m^3/week" by GPT-4o, due to interference from the lines and numbers. This construction information is a key signal for the suitable place of the water pumping station. For the other modules, we feed GPT-4o with the augmented screenshots.

Self-Reflection. Since actions in this game are very short, and each of them has a significant effect shown in the last screenshot. We only use the first screenshot and the last screenshot of the video clip as input to this module, which is proved to be enough for not missing any important information.

Task Inference. Due to the lack of a detailed tutorial, we have to provide a draft blueprint for the GPT-4o as the plan at the beginning to help GPT-4o to determine the next step to do. This

plan provides guidance to the orders of building each facility and how to build a closed road, how to ensure water and electricity supply and zone placement. Even so, we find that GPT-4o failed frequently to follow the plan, resulting in the lack of building some important facilities, like water pumping stations.

Skill Curation. Due to the lack of detailed tutorials in the game, we generate the skills through self-exploration in this game. The skill generation basically involves manipulating the toolbar to understand the items on it. The pseudo-code for skill generation is described in Algorithm 1. This process leverages SAM for objective grounding and GPT-4o to gather information about the objects provided by the game, subsequently generating skills based on a predefined template. An example of the process is shown in Fig 30, 31, 32, 33, 34 and 35.

Figure 30: The toolbar in Cities: Skylines

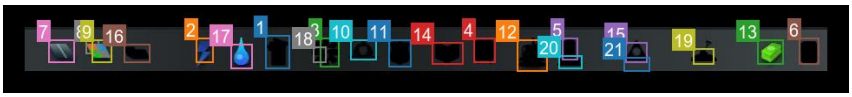


Figure 31: The grounding result of the toolbar in Cities: Skylines

Figure 32: When hovering the mouse over a toolbar item, the pop-up description is "Water & Sewage". The skill generated is then called "open_water_sewage_menu".

Figure 33: When hovering the mouse over a toolbar item, the pop-up description is "Education - Reach a population of 440". As this is not selectable for now, GPT-4o does not generate a new skill for it.

Action Planning. In this game, we only let GPT-4o output one skill for each action since we observe that GPT-4o tends to output *try_place* and *confirm placement* together if we allow it to output and execute multiple skills in one action, which is against the intention of our design for the *try_place* action.

Procedure Memory. Skills generated through self-exploration are listed below:

- *open_roads_menu()*: The function to open the roads options in the lower menu bar for further determination of which types of roads to build.
- *open_electricity_menu()*: The function to open the electricity options in the lower menu bar for further determination of which types of power facility to build.
- *open_water_sewage_menu()*: The function to open the water and sewage options in the lower menu bar for further determination of which types of water and sewage to build.
- *open_zoning_menu()*: The function to open the zoning options in the lower menu bar for further determination of which types of zonings to build.
- *try_place_two_lane_road*(x_1, y_1, x_2, y_2): Previews the placement of a road between two specified points, (x_1, y_1) and (x_2, y_2), with x_1, y_1 being the coordinate of start point of the road, and (x_2, y_2) being the coordinate of end point of the road. This function does not actually construct the road, but rather displays a visual representation of where the road would be placed if confirmed.

Figure 34: The Water & Sewage menu is opened by executing the new skill "open_water_sewage_menu". The Agent then hovers the mouse over a second-level toolbar item, the pop-up description is "Water Pipe", and the generated skill is called "try_place_water_pipe".

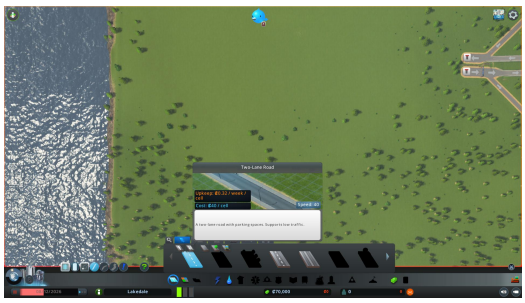


Figure 35: The Roads menu is opened by executing the new skill "open_roads_menu". The Agent then hovers the mouse over a second-level toolbar item, the pop-up description is "Two-Lane Road", and the generated skill is called "try_place_two_lane_road".

Algorithm 1: Skill Generation

Input: Toolbar with objects, Skill template
Output: Procedure memory with generated skills

```
Initialize procedure memory;
for each object in the toolbar do
    Hover the mouse on the object to get the description;
    Generate skill using GPT-4o based on the object description and the skill template;
    Store generated skill in procedure memory;
    Execute the generated skill to enter the second-level toolbar;
    for each object in the second-level toolbar do
        Hover the mouse on the object to get the description;
        Generate skill using GPT-4o based on the object description and skill template;
        Store generated skill in procedure memory;
return procedure memory
```

- *try_place_wind_turbine*(x, y): Previews the placement of a wind turbine on point, (x, y). This function does not actually construct the wind turbine, but rather displays a visual representation of where the wind turbine would be placed if confirmed.
- *try_place_water_pumping_station*(x, y): Previews the placement of a water pumping station on point, (x, y). This function does not actually construct the water pumping station, but rather displays a visual representation of where the water pumping station would be placed if confirmed.
- *try_place_water_pipe*(x_1, y_1, x_2, y_2): Previews the placement of a water pipe between two specified points, (x_1, y_1) and (x_2, y_2). This function does not actually construct the water pipe, but rather displays a visual representation of where the water pipe would be placed if confirmed.
- *try_place_water_drain_pipe*(x, y): Previews the placement of a water drain pipe on point, (x, y). This function does not actually construct the water drain pipe, but rather displays a visual representation of where the water drain pipe would be placed if confirmed.
- *try_place_commercial_zone*(x_1, y_1, x_2, y_2): Previews the placement of a commercial zone within a rectangular region with diagonal corners at (x_1, y_1) and (x_2, y_2). This function does not actually construct the commercial zone, but rather displays a visual representation of where the commercial zone would be placed if confirmed.
- *try_place_industrial_zone*(x_1, y_1, x_2, y_2): Previews the placement of a industrial zone within a rectangular region with diagonal corners at (x_1, y_1) and (x_2, y_2). This function does not actually construct the industrial zone, but rather displays a visual representation of where the industrial zone would be placed if confirmed.

- *try_de_zone*(x_1, y_1, x_2, y_2): The function to remove the zone in the game. The zone must cover the road.
- *confirm_placement()*: The function to confirm the placement and build the object after the *try_place_[object]* function.
- *cancel_placement()*: The function to cancel the placement of the object after the *try_place_[object]* function.

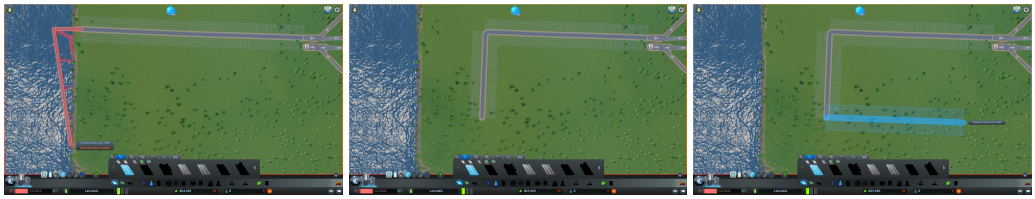
Episodic Memory. Besides the common information to store in the episodic memory. We initialize the memory with the coordinates of the entry and exit of the highway. Then **CRADLE** is able to extend the roads according to these two points at the beginning. When a road or a facility such as wind turbine, water pumping station, water drain pipe and water pipe is placed on the map, the corresponding coordinates will also be stored in the memory for future development of the city.

H.5 CASE STUDIES

H.5.1 FAILURE FOR ROAD BUILDING.

As shown in Figure 36, sometimes GPT-4o will build a long road, which ends on the top of water. The recorded endpoint of the road is actually the projection of the road on the sea level, resulting in the offset from the projection point and the real endpoint of the road. It leads to the failure of extending the road to the other places.

Figure 36b, 36c, 36d and 36e tells a story that GPT-4o sometimes forgets to confirm the placement (from 36c to 36d) and directly moves to the next step of building the next road (from 36d to 36e), resulting in the disconnection of the roads.



(a) (b) (c)

(d) (e)

Figure 36: Failure cases of building roads in a closed loop. Figure 36a shows that the road is built over the water and is difficult to continue. Figure 36b, 36c, 36d and 36e tells a story that GPT-4o sometimes forgets to confirm the placement (from 36c to 36d) and directly moves to the next step of building (from 36d to 36e), resulting in the disconnection of the roads.

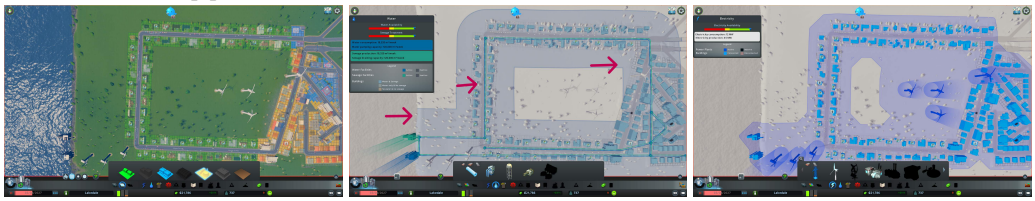
H.5.2 FAILURE FOR SUFFICIENT WATER SUPPLY.

Figure 37 displays three cases where **CRADLE** fails to ensure the water supply due to the disconnection of water pipes and the missing water pumping station. All of them can be fixed within three unit operations. As shown in Figure 37b and 37f, we observe a significant increase in the population if these mistakes are fixed, which proves that **CRADLE** already has the ability to build a reasonable city but some minor adjustments are needed.

(a) **CRADLE**'s craftwork I. The upper left corner of the city is experiencing a severe local water shortage since the water pipes there are not connected. **Population: 800+**.

(b) **CRADLE**'s craftwork I with assistant within three unit operations to develop the idle area in the upper right corner of the city into a residential zone and put two water pipes to ensure all the water pipes connected and cover the whole city. **Population: 1150+**.

(c) **CRADLE**'s craftwork II. The left side of the city a localized area on the right suffers from water shortage because of the water pipes connected issues. **Population: 640+.**



(d) **CRADLE**'s craftwork II with assistant within three unit operations by selling the redundant water pumping station and the independent water pipe on the right to get some budget and using the budget to get the water pipes connected. **Population: 730+**.

(e) **CRADLE**'s craftwork III. The entire city is experiencing a severe water shortage due to the lack of the water pumping station. **Population: 200+**.

(f) **CRADLE**'s craftwork III with assistant within three unit operations to place the water pumping station, lay water pipe on the right side and develop the bottom area with industrial zones. **Population: 780+**.

Figure 37: Demonstrations of three cities built by **CRADLE** in zoning view (left), water view (middle) and electricity view (right). Figures 37b, 37d, 37f show the cities with human assistance to address construction issues (shown in red arrow). Populations shown in the figures are close to but not exactly the maximal population since they are changed dynamically.

I SOFTWARE APPLICATIONS

I.1 SELECTED SOFTWARE APPLICATIONS

Besides targeting complex digital games, **CRADLE** also includes an initial benchmark task set across diverse software applications. The selected applications include Chrome, Outlook, Feishu, CapCut, and Meitu. These applications cover popular applications for daily tasks in different usage categories, such as web browsing, communication, work, and media manipulation. Table 12 shows the exact application versions benchmarked in this paper. Five distinct tasks were designed for each application to represent their target domains and explore the difficulties posed to LMM-based agents and analyze their limitations. Figure 9 shows an overview of all tasks across applications and Tables 13 and 14 detail each task.

Chrome and Outlook were selected as common representatives for web browsing and e-mail, with well-known functionality and UI design. CapCut and Meitu are two popular media editing applications for video/image editing with their own interaction styles. Lastly, Feishu (also known as Lark) is an office collaboration and productivity application, which includes messaging, calendar/meetings, and approval workflows. It represents a complex business application that doesn't strictly follow OS-specific UI guidelines. To the best of our knowledge, this is the **first agent** targeting applications like CapCut, Meitu, and Feishu.

I.1.1 BRIEF DESCRIPTIONS

Chrome is a web browser developed by Google. It allows users to access and utilize online resources through activities such as browsing websites, streaming videos, and using web applications. Additionally, users can customize their browsing experience with various extensions, manage bookmarks and passwords, and synchronize their data across multiple devices for seamless access.

Table 12: Exact software versions utilized in the described experiments. Similar versions should behave similarly.

Software	Version
Chrome	125.0.6422.142
Outlook	1.2024.529.200
CapCut	4.0.0
Meitu	7.5.6.1
Feishu	7.19.5

Outlook is an application by that allows users to manage emails, calendars, contacts, and tasks. It includes tools for communication and scheduling through features such as sending and receiving emails, setting up meetings, and keeping track of appointments. Additionally, users can customize their experience and integrate Outlook with other Microsoft Office applications.

CapCut is a popular video editing application developed by ByteDance. It provides easy-to-use editing tools and and enables users to create quality videos with a range of advanced features. CapCut offers a set of editing tools, including trimming, cutting, merging, and splitting video clips; the application of various effects, filters, and transitions; as well as adjusting speed, and adding music or text overlays.

Meitu is a photo editing application. It is designed to cater to a broad audience and enables users to enhance and transform their photos with minimal effort. Meitu offers editing tools, including basic adjustments like cropping, rotating, and resizing, as well as advanced features such as beauty retouching, filters, and special effects. Additionally, Meitu offers a wide range of stickers, frames, and text options to further personalize photos.

Feishu, also known as Lark, is a business communication and collaboration platform by ByteDance. It integrates various tools for office workflows and project management. Feishu offers a wide array of functionalities, including instant messaging, video conferencing, file sharing, and collaboration within the app. It also includes an integrated calendar, which helps users schedule and manage meetings and events, and task management tools that allow users to assign and track tasks.

I.2 SOFTWARE TASKS

For each of the five applications, we selected a set of representative tasks for their respective domains. For example, search, navigation, and settings tasks on Chrome; sending, searching, and deleting emails, plus changing settings on Outlook; basic video and image editing operations on

Table 13: Task Descriptions for Chrome, Outlook, and CapCut. *Difficulty* refers to how hard it is for our agent to accomplish the corresponding tasks. Figures 38, 39, and 40 illustrate each task (specific sub-figures marked in parenthesis in the left-most column along with task name).

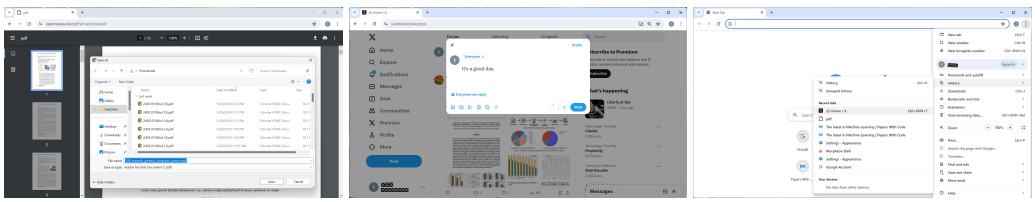
Software	Description	Difficulty
Chrome		
Download Paper (Fig. 38a)	Search for an article with a title like *{paper_title}* and download its PDF file.	Hard
Post in Twitter (Fig. 38b)	Post "It's a good day." on my Twitter.	Hard
Open Closed Page (Fig. 38c)	Open the last closed page.	Easy
Go to Profile (Fig. 38d)	Find and navigate to *{person_name}*'s homepage on GitHub.	Medium
Change Mode (Fig. 38e)	Customize Chrome to dark mode.	Medium
Outlook		
Send New E-mail (Fig. 39a)	Create a new e-mail to *{email_address}* with subject "Hello friend" and send it.	Medium
Empty Junk Folder (Fig. 39b)	Open the junk folder and delete all messages in it, if any.	Medium
Reply to Person (Fig. 39c)	Open an e-mail from *{person_name}* in the inbox, reply to it with "Got it. Thanks.", and click send.	Medium
Find Target E-mail (Fig. 39d)	Find the e-mail whose subject is "Urgent meeting" and open it.	Easy
Setup Forwarding (Fig. 39e)	Set up email forwarding for every email received to go to *{email_address}*.	Medium
CapCut		
Create Media Project (Fig. 40a)	Create a new project, then import *{video_file_name}* to the media, click the "Audio" button to add music to the timeline, and finally export the video.	Hard
Add Transition (Fig. 40b)	Open the first existing project. Switch to Transitions panel. Drag a transition effect between the two videos, and then export the video.	Medium
Crop by Timestamp (Fig. 40c)	Delete the video frames after five seconds and then before one second in this video, and then export the video.	Medium
Add Sticker (Fig. 40d)	Open the first existing project. Switch to Stickers panel. Drag a sticker of a person's face to the video, and then export the video.	Hard
Crop by Content (Fig. 40e)	Crop the video when the ball enters the goal, and then export the video.	Very hard

CapCut and Meitu (*e.g.,* adding special effects and creating a collage); and communication and organization operations on Feishu. Tables 13 and 14 describe in detail the 25 tasks **CRADLE** performs and analyzes on the five selected applications; also illustrated in Figures 38, 39, 40, 41, 42, and 9.

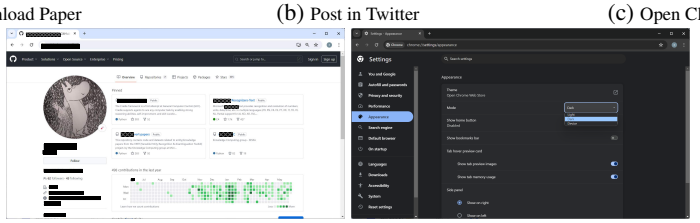
It is worth noting that we add a *special* task on CapCut to demonstrate the agent's ability for tool use. In this task, a pre-defined skill uses GPT-4o as a tool for video understanding capabilities. The skill can be selected to answer content-based questions about a video (*e.g.,* "when the ball enters the goal") and the response be used during task completion. This task is illustrated in detail in Figure 49.

Table 14: Task Descriptions for: Meitu, and Feishu. *Difficulty* refers to how hard it is for our agent to accomplish the corresponding tasks. Figures 41, and 42 illustrate each task (specific sub-figures marked in parenthesis in the left-most column along with task name).

Software	Description	Difficulty
Meitu		
Apply Filter (Fig. 41a)	Apply a filter from Meitu to *{picture_file_name}* and save the project.	Easy
Cutout (Fig. 41b)	Cutout a person from *{picture_file_name}* and save the project.	Easy
Add Sticker (Fig. 41c)	Add a flower sticker to *{picture_file_name}* and save the picture.	Middle
Create Collage (Fig. 41d)	Make a collage using 3 pictures and save the project.	Hard
Add Frame (Fig. 41e)	Add a circle-shaped frame to *{picture_file_name}* and save the picture.	Hard
Feishu		
Create Appointment (Fig. 42a)	Create a new appointment in my calendar anytime later today with title "Focus time".	Hard
Message Contact (Fig. 42b)	Please send a "Hi" chat message to *{contact_name}*.	Easy
Send File (Fig. 42c)	Send the AWS bill file at *{pdf_path}* in a chat with *{contact_name}*.	Hard
Set User Status (Fig. 42d)	Open the user profile menu and set my status to "In meeting".	Medium
Start Video Conference (Fig. 42e)	Create a new meeting and meet now.	Easy

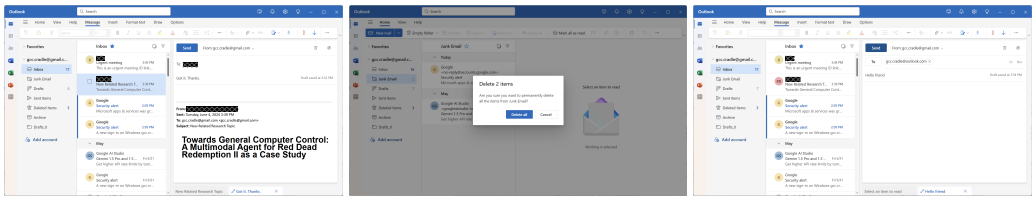


(a) Download Paper (b) Post in Twitter (c) Open Closed Page



(d) Go to Profile (e) Change Mode

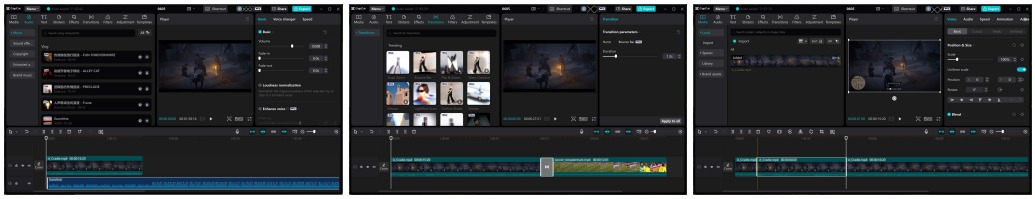
Figure 38: Screenshots of Chrome tasks.



(a) Send New E-mail (b) Empty Junk Folder (c) Reply to Person

(d) Find Target E-mail (e) Setup Forwarding

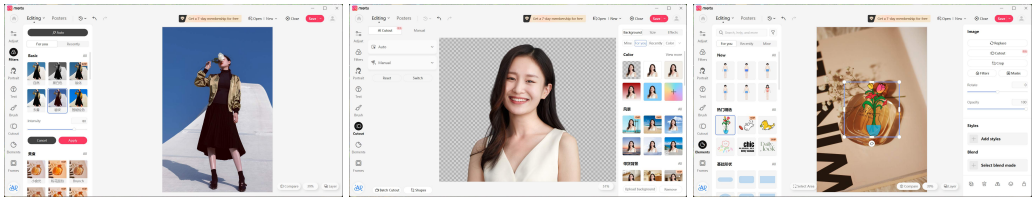
Figure 39: Screenshots of Outlook tasks.



(a) Create Media Project (b) Add Transition (c) Crop by Timestamp

(d) Add Sticker (e) Crop by Content

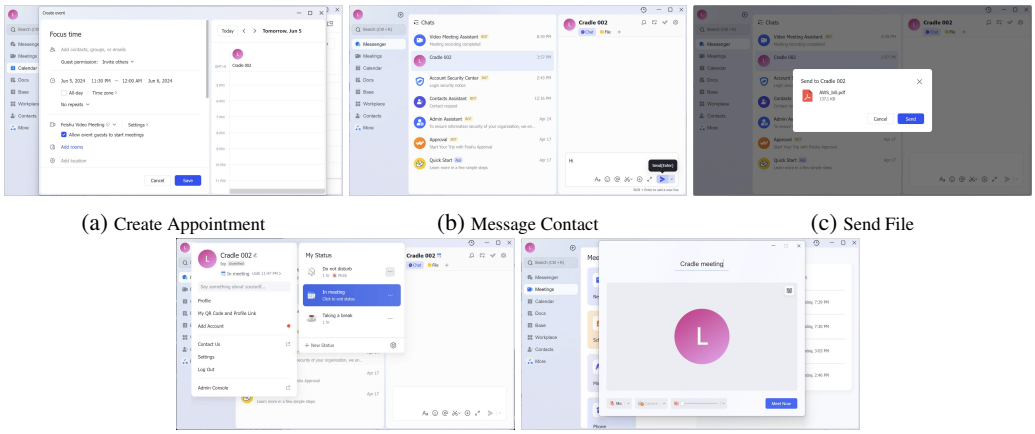
Figure 40: Screenshots of CapCut tasks.



(a) Apply Filter (b) Cutout (c) Add Sticker

(d) Create Collage (e) Add Frame

Figure 41: Screenshots of Meitu tasks.



(a) Create Appointment (b) Message Contact (c) Send File

(d) Set User Status (e) Start Video Conference

Figure 42: Screenshots of Feishu tasks.

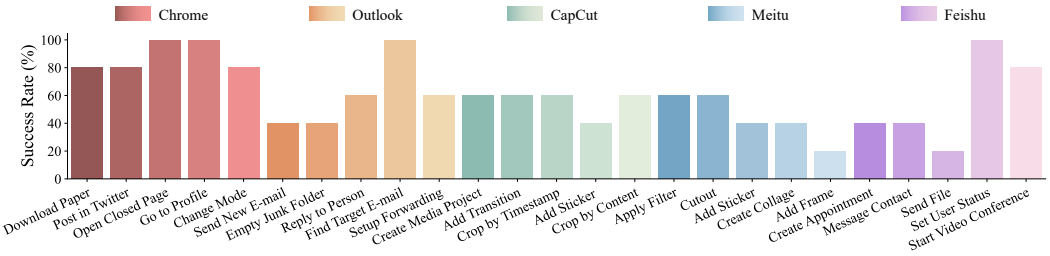


Figure 43: Success rates for tasks in software applications

I.3 Quantitative Evaluation

We calculate **CRADLE**'s performance over the 25 tasks in the applications set. Each task is executed five times and performance is measured in three metrics: success rate, average number of steps taken by the agent (and variance over the five runs), and efficiency. *Efficiency* is defined as the ratio between the expected number of steps in a given task and the total number of steps taken by the agent. The expected number of steps per task is calculated by having humans perform each task.

Table 15 and Figure 43 show the details of the evaluation. **CRADLE** presents overall good performance over the diverse tasks and applications (compared to Expected Steps, **CRADLE** achieves an overall efficiency of 50%). However, performance for certain tasks can vary considerably due to different factors. The main reason for the higher number of task step during agent execution is the frequent incorrect positioning decisions for the mouse, *i.e.,* the backbone model chooses a position of bounding box tag that does not correspond to the UI item described in the model reasoning. We discuss examples of task-specific issues in Sections I.5 and I.6 below.

It is worth noting that in Chrome's task 3 ("Open the last closed page"), **CRADLE** knows how to use the shortcut key directly, calling the key_press skill directly with the correct keyboard shortcut: *'Ctrl + Shift + T'*, whereas humans typically do not know this.

To further evaluate the performance of **CRADLE** in diverse software applications scenarios, we provide quantitative results over OSWorld, a new contemporaneous benchmark with similar characteristics to our settings. More details in Appendix J and overview of the results in Table 16.

I.4 Implementation Details

The implementation of **CRADLE** targeting all five software applications follows the GCC setting and framework modules (which include Information Gathering, Self-Reflection, Task Inference, Skill Curation, Action Planning, and Action Execution). Implementation details of the overall framework

Table 15: Application Software results. *Success Rate* determines the ratio of successful completions over five runs. *Average Steps* refers to the number of actions the agent takes to fulfil a task, if successful. *Expected Steps* represents the number of steps as estimated by humans performing the task. *Efficiency* represents the ratio between the expected number of steps and the total number of steps taken by the agent.

Software	Success Rate	Average Steps	Expected Steps	Efficiency
Chrome	88%	8.23 ± 6.75	4.20	48.05%
Download Paper	80%	16.00 ± 5.52	6	37.50%
Post in Twitter	80%	11.75 ± 5.26	7	61.14%
Open Closed Page	100%	1.00 ± 0	3	300.00%
Go to Profile	100%	4.00 ± 0.63	1	25.00%
Change Mode	80%	11.25 ± 4.71	4	35.56%
Outlook	60%	7.13 ± 5.61	4	48.48%
Send New E-mail	40%	11.00 ± 4	5	45.45%
Empty Junk Folder	40%	8.50 ± 3.50	3	35.29%
Reply to Person	60%	8.33 ± 4.71	4	48.02%
Find Target E-mail	100%	1.40 ± 0.80	1	71.43%
Setup forwarding	60%	12.00 ± 4.90	7	58.33%
CapCut	56%	10.87 ± 5.56	4.80	44.16%
Create Media Project	60%	13.67 ± 5.25	7	51.20%
Add transition	60%	10.67 ± 4.03	4	37.49%
Crop by Timestamp	60%	11.00 ± 5.66	5	45.45%
Add Sticker	40%	12.00 ± 8.00	4	33.33%
Crop by Content	60%	7.00 ± 1.41	4	57.14%
Meitu	44%	12.36 ± 3.34	8.00	64%
Apply Filter	60%	14.67 ± 2.36	7	47.72%
Cutout	60%	9.33 ± 1.89	5	53.59%
Add Sticker	40%	9.50 ± 0.50	8	84.21%
Create Collage	40%	16.00 ± 2.00	12	75.00%
Add Frame	20%	13.00 ± 0.00	7	53.85%
Feishu	56%	7.50 ± 4.50	4.00	46.07%
Create Appointment	40%	8.00 ± 1.00	4	50.00%
Message Contact	40%	6.00 ± 1.00	3	50.00%
Send file	20%	11.00 ± 0.00	7	63.64%
Set User Status	100%	14.60 ± 7.50	3	20.55%
Start Video Conference	80%	4.50 ± 2.60	3	46.15%

are described in Appendix D. Therefore, here we emphasize any application-specific differences or customization.

To apply CRADLE to the target application set described in this appendix, we start with base common prompts, and customize those prompts for specific modules, if necessary, to handle application-specific characteristics. For example, for CapCut we add few-shot examples for Self-Reflection, to let it properly perform success detection, as the application UI by itself is non-standard and sometimes provides little post-action feedback to users, making it harder for the backend model to determine action success.

Information Gathering. Noticeably, GPT-4o presents the same limitations in both spatial reasoning (*e.g.,* confusing up/down, left/right) and image understanding identifying specific UI items or the state of the forefront GUI, across all applications.

To help mitigate such issues, we perform augmentation on the captured screenshots similarly to the Set-of-Mark (SoM) approach Yang et al. (2023a), by only utilizing SAM Kirillov et al. (2023) to generate potential UI items bounding boxes and assign them numerical tags. Our SoM-like augmentation *differs* from recent agent-related work (*e.g.,* (Zhang et al., 2024; Xie et al., 2024)), which use

OS-specific APIs to draw ground-truth bounding boxes for interactable elements (plus UI structure info, like types and element tree) to the results, while **CRADLE** relies only on image input and the segmentation output as augmentation. To make this distinction explicit, we call our augmentation approach SAM2SOM [10]. Figure 47 illustrates the difference. While our approach produces many more potential bounding boxes, it is more general by relying only on a screenshot (or video frame).

To ensure all bounding box labels are consistently positioned, **CRADLE**'s SAM2SOM implements two rendering styles, as shown in Figure 45 first and second rows. In the *standard* style, we pad the SAM2SOM-enhanced image when showing the label IDs in the upper left corner of the bounding boxes (to prevent labels from hiding the contents of small areas), so no numerical label ID is drawn outside the image area). In the *uniform* style, all bounding boxes utilize single-color borders with labels in black text over white background, placed within the bounding box area (top left corner).

Moreover, in specific situations we may still need to refine SAM2SOM's output further. For example, in the Feishu case, we observe that watermarks generated by the software affect the segmentation negatively, complicating GPT-4o's selection of the correct bounding boxes to interact with. Therefore, we implement a simple filtering method for such watermarks. This filter is enabled only in the Feishu benchmark and, as shown in Figure 46, can greatly reduce the number of unnecessary bounding boxes (from 216 to 166, in this example).

In addition to using the SAM2SOM method for image augmentation, we also redraw the mouse pointer not present in captured screenshots in a more prominent magenta color based on its screen position, to emphasize both its presence and position for image understanding (*e.g.,* Figure 44). The augmentation process in Information Gathering can then result in four versions of a screenshot: a) base image, b) SAM2SOM image, c) base image with mouse pointer, and d) SAM2SOM image with mouse pointer.

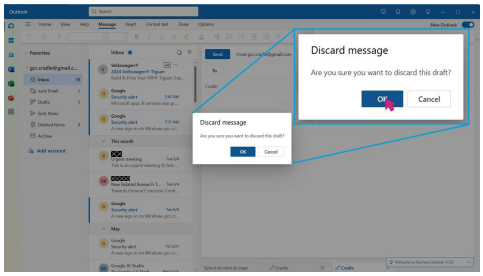
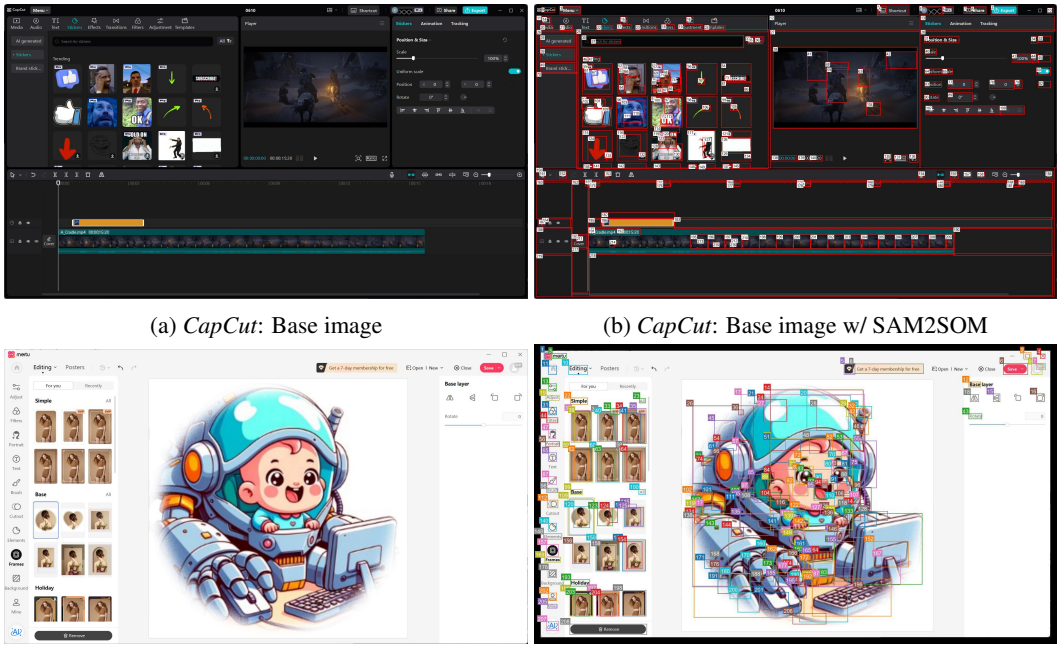


Figure 44: Sample augmented image w/ drawn mouse pointer. Zoom overlay shows the image difference.

Self-Reflection. As the applications in the software set are much less dynamic than complex games, there is no need to send multiple video frames to Self-Reflection. For the software applications, pre- and post-action screenshot usually suffice, *i.e.,* one image before and one image after an action is executed. Digital games often have continuous and dynamic environments that require multiple frames to properly capture the full context and thus help the backbone LMMs understand what happened. In contrast, software operations are typically more discrete and static, where the state before and after an action provides sufficient information for most analysis.

Nonetheless, we find that irrespective of images used, GPT-4o sometimes can have difficulty determining the success of certain tasks. For example, when downloading a file on Chrome, after either pressing 'Ctrl + S', or using a 'Save' menu, the agent must also press 'Enter' or click the 'Save' button to complete the task. However, GPT-4o often assumes the task is complete when the dialog opens and before this final step. Similar cases of incorrect conclusion happen when an action correctly closes a new panel or dialog. To address this category of issues, we add mandatory reasoning rules in the prompt for the Self-Reflection module to help mitigate such mistakes. If for specific applications this still remains an issue, we can use few-shot image examples to reinforce how the backend model should correctly judge success.

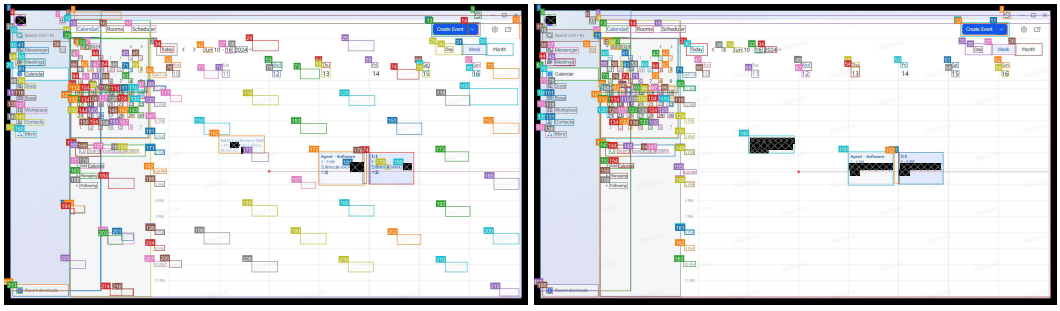
[10] We do not claim the method itself as a core contribution. SAM2SOM is used to illustrate a possible extra capability of the backend model, as mitigation for current spatial reasoning issues.



(a) *CapCut*: Base image (b) *CapCut*: Base image w/ SAM2SOM

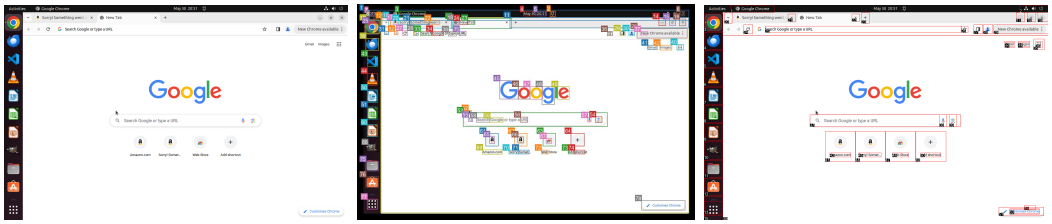
(c) *Meitu*: Base image (d) *Meitu*: Base image w/ SAM2SOM

Figure 45: Image examples of the two SAM2SOM augmentation styles. As CapCut's UI (top row) has very dark background, we utilize single-color borders with IDs in black text over white background, placed within the bounding box area. Other application software and OSWorld use the "standard" SAM2SOM multi-color style, as shown for Meitu (bottom row).

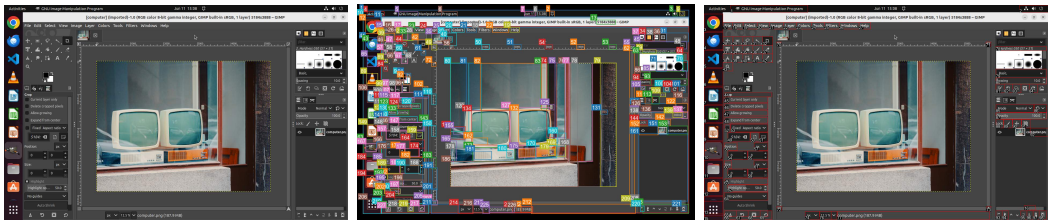


(a) SAM2SOM image w/ watermarks (b) SAM2SOM image w/o watermarks

Figure 46: Examples of filtering watermark in Feishu. The number of labels is greatly reduced from 216 to 166.



(a) Chrome window (b) **CRADLE** SAM2SOM output (c) *OSWorld* SOM image output



(d) GIMP window (e) **CRADLE** SAM2SOM output (f) *OSWorld* SOM image output

Figure 47: Comparison of **CRADLE**'s visual-only SAM2SOM and *OSWorld*'s API-based SOM image results. Chrome: 78 vs. 53 bounding boxes; GIMP: 227 vs. 98 bounding boxes.

Skill Curation. In software tasks, direct skill generation was not necessary, as UI operations generally map closely to specific mouse or keyboard actions, making them more straightforward. In contrast, digital game environments involve continuous interactions and decision-making, raising new previously undiscovered information, and requiring the development of new skills to handle novel scenarios and adapt to changing contexts.

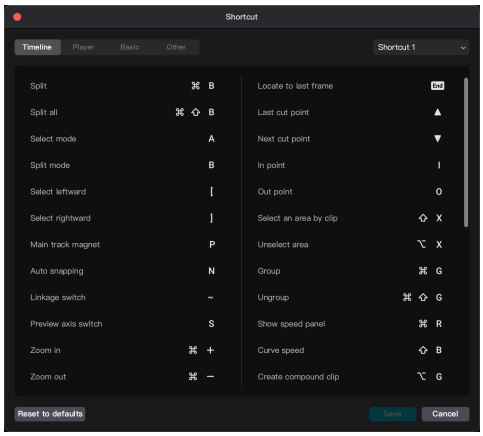


Figure 48: Shortcuts screen in CapCut.

However, we do add some additional pre-defined skills, on a per-application basis, for specific knowledge like less-widely known keyboard shortcuts which could be learnt from the application. For example, CapCut's shortcuts screen, shown in Figure 48, or toolbar/icon processing output similarly to the process described for Cities: Skylines. Moreover, we also introduce pre-defined complex skills to demonstrate **CRADLE**'s capability to leverage tools into novel functionality, such as using GPT-4o as a tool to extract information from a video to complete task 5 in CapCut.

When dealing with shortcuts, *e.g.,* as alternatives to mouse operations, it may be the case that specific shortcuts require "calibration". For example, using the keyboard to navigate the timeline in CapCut (as seen in the bottom area of Figure 45b) requires mapping the keyboard shortcut ('Alt + arrow keys') to pixels or time, which we perform a priori and use the mapping in the pre-defined skill go_to_timestamp(seconds).

Task Inference. During the execution of an application task, we let GPT-4o decompose the execution strategy for the next step based on the overall task description and the subtask description. If the previous task decomposition is found to be unreasonable, a new decomposition plan should be proposed and this is evaluated at each iteration round.

Action Planning. To enable usage of SAM2SOM, for Action Planning, we insert new mouse skills, which mirror existing coordinates-based mouse skills (*i.e.,* that use x,y coordinates), but take a bounding box numerical label as an argument.

Furthermore, unlike in game playing, which focuses on performing one action per turn, when manipulating software **CRADLE** can be configured to perform two actions in sequence and thus lower interaction frequency requirements to the backend model. We find that GPT4-o can usually correctly output two-step compound actions. For example, when performing a search in the browser, it can typically output two consecutive action steps, *e.g.,* type_text(text='{user_query}'), followed by the required press_key(key='enter').

Action Execution. While atomic and composite skills can involve complex operations, Action Execution happens over the regular **CRADLE** action space, as shown in Table 7. For example, during Action Execution, a post-processing step converts the bounding box calls into regular mouse actions, using the centroid of a given bounding box as its coordinates for regular mouse operations.

Tool usage, like calling GPT-4o separately to analyze the contents of a media file, is not considered as an action, as tools do not operate on the environment, only as code steps inside a composite skill.

I.5 CASE STUDIES

I.5.1 TASK HARDNESS

It is well known that the difficulty of task completion can vary widely between humans and agents. The results in Table 15 help illustrate some such cases. While many application operation issues may be attributed to UI variety or non-conformity, that is not necessarily the main source of task hardness (*i.e.,* how unexpectedly complex performing an operation is).

Here we use Outlook, a well-known e-mail client, as a case study to discuss how different factors affect CRADLE task completion in real-world application situations (the exact version used is listed in Table 12). Taking task 1 ("Create a new e-mail to {email_address} with the subject 'Hello friend' and send it.") as an example, a success rate of 40% and efficiency of 45.45% may seem lower than expected.

Such a task could be reasonably broken down into steps like: a) Create new e-mail, b) Add recipient, c) Write title, and d) Send e-mail. And the Task Inference module performs such decomposition consistently. However, Action Planning needs to define specific actionable operations with mouse and keyboard to execute each step.

Firstly, CRADLE needs to decide based on the knowledge and visual understanding capabilities available to it to either use a known keyboard shortcut (*e.g.,* 'Ctrl + N') or to click at the "New mail" button. In our experiments, CRADLE tends to chose clicking on the button, which is then affected by the previously discussed issues that led to the integration of SAM2SOM into the framework. Issues in spatial reasoning issues or icon/image understanding may cause a few incorrect click attempts.

Adding the recipient to the e-mail requires typing an address at the appropriate location, *i.e.,* the typical "To" field. This can be accomplished in multiple ways, mainly by typing the address on the UI next to the "To" item or choosing a pre-existing contact.

Clicking on the "To" button triggers the UI to search and select a pre-existing contact e-mail address (with no option of adding a new contact entry, which requires first accessing the "Contacts" menu, outside of "Mail"). Moreover, the UI interaction sequence to select an existing contact can be unintuitive even to experienced users, requiring a minimum of four steps, at each step offering multiple UI options that go away from contact selection. Attempting this flow usually leads CRADLE to exceed the maximum number of allowed step as it gets confused by the UI design.

Nonetheless, choosing the simpler alternative of typing the e-mail address (assuming the correct text field is selected) triggers assistive UI pop-ups (as shown in Figure 50), which lead GPT-4o to falsely conclude the e-mail address is either already typed at the correct location or that it is duplicated and needs to be edited/removed. Furthermore, the pop-ups partially hide the subject area, making it harder for CRADLE to choose the next UI item to interact with for the next task step.

Similar issues with positioning and correctly identifying the typed subject text can also occur, but at a much smaller frequency.

Lastly, completing the task and sending the e-mail requires step similar to creating a new message. But determining send success requires additional attention/reflection as not all cases of the "Send mail" interface disappearing indicate a successful send (*e.g.,* clicking on an unrelated e-mail on the Inbox or closing the current window pop-up).

The Self-Reflection module plays a key role in moving task completion forward by detecting failed attempts at executing each sub-task and providing rationale for failures, even if Information Gathering and Action Planning make repeated mistakes. Such feedback from Self-Reflection and allows Action Planning to tune its process and move ahead.

I.5.2 Tool Use in CapCut

Some general computer control tasks may require additional capabilities during execution preparation that can benefit from external tools to enhance agent abilities.

When performing video editing, like in CapCut, a user may need to determine the precise frames to operate on based on video content. For such scenarios, CRADLE can easily leverage tool-using skills, like the LMM's ability to understand actions in a sequence of video frames, enabling it to comprehend video content and identify the exact frames for editing.

We exemplify such tasks with task 5 ("Crop the video when the ball enters the goal, and then export the video") for CapCut, as illustrated in Figure 49. This means our agent can effectively execute tool usage to find the specific frame where "the ball enters the goal". After the first round of Task Inference, CRADLE decomposes the task into three subtasks: 1. Identify the exact frame, 2. Crop the video, and 3. Export the video. Action Planning can then plan to execute

'get_information_from_video(event)' from our curated skills and generate "ball enters the goal" as its required argument for execution.

In this skill, we input a frame set of the video at 1 fps to identify the specific frame where the event occurs. The response is then recorded in Episodic Memory to ensure that subsequent operations can accurately utilize it and target the moment when the action occurs. Across subsequent iterations, **CRADLE** can then correctly plan and execute the remaining necessary actions for task completion: 'go_to_timestamp(seconds=8)', 'delete_right()', and 'export_project()'].

We have integrated few-shot learning into Self-Reflection to ensure **CRADLE** recognizes that following export_project(), the expected screen is the CapCut application main window. This information allows it to verify the successful execution of the task, leading to success detection for the overall task.

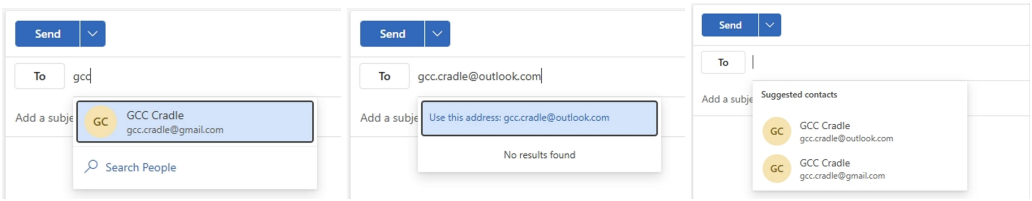
Figure 49: Showcase of Task 5 ("Crop the video when the ball enters the goal, and then export the new video") in CapCut.

I.6 LIMITATIONS OF GPT-4O

Besides the previously discussed limitations of GPT-4o, it is important to highlight a couple other GUI grounding issues.

Non-standard UI and Noise.

Non-standard UI, be it in visual style or in behaviour, can lead GPT-4o to misinterpret UI item functionality and application context state. The same applies to visual noise in the form of update pop-up, external contents (*e.g.,* ads), new e-mail/chat messages, etc.



(a) Pre-existing contact dropdown (b) Contact search dropdown (c) Contact suggestions

Figure 50: Visual behaviour in Outlook that may lead GPT-4o to visual understanding mistakes.

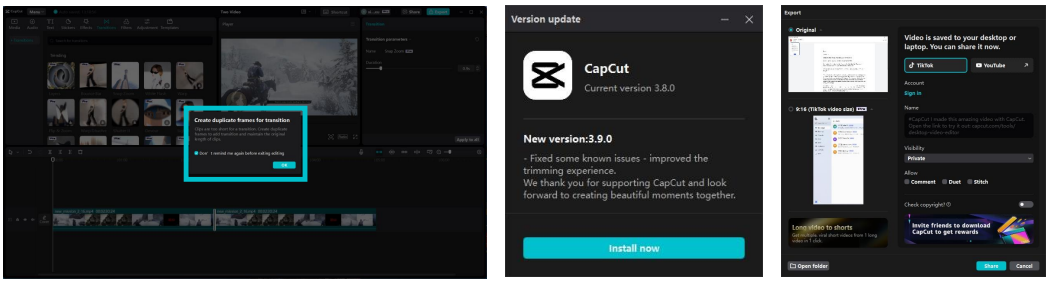


Figure 51: Different *CapCut* pop-ups

CapCut is affected by both factors, as further illustrated in Figure 51. Moreover, its UI includes non-standard layouts involving precise positioning and drag/dropping. Lack of such prior knowledge by GPT4-o and differences in behaviour between similar functions, may also lead to mistakes in trying to decompose actions to perform. E.g., "Add an effect" requires very different UI-interaction depending on details. Users can add effects in three different ways: i) dragging an effect to the timeline; ii) click the plus sign in a given effect in the effects panel, which adds the effect to the current place on the timeline; and iii) drag an effect directly onto a video and apply the effect to the entire video.

Visual Context Detail.

GPT-4o still struggles with detailed visual understanding and over-relies on textual information or hallucinations, which results in insufficient attention to visual context and leads to understanding and reasoning mistakes.

One such common example is GPT-4o declaring a dialog state to be ready to press a button like "Save", while ignoring no file name was provided, even if GPT-4o has been prompted to check for such situations. The same applies to it suggesting keyboard shortcuts to open menus that do not exist in the image being interpreted, *e.g.,* trying to press ‘Alt + F’ to open the "File" menu on a screenshot that has no "File" menu.

Lastly, this lack of attention to context details can also affect understanding the outcome of operations over visual content, leading to incorrect estimation of operation success, *e.g.,* when retouching an image or deciding between a circle and a heart for a shape form.

J OSWORLD

J.1 INTRODUCTION TO OSWORLD

OSWorld is a scalable, computer environment designed for multimodal agents. This platform provides a unified environment for assessing open-ended computer tasks involving various applications.

J.2 OSWORLD TASKS

OSWorld is a benchmark suite of 369 real-world computer tasks (mostly on an Ubuntu Linux environment, but including a smaller set on Microsoft Windows) collected from authors and diverse

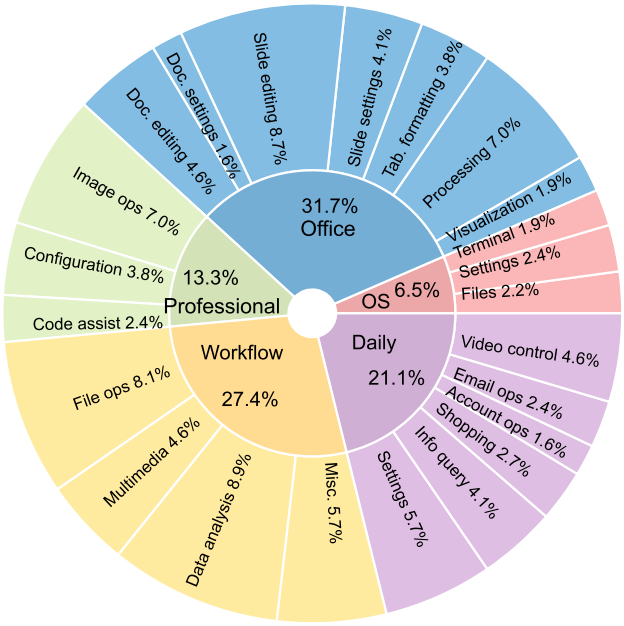


Figure 52: Task instructions distribution in OSWorld Xie et al. (2024)

sources such as forums, tutorials, guidelines. Each task is annotated with a natural language instruction and a manually crafted evaluation script for scoring.

J.3 Implementation Details

The OSWorld environment uses a virtual machine that takes in Python scripts based on PyAutoGUI for actions and provides screenshots and an accessibility tree for observations. We strictly follow the GCC settings. Our agent only uses the screenshot as input and outputs Python scripts using PyAutoGUI methods to control the keyboard and mouse (these operations are analogous to the regular action space for **CRADLE**). All 369 tasks use a same set of prompt templates.

We employ GPT-4o as the framework's backbone model. We use the default experimental settings, as in OSWorld's baseline agent. The executable action space is the same as the OSWorld setting, the atomic skills are as follows:

- **Mouse Actions**
  - *move_mouse_to_position(x, y)*: Moves the mouse to a specified position on the screen.
  - *click_at_position(x, y)*: Performs a click at a specified position.
  - *mouse_down(button)*: Presses the specified mouse button.
  - *mouse_up(button)*: Releases the specified mouse button.
  - *right_click(x, y)*: Right-clicks at the specified position.
  - *double_click_at_position(x, y)*: Double-clicks at the specified position.
  - *mouse_drag(x, y)*: Drags the cursor to the position.
  - *scroll(direction, amount)*: Scrolls the mouse wheel up or down by a specified amount.
- **Keyboard Actions**
  - *type_text(text)*: Types the specified text.
  - *press_key(key)*: Presses and releases the specified key.
  - *key_down(key)*: Holds a specified key.
  - *key_up(key)*: Releases a specified key.
  - *press_hotkey(keys)*: Presses a combination of keys and releases them in the opposite order (e.g., Ctrl+C), useful for shortcuts.

- **Task Status**
  - *task_is_not_feasible()*: Indicates that the task cannot be completed, providing feedback for scenarios where the agent encounters infeasible tasks.

Many of these basic skills require GPT-4o to directly output an (x,y) position based on a screenshot. Given that the current GPT-4o is not able to achieve such precise control, we use a grounding tool to augment the screenshot. This way, GPT-4o only needs to choose an object ID. With the object ID and the bounding box of the object, we automatically convert it to the (x,y) position needed for skill execution. Instead of having GPT-4o directly choose the executable skills that require (x,y) position input, we provide several skills that only require a label ID as input for GPT-4o.

- **Actions with Grounding Tools**
  - *click_on_label(label_id)*: Clicks on a specified label in the grounding result.
  - *double_click_on_label(label_id)*: Double-clicks on a specified label in the grounding result.
  - *hover_over_label(label_id)*: Moves the mouse to hover over a specified label in the grounding result.
  - *mouse_drag_to_label(label_id)*: Drags the mouse to a specified label in the grounding result.

Information Gathering. Tasks in OSWorld require pixel-level mouse control. While GPT-4 exhibits grounding ability, using tools like SAM can further augment the screenshot with the grounding of icons in complex computer control tasks. The bounding box is helpful for GPT-4 to understand the occurrence of objects on the screen and can also be used to calculate the precise position for mouse control.

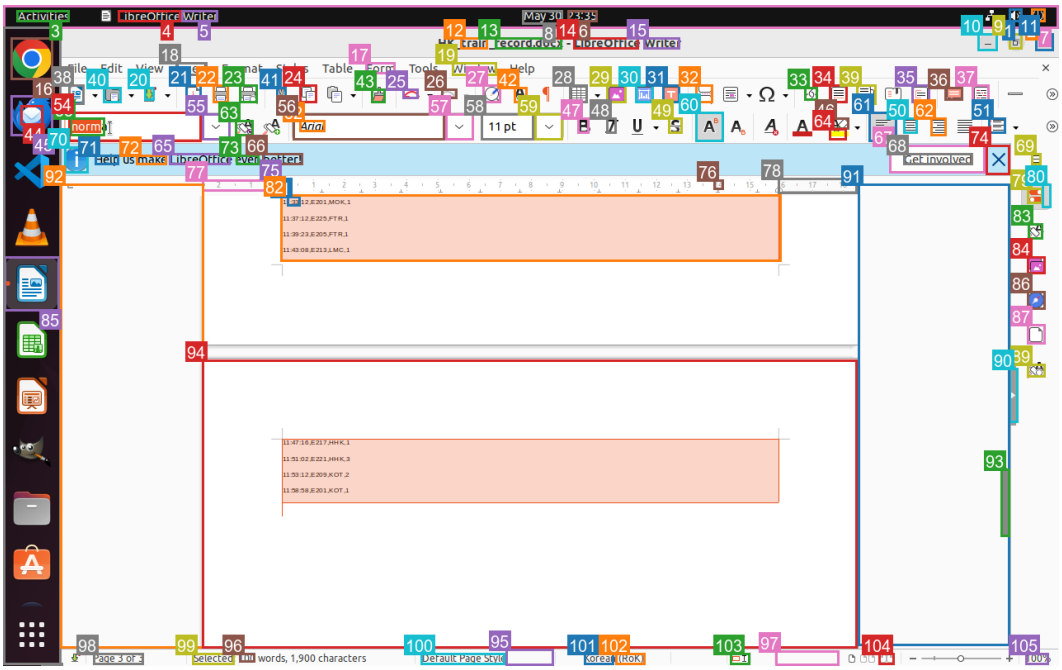


Figure 53: Augmented screenshot using CRADLE's SAM2SOM

Self-Reflection. The reflection module evaluates whether previous actions have been successfully executed and determines if the entire task was successful. The self-reflection module is important for tasks in OSWorld, which are sequential decision-making problems that require re-planning based on the current state and previous actions. The self-reflection module also helps to identify infeasible tasks.

J.4 Application Target and Setting Challenges

Evaluations within OSWorld reveal notable challenges in agents' abilities, particularly in GUI understanding and operational knowledge Xie et al. (2024). To further complete tasks in OSWorld, the agent needs advanced visual capabilities and robust GUI interaction abilities. Furthermore, the agents face challenges in leveraging lengthy raw observation and action records. The next-level approach encompasses designing more effective agent architectures that augment the agents' abilities to explore autonomously and synthesize their findings.

J.5 Case Studies

J.5.1 Information Gathering

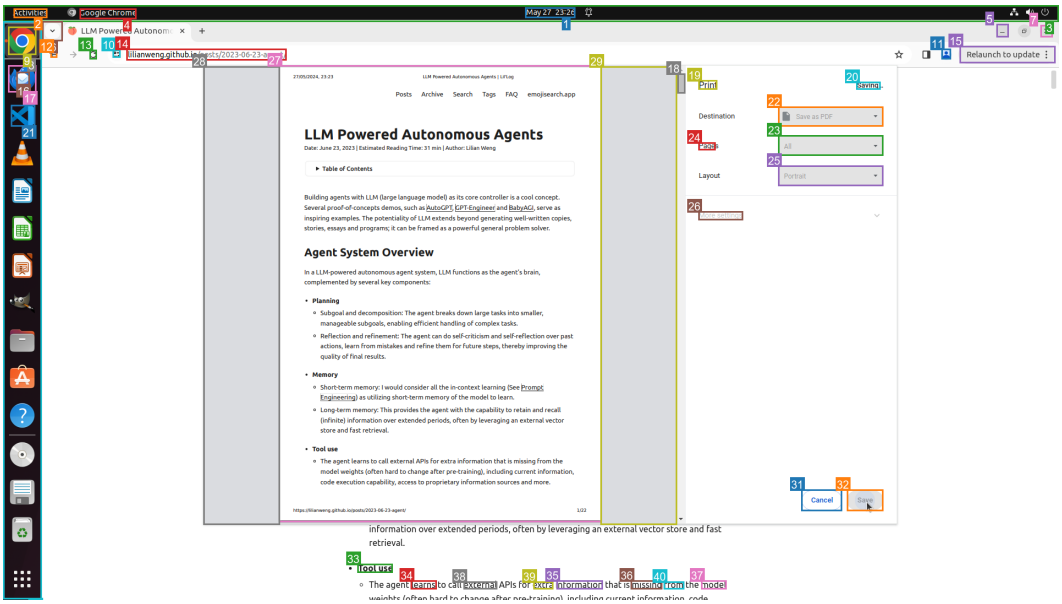


Figure 54: Case Study of robust and precise GUI interaction via information gathering

With SAM as the grounding tool, we prompt the agent to identify the objects in each bounding box to determine the exact position of each object. As shown in Figure 54, the agent recognized the GUI element in box 32 as the Save button. In the planner, the agent chose to click on box 32 to save the PDF, resulting in success.

J.5.2 Planning with Self-Reflection

We showcase how self-reflection combined with planning helps the agent complete a task by coming up with an alternative plan and validating its success.

The current task instruction is "Copy the file 'file1' to each of the directories 'dir1', 'dir2', 'dir3'." As shown in Figure 55, the agent made two attempts at implementing the command but encountered errors and warnings.

As shown in Figure 56, after observing the errors and warnings in the previous steps, the agent checked the files in the directory to debug. After confirming the file structure, the agent tried different commands.

As shown in Figure 57, after executing the new command without receiving an error message, the agent checks whether the files have been copied to the folders. After observing the result, it marks this task as a success.

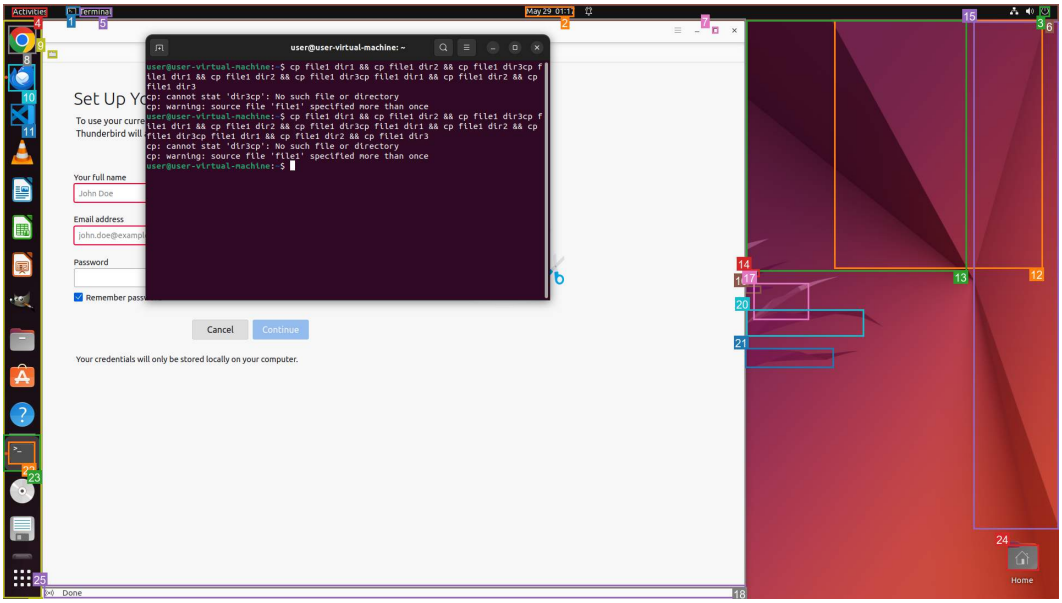


Figure 55: The agent fails to copy the files due to using incorrect commands

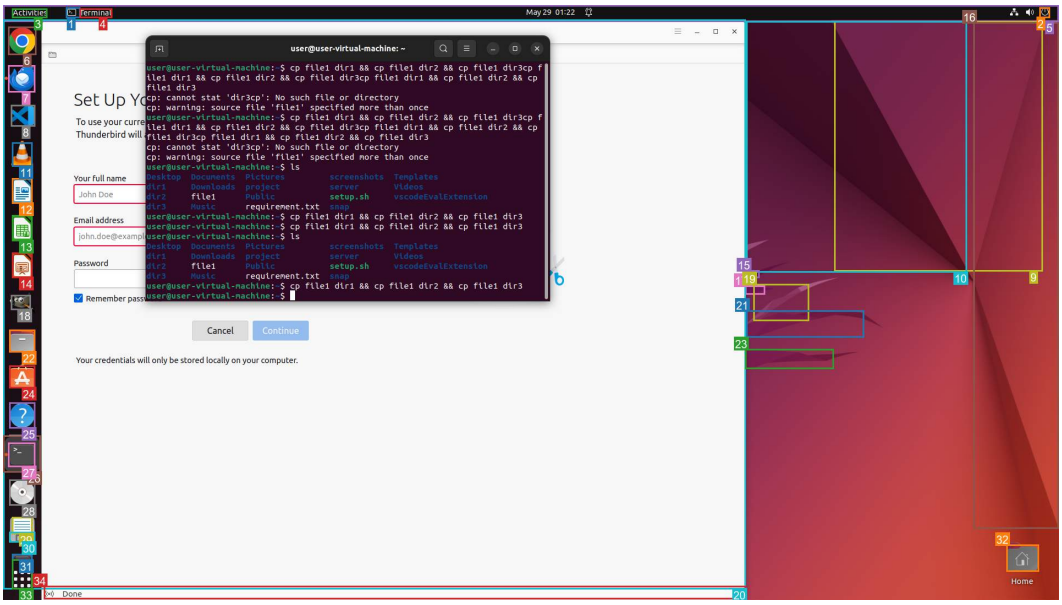


Figure 56: The agent reflects on the errors, checks the file structure and tries to debug

Table 16: Detailed success rates divided by domains: OS, LibreOffice Calc, LibreOffice Impress, LibreOffice Writer, Chrome, VLC Player, Thunderbird, VS Code, GIMP, and Workflow (*i.e.,* involves multiple applications).

Method	OS (24)	Calc (47)	Impress (47)	Writer (23)	VLC (17)	TB (15)	Chrome (46)	VSC (23)	GIMP (26)	Workflow (101)
GPT-4o	8.33	0.00	6.77	4.35	16.10	0.00	4.35	4.35	3.85	5.58
GPT-4o+SoM	20.83	0.00	6.77	4.35	6.53	0.00	4.35	4.35	0.00	3.60
CRADLE	16.67	0.00	4.65	8.70	6.53	0.00	8.70	0.00	38.46	5.48

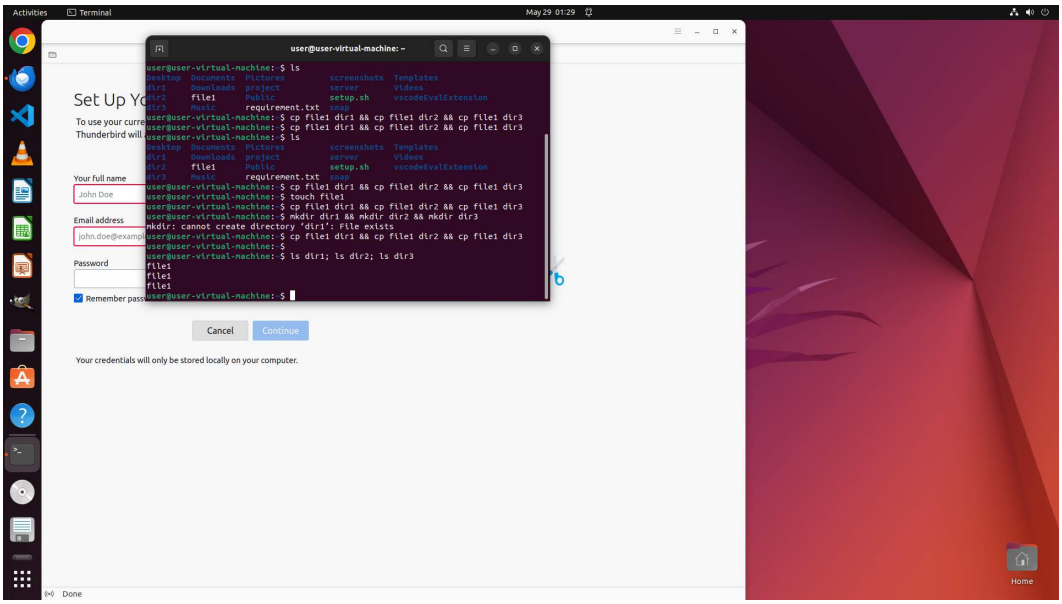


Figure 57: The agent checks if the files have already been copied

J.6 Quantitative Evaluation

The detailed success rates for each application are listed in Table 16. We followed the same experimental settings as the OSWorld paper, running the experiment only once. Our results show that our agent performs better in the Chrome and GIMP domains. However, the difference in performance in the OS, Writer, and VSC domains is less statistically significant due to the smaller number of tasks. While improved information gathering and self-reflection empowered the agent in these domains, the complex pipeline and limitations of current grounding tools and GPT-4 hindered performance in domains like VLC and VSC. We identify these limitations as future directions for implementing the agent in real-world scenarios.

K Cradle Prompts

Here we exemplify the utilized prompts, for each module in the framework. All prompts and customizations are included in the relevant branch in **Cradle**'s open-source repository in GitHub [11].

K.1 Prompts for RDR2

Prompt 1: RDR2: Information Gathering prompt.

```
Assume you are a helpful AI assistant integrated with 'Red Dead
    Redemption 2' on the PC, equipped to handle a wide range of tasks in
    the game. Your advanced capabilities enable you to process and
    interpret gameplay screenshots and other relevant information.

<$few_shots$>

<$image_introduction$>

Current task:
<$task_description$>

Target_object_name: Assume you can use an object detection model to
    detect the most relevant object for completing the current task if
```

[11] https://cradle2024acc.github.io/Cradle

```
    needed. What object should be detected to complete the task based on
    the current screenshot and the current task? You should obey the
    following rules:
1. The object should be relevant to the current target or the
    intermediate target of the current task. Just give one name without
    any modifiers.
2. If no explicit weapon is specified on the weapon radial menu,
    prioritize choosing 'gun' as the weapon.
3. If no explicit shoot target is specified, prioritize choosing 'person'
     as the target.
4. If no explicit item is specified, only output 'null'.
5. If the object name belongs to the person type, replace it with 'person
    '.
6. If there is no need to detect an object, only output "null".
7. If you are on the trade, map, inventory, or satchel interfaces, only
    output 'null'.

Reasoning_of_object: Why was this object chosen, or why is there no need
    to detect an object?

Description: Please describe the screenshot image in detail. Pay
    attention to any maps in the image, if any, especially critical icons
    , red paths to follow, or created waypoints. If there are multiple
    images, please focus on the last one.

Screen_classification: Please select the class that best describes the
    screenshot among "Inventory", "Radial menu", "Satchel", "Map", "Trade
    ", "Pause", and "General game interface without any menu". Output the
     class of the screenshot in the output of Screen_classification.

Reasoning_of_screen: Why was this class chosen for the current screenshot
    ?

Movement: Does the current task require the character to go somewhere?

Noun_and_Verb: The number of nouns and verbs in the current task.

Task_horizon: Please judge the horizon of the current task, i.e., whether
     this task needs multiple or only one interaction.
There are two horizon types: long-horizon and short-horizon. For long-
    horizon tasks, the output should be 1. For short-horizon tasks, the
    output should be 0. You should obey the following rules:
1. If the task contains only nouns without verbs, it is short-horizon.
2. If the task contains more than one verb, it is long-horizon.
3. If the task requires the character to go somewhere, it is long-horizon
    .
Short-horizon tasks are sub-goals during a long-horizon task, which only
    need one interaction. There are some examples of short-horizon tasks:
1. Pick up something: To complete this task, the character needs to
    execute the action "pick up" only once, so it is short-horizon.
2. Use or press [B] key: The character needs to press the key [B] only
    once to talk, so it is short-horizon.
3. Talk to somebody: The character needs to press a certain button once
    to complete this task, so it is short-horizon.
Long-horizon tasks are long-term goals, which usually need many
    interactions. There are some examples of long-horizon tasks.
1. Go outside: The character should go outside step by step, so it is
    long-horizon.
2. Approach something: The character should move closer to the target
    step by step, so it is long-horizon.
3. Keep away from something, shoot, take down, or battle with something:
    The character must engage in a series of interactions, so it is long-
    horizon.

Reasoning_of_task: Why do you make such a judgment of task_horizon?
```

```
You should only respond in the format described below and not output
    comments or other information.
Target_object_name:
Name
Reasoning_of_object:
1. ...
2. ...
...
Description:
The image shows...
Screen_classification:
Class of the screenshot
Reasoning_of_screen:
1. ...
2. ...
...
Movement:
Yes or No
Noun_and_Verb:
1 noun 1 verb
Task_horizon:
1
Reasoning_of_task:
1. ...
2. ...
...
```

Prompt 2: RDR2: Gather Text Information prompt.

```
Assume you are a helpful AI assistant integrated with 'Red Dead
    Redemption 2' on the PC, equipped to handle a wide range of tasks in
    the game. Your advanced capabilities enable you to process and
    interpret gameplay screenshots and other relevant information.

<$image_introduction$>

Information: List all text prompts on the screenshot from the top to the
    bottom, even the text prompt is one word.

All information should be categorized into one or more kinds of <
    $information_type$>. If you think a piece of information is both "A"
    and "B" categories, you should write information in both "A" and "B"
    categories. For example, "use E to drink water" could both be "Action
     Guidance" and "Task Guidance" categories.

Item_status: The helpful information to the current context in the game,
    such as the cash, amount of ammo, current using item, if the player
    is wanted, etc. This content should be pairs of status names and
    their values. For example, "cash: 100$". If there is no on-screen
    text and no item status, only output "null".

Environment_information: The information about the location, time,
    weather, etc. This content should be pairs of status names and their
    values. For example, "location: VALENTINE". If there is no on-screen
    text and environment information, only output "null".

Notification: The game will give notifications showing the events in the
    world, such as obtaining items or rewards, completing objectives, and
     becoming wanted. Besides, it also contains valuable notifications of
     the game's mechanisms, such as "Health is displayed in the lower
    left corner". The content must be the on-screen text. If there is no
    on-screen text or notification, only output "null".

Task_guidance: The content should obey the following rules:
```

```
1. The content of task guidance must be an on-screen text prompt,
    including the menu and the general game interface.
2. The game will give guidance on what should be done to proceed with the
     game, for example, "follow Tom". This is task guidance.
3. The game will give guidance on how to perform a task using keyboard
    keys or mouse buttons, for example, "use E to drink water". This is
    task guidance.
4. If no on-screen text prompt or task guidance exists, only output "null
    ". Never derive the task guidance from the dialogue or notifications.

Action_guidance: The game will give guidance on how to perform a task
    using keyboard keys or mouse buttons; you must generate the code
    based on the on-screen text. The content of the code should obey the
    following code rules:
1. You should first identify the exact keyboard or mouse key represented
    by the icon on the screenshot. 'Ent' refers to 'enter'. 'RM' refers
    to 'right mouse button'. 'LM' refers to 'left mouse button'. You
    should output the full name of the key in the code.
2. You should refer to different examples strictly based on the word used
     to control the key, such as 'use', 'hold', 'release', 'press', and '
    click'.
3. If 'use' or 'press' is in the prompt to control the keyboard key or
    mouse button, io_env.key_press('key', 2) or io_env.mouse_click('
    button', 2) must be used to act on it. Refer to Examples 1, 2, and 3.
4. If there are multiple keys, io_env.key_press('key1,key2', 2) must be
    used to act on it. Refer to Example 4.
5. If 'hold' is in the prompt to control the keyboard key or mouse button
    , it means keeping the key held with io_env.key_hold or the button
    held with io_env.mouse_hold (usually indefinitely, with no duration).
     If you need to hold it briefly, specify a duration argument. Refer
    to Examples 5 and 6.
6. All durations are set to a minimum of 2 seconds by default. You can
    choose a longer or shorter duration. If it should be indefinite, do
    not specify a duration argument.
7. The name of the created function should only use phrasal verbs, verbs,
     nouns, or adverbs shown in the prompt and should be in the verb+noun
     or verb+adverb format, such as drink_water, slow_down_car, and
    ride_faster. Note that words that do not show in the prompt are
    prohibited.

This is Example 1. If "press" is in the prompt and the text prompt on the
     screenshot is "press X to play the card", your output should be:
'''python
def play_card():
    """
    press "x" to play the card
    """
    io_env.key_press('x', 2)
'''
This is Example 2. If the instructions involve the mouse and the text
    prompt on the screenshot is "use the left mouse button to confirm",
    your output should be:
'''python
def confirm():
    """
    use "left mouse button" to confirm
    """
    io_env.mouse_click("left mouse button")
'''
This is Example 3. If "use" is in the prompt and the text prompt on the
    screenshot is "use ENTER to drink water", your output should be:
'''python
def drink_water():
    """
    use "enter" to drink water
```

```
    """
    io_env.key_press('enter', 2)
```
This is Example 4. If "use" is in the prompt and the text prompt on the screenshot is "use W and J to jump the barrier", your output should be:
```python
def jump_barrier():
    """
    use "w" and "j" to jump the barrier
    """
    io_env.key_press('w,j', 3)
```
This is Example 5. If "hold" is in the prompt and the text prompt on the screenshot is "hold H to run", your output should be:
```python
def run():
    """
    hold "h" to run
    """
    io_env.key_hold('h')
```
This is Example 6. If the instructions involve the mouse and the text prompt on the screenshot is "hold the right mouse button to focus on the target", your output should be:
```python
def focus_on_target():
    """
    hold "right mouse button" to focus
    """
    io_env.mouse_hold("right mouse button")
```
This is Example 7. If "release" is in the prompt and the text prompt on the screenshot is "release Q to drop the items", your output should be:
```python
def drop_items():
    """
    release "q" to drop the items
    """
    io_env.key_release('q')
```

Dialogue: Conversations between characters in the game. This content should be in the format of "character name: dialogue". For example, "Arthur: I'm fine". If there is no on-screen text or dialogue, only output "null".

Other: Other information that does not belong to the above categories. If there is no on-screen text, only output "null".

Reasoning: The reasons for classification for each piece of information. If the on-screen text prompt is an instruction on how to perform a task using keyboard keys or mouse buttons, it should also classified as action guidance and task guidance.
For action guidance, which code rules should you follow based on the word used to control the key or button, such as press, hold, release, and click?

The information should be in the following categories, and you should output the following content without adding any other explanation:
Information:
1. ...
2. ...
...

```
Reasoning:
1. ...
2. ...
...
Item_status:
Item_status is ...
Environment_information:
Environment information is ...
Notification:
Notification is ...
Task_guidance:
Task is ...
Action_guidance:
```python
Python code to execute
```
```python
Python code to execute
```
...
Dialogue:
Dialogue is ...
Other:
Other information is ...
```

Prompt 3: RDR2: Self-Reflection prompt.

```
Assume you are a helpful AI assistant integrated with 'Red Dead
    Redemption 2' on the PC, equipped to handle a wide range of tasks in
    the game. Your advanced capabilities enable you to process and
    interpret gameplay screenshots and other relevant information. Your
    task is to examine these inputs, interpret the in-game context, and
    determine whether the executed action takes effect.

Current task:
<$task_description$>

Last executed action:
<$previous_action$>

Implementation of the last executed action:
<$action_code$>

Error report for the last executed action:
<$executing_action_error$>

Reasoning for the last action:
<$previous_reasoning$>

Valid action set in Python format to select the next action:
<$skill_library$>

<$image_introduction$>

Reasoning: You need to answer the following questions step by step to get
     some reasoning based on the last action and sequential frames of the
     character during the execution of the last action.
1. What is the last executed action not based on the sequential frames?
2. Was the last executed action successful? Give reasons. You should
    refer to the following rules:
- If the action involves moving forward, it is considered unsuccessful
    only when the character's position remains unchanged across
    sequential frames, regardless of background elements and other people
    .
```

```
3. If the last action is not executed successfully, what is the most
    probable cause? You should give only one cause and refer to the
    following rules:
- The reasoning for the last action could be wrong.
- Not holding enough time should not be considered in this part.
- If it is an interaction action, the most probable cause was that the
    action was unavailable or not activated at the current place.
- If it is a movement action, the most probable cause was that you were
    blocked by seen or unseen obstacles.
- If there is an error report, analyze the cause based on the report.

You should only respond in the format as described below:
Reasoning:
1. ...
2. ...
3. ...
...
```

Prompt 4: RDR2: Task Inference prompt.

```
Assume you are a helpful AI assistant integrated with 'Red Dead
    Redemption 2' on the PC, equipped to handle a wide range of tasks in
    the game. You will be sequentially given <$event_count$> screenshots
    and corresponding descriptions of recent events. You will also be
    given a summary of the history that happened before the last
    screenshot. You should assist in summarizing the events for future
    decision-making.

The following are <$event_count$> successive screenshots and
    corresponding descriptions:

<$image_introduction$>

The following is the summary of history that happened before the last
    screenshot:
<$previous_summarization$>

Current task:
<$task_description$>

Info_summary: Based on the above input, please make a summary from the
    screenshots with descriptions and the history in no less than 10
    sentences, following the rules below.
1. Summarize the tasks from the history and the current task, with a
    special note on the method of crucial press operations.
2. Summarize the entities and behaviors mentioned in the successive
    descriptions.
3. If entities and behaviors in the history and screenshots are missed in
     the descriptions, please add them to the summarization.
4. Organize the summarization as a story in order of time, including the
    past entities and behaviors.
5. Only give descriptions; do not provide suggestions.

Entities_and_behaviors: Entities and behaviors which are summarized, e.g
    ., The entities include the player's character, the target character,
     and horses for both the player and the target. The behaviors consist
     of the player character riding horseback, following the target on
    horseback, and moving forward to maintain a distance behind the
    target.

The output should be in the following format:
Info_summary:
The summary is...
Entities_and_behaviors:
The summary is...
```

Prompt 5: RDR2: Action Planning prompt.

```
You are a helpful AI assistant integrated with 'Red Dead Redemption 2' on
     the PC, equipped to handle various tasks in the game. Your advanced
    capabilities enable you to process and interpret gameplay screenshots
     and other relevant information. By analyzing these inputs, you gain
    a comprehensive understanding of the current context and situation
    within the game. Utilizing this insight, you are tasked with
    identifying the most suitable in-game action to take next, given the
    current task. You control the game character and can execute actions
    from the available action set. Upon evaluating the provided
    information, your role is to articulate the precise action you would
    deploy, considering the game's present circumstances, and specify any
     necessary parameters for implementing that action.

Here is some helpful information to help you make the decision.

Current task:
<$task_description$>

Memory examples:
<$memory_introduction$>

<$few_shots$>

<$image_introduction$>

Last executed action:
<$previous_action$>

Reasoning for the last action:
<$previous_reasoning$>

Self-reflection for the last executed action:
<$previous_self_reflection_reasoning$>

Summarization of recent history:
<$info_summary$>

Valid action set in Python format to select the next action:
<$skill_library$>

Minimap information:
<$minimap_information$>

Based on the above information, you should first analyze the current
    situation and provide the reasoning for what you should do for the
    next step to complete the task. Then, you should output the exact
    action you want to execute in the game. You should respond to me with
    :

Reasoning: You should think step by step and provide detailed reasoning
    to determine the next action executed on the current state of the
    task. You need to answer the following questions step by step. You
    cannot miss the question number 13:
    1. Only answer this question when the radial menu, trade, map,
    satchel or inventory interfaces are open. You should first describe
    each item in the screen line by line, from the top left and moving
    right. Is the target item in the current screen?
    2. Only answer this question when the radial menu, trade, map,
    satchel or inventory interfaces are open. Which item is selected
    currently?
```

```
    3. Only answer this question when the character is visible in the
    screenshot of the current step. Where is the character in the
    screenshot of the current step?
    4. Where is the target in the screenshot of the current step based on
     the task description, on the left side or on the right side? Does it
     appear in the previous screenshots?
    5. Are there any bounding boxes with coordinates values and object
    labels, such as "door x = 0.5, y = 0.5", shown in the screenshot? The
     answer must be based only on the screenshot of the current step, not
     on any previous steps. If the answer is no, ignore the questions 6
    to 8.
    6. You should first describe each bounding box, from left to right.
    Which bounding box is more relevant to the target?
    7. What is the value x of the most relevant bounding box only in the
    current screenshot? The value is the central coordination (x,y) of
    the central point of the box.
    8. Based on the few shots and the value x, where is the relevant
    bounding box in the current screenshot? Clearly on the left side,
    slightly on the left side, in the center, slightly on the right side,
     or clearly on the right side?
    9. Only answer this question when the radial menu, trade, map,
    satchel or inventory interfaces are not open. Summarize the contents
    of recent history, mainly focusing on the historical tasks and
    behaviors.
    10. Only answer this question when the radial menu, trade, map,
    satchel or inventory interfaces are not open. Summarize the content
    of self-reflection for the last executed action, and do not be
    distracted by other information.
    11. What was the previous action? If the previous action was a turn,
    was it a left or a right turn? If the previous action was a movement,
     were you blocked?
    12. List conditions in action rule 12 and which condition is
    satisfied. Only when you do not satisfy any conditions, summarize the
     content of the minimap information.
    13. This is the most critical question. Based on the action rules and
     self-reflection, what should be the most suitable action in the
    valid action set for the next step? You should analyze the effects of
     the action step by step.

Actions: The best action, or short sequence of actions without gaps, to
    execute next to progress in achieving the goal. Pay attention to the
    names of the available skills and to the previous skills already
    executed, if any. You should also pay more attention to the following
     action rules:
    1. You should output actions in Python code format and specify any
    necessary parameters to execute that action. If the function has
    parameters, you should also include their names and decide their
    values, like "move(duration=1)". If it does not have a parameter,
    just output the action, like "mount_horse()".
    2. Given the current situation and task, you should only choose the
    most suitable action from the valid action set. You cannot use
    actions that are not in the valid action set to control the character
    .
    3. If the target is not on the radial menu, trade, satchel or
    inventory interfaces, you MUST choose the skill 'view_next_page'. For
     the map, ignore the skill 'view_next_page'.
    4. If the minimap information exists, it may include angle
    information for red points, yellow points, or yellow regions. Angle
    information specifies the direction of the corresponding point or
    area. A negative angle indicates the left side, while a positive
    value signifies the right side. If the angle is 30, the corresponding
     point or area is 30 degrees to the character's right. If the angle
    is -50, the corresponding point or area is 50 degrees to the
    character's left. Do not doubt the correctness of these angles; you
    can refer to them when you approach these points or regions.
```

```
    5. When you decide to control the character to move, if the relevant
    bounding box is clearly on the left side in the current screenshot,
    you MUST turn left with a big degree. If the relevant bounding box is
     slightly on the left side in the current screenshot, you MUST turn
    left with a small degree. If the relevant bounding box is clearly on
    the right side in the current screenshot, you MUST turn right with a
    big degree. If the relevant bounding box is slightly on the right
    side in the current screenshot, you MUST turn right with a small
    degree. If the relevant bounding box is on the central side of the
    current screenshot, you can choose to move forward.
    6. When you decide to control the character to move, if yellow
    regions or yellow points exist in minimap information, they are
    related to the current task or instruction. This implies that you
    should approach within the yellow region or approach the yellow
    points. You can refer to the corresponding angle information when
    deciding to approach these regions or points. If red points exist in
    the minimap information, they are also related to the current task or
     instruction. This implies that you should turn towards them, and you
     can also refer to the corresponding angle information.
    7. When you decide to control the character to move, if minimap
    information does not exist, the 'theta' you use to turn MUST be more
    than 10 degrees and less than 60 degrees.
    8. When you decide to control the character to move, if you are in a
    normal road condition, the 'duration' you use to move forward should
    be 1 second. If you have bad road conditions, such as snow, and grass
    , that can slow you down, the 'duration' you use to move forward
    should be 2 seconds.
    9. When you are exploring or searching a place, if you are leaving
    the place, you MUST make a sharp turn to face the inside of the place
    . Any values for degrees are allowed.
    10. If upon self-reflection you think the last action was unavailable
     at the current place, you MUST move to another place.
    11. If upon self-reflection you think you were blocked, you MUST make
     a moderate turn in the same direction as the previous turn action
    and move forward, so that you can pass obstacles.
    12. The conditions to ignore the minimap information for decision-
    making are: 1. When self-reflection implies you were blocked. 2. When
     you were inside the highlighted area in the minimap. If any of the
    conditions satisfied, you must ignore the minimap information for
    decision-making even if it is relevant to the current task.
    13. When you are indoors, or the current task does not imply
    following, you MUST not use the follow action.
    14. When you are outdoors, and the current task implies following,
    you MUST use the follow action.
    15. If you were dead or the game failed, you MUST retry from the
    checkpoint, and MUST NOT restart the mission.

You should only respond in the format described below, and you should not
     output comments or other information:
Reasoning:
1. ...
2. ...
3. ...
Actions:
'''python
    action(args1=x,args2=y)
'''
```

K.2 PROMPTS FOR CITIES: SKYLINES

Prompt 6: Skylines: Information Gathering prompt.

```
Assume you are a helpful AI assistant integrated with 'Cities: Skylines'
    on the PC, equipped to handle a wide range of tasks in the game. Your
```

```
     advanced capabilities enable you to process and interpret gameplay
    screenshots and other relevant information.

<$image_introduction$>

Current task:
<$task_description$>

Description: Please analyze and describe the screenshot image in detail
    and then provide an overall image description. Pay attention to
    anything related to the task. If there are specific features such as
    characters or text, mention these as well.

Budget: Bank Balance is shown at the bottom of the screenshot.

Population: The population of the city is shown at the bottom of the
    screenshot, next to the budget.

Error_message: If there are some in-game error messages, which are
    usually in red color, such as "Space already occupied!", extract the
    text, otherwise, only output "null".

Construction_information: If there is some in-game construction
    information, which is usually in blue colors, such as "Construction
    cost: 2500 Estimated production:0 m^3/week" and "Construction cost:
    2500 Shoreline recommended", extract the text, otherwise, only output
     "null".

Other: Other information that does not belong to the above categories. If
     none of them applies, only output "null".

You should only respond in the format described below and not output
    comments or other information.
Description:
The image shows...
Budget:
The amount of budget
Population:
The amount of population
Error_message:
The text of the error message
Construction_information:
The text of the construction information
Other:
Other information is
```

Prompt 7: Skylines: Self-Reflection prompt.

```
Assume you are a helpful AI assistant integrated with 'Cities: Skylines'
    on the PC, equipped to handle a wide range of tasks in the game. Your
     advanced capabilities enable you to process and interpret gameplay
    screenshots and other relevant information. Your task is to examine
    these inputs, interpret the in-game context, and determine whether
    the executed action takes effect.

Target task:
<$task_description$>

Current subtask for completing the target task:
<$subtask_description$>

Current coordinates:
<$coordinates$>

Last executed action for completing the subtask:
```

```
<$actions$>

Error message for the last executed action:
<$error_message$>

Construction information:
<$construction_information$>

Summarization of recent history:
<$history_summary$>

<$image_introduction$>

Reasoning: You MUST answer the following questions step by step to get
    some reasoning based on the last action and sequential frames during
    the execution of the last action.
1. What is the executed action? Please answer this question not based on
    the sequential frames.
2. Is the construction information provided in the information shown
    above? If yes, what is it?
3. Was the last executed action successful? Give reasons. You should
    refer to the following rules:
- Buildings and roads cannot be built on the river.
- Water pumping station and water drain pipe need to be built as close as
     possible to the river.
- If you are try_place a water pumping station and the construction
    information provided above shows that the estimated production is 0 m
    ^3/week, then it means that it is not close enough to the river. So
    you need to try_place to place the building to another place. If the
    estimated production is not 0 m^3/week, or the construction
    information is not provided, regard this action as a success. You
    should only refer to the textual construction information instead of
    extracting it from the sequential frames.
- If you are try_place a water drain pipe and the construction
    information shows that shoreline is recommended. Then it means that
    it is not close enough to the river. So you need to try_place to
    place the building in another place.
- Roads are prohibited from crossing together and do not build roads on
    water.
4. If the last action is not executed successfully, what is the most
    probable cause? How to improve this action? You should give only one
    cause and refer to the following rules:
- The reasoning for the last action could be wrong.
- If there is an error message for the last executed action provided in
    the above information, analyze the cause based on the report,
    otherwise, you should regard that there are no error messages. You
    are not allowed to guess the error message by yourself.
5. Is the subtask completed? Give your reasons. You MUST remember that
    action starts with "try_place" can NEVER complete the subtask. Only "
    confirm_placement()" can make the building happen and complete the
    task. If you want to make any confirmation, regard it as a success.
6. Do you think the subtask is reasonable? Give your reasons.

Success: You need to output whether the last action was executed
    successfully or not.
- If the last action is successful, you should only output 'True'.
    Otherwise, you should only output 'False'.

You should only respond in the format described below.
Reasoning:
1. ...
2. ...
3. ...
4. ...
5. ...
```

```
6. ...
...
Success:
True
...
```

Prompt 8: Skylines: Task Inference prompt.

```
Assume you are a helpful AI assistant integrated with 'Cities: Skylines'
    on the PC, equipped to handle a wide range of tasks in the game. You
    will also be given a summary of the history that happened before the
    last screenshot. You should assist in summarizing the events for
    future decision-making and also propose a new subtask, which is the
    most suitable subtask for the current situation, given the target
    task.

Here is some helpful information to help you do the summarization and
    propose the subtask.

Current task:
<$task_description$>

Previous proposed subtask for the task:
<$subtask_description$>

Previous reasoning for proposing the subtask:
<$subtask_reasoning$>

<$image_introduction$>

Current budget:
<$budget$>

Current population:
<$population$>

Last executed action:
<$actions$>

Self-reflection for the last executed action:
<$self_reflection_reasoning$>

Error message for the last action:
<$error_message$>

The following is the summary of history that happened before the last
    screenshot:
<$previous_summarization$>

The task can be decomposed into the following subtasks:
1. Start from the Highway entry: Build a road from the highway entry in
    grid (4, 2) vertically northwards towards grid (3,1).
2. Extend Horizontally to the Left (1,1): From the endpoint in grid (1,1)
    , construct a road horizontally to the left, spanning across grids
    (3,1) and (2,1), and ending at the center of grid (1,1).
3. Build a Road Down to the bottom of Grid (2,2): Start from grid (1,1)
    and construct the road to the top of grid (2, 3).
4. Extend Eastward to Grid (3,3): From the bottom of grid (2,2), build a
    road eastward to reach the center of grid (3,3).
5. Connect the road to the Highway Exit: Extend the end of the road from
    grid (3,3) to the exit of the highway, completing the road loop.
6. Install a Water Pumping Station near the River at the top-left corner
    of grid (2,3): Place the water pumping station near the river in grid
     (2,3) to ensure an adequate water supply.
```

```
7. Position a Water Drain Pipe near the River at the top-left corner of
    grid (2,3): Install a water drain pipe slightly downstream from the
    pumping station but within the same grid to prevent water
    contamination.
8. Lay Water Pipes: Connect the water pumping station to the water drain
    pipe using water pipes. Additionally, ensure all roads built are
    covered with water pipes to provide water access across the entire
    area.
9. Erect Wind Turbines for Power: Construct several wind turbines near
    the water pumping station and along the roads to provide sustainable
    electricity to the area.
10. Designate Residential Zones: Allocate spaces adjacent to the roads
    for residential zones to foster community living.
11. Establish Industrial Zones: Set aside areas near the roads for
    industrial purposes, ideally in parts of the grid further from
    residential zones to manage noise and pollution.
12. Create Commercial Zones: Develop commercial zones near the roads to
    provide services and retail options for the residents and workers in
    the area.
13. Make sure all the zones near roads are built with Residential Zones,
    Industrial Zones or Industrial Zones.
14. Build more roads and zones and ensure water and electricity supply.

History_summary: Summarize what happened in the past experience,
    especially the last step according to the decision-making reasoning
    and self-reflection reasoning for the last executed action. The
    summarization needs to be precise, concrete and highly related to the
     task and follow the rules below.
1. Summarize the tasks from the history and the current task. What is the
     current progress of the task?
2. Which subtask has been completed? Which subtasks are not?

Subtask_reasoning: According to the task decomposition, analyze the
    current progress step by step and then decide whether the previous
    subtask is finished and whether it is necessary to propose a new
    subtask. The subtask should be straightforward, contribute to the
    target task and be most suitable for the current situation, which
    should be completed within a few actions. You should respond to me
    with:
1. What is the previous subtask? Which step it is for in the task
    decomposition?
2. According to the reasoning of self-reflection, is the previous subtask
     completed? Note that the success of the action does not mean the
    success of the subtask. You should strictly follow the reasoning of
    whether the subtask is completed in the self-reflection. If yes, you
    should move to the next step and propose it as the new subtask. If
    not, you should continue the previous subtask without changing
    anything.  Please do not make any assumptions if they are not
    mentioned in the above information. You should assume that you are
    doing the task from scratch. Please strictly follow the description
    and requirements in the current task.
3. The proposed subtask needs to be precise and concrete within one
    sentence. It should not be related to any skills.
4. To enable water supply, you should first build a water pumping station
     and then build a water drain pipe near the river, and finally use
    water pipes to connect them with the roads. And ensure the water
    pipes cover all the roads.
5. The water pumping station and water drain pipe also need electricity
    to work. So you also need to provide electricity for them.
6. If you want to build roads for the village at the beginning, make sure
     to mention that the road needs to be as long as possible and use
    several roads to form a large square for the village.
```

```
Subtask: According to the subtask reasoning, determine and output the
    most suitable subtask for the current situation. You MUST output the
    subtask in the output.

You should only respond in the format described below, and you should not
     output comments or other information.
History_summary:
The summary is ...
Subtask_reasoning:
1. ...
2. ...
3. ...
Subtask:
The current subtask is ...
```

Prompt 9: Skylines: Action Planning prompt.

```
You are a helpful AI assistant integrated with 'Cities: Skylines' on the
    PC, equipped to handle various tasks in the game. Your advanced
    capabilities enable you to process and interpret gameplay screenshots
     and other relevant information. By analyzing these inputs, you gain
    a comprehensive understanding of the current context and situation
    within the game. Utilizing this insight, you are tasked with
    identifying the most suitable in-game action to take next, given the
    current task. You control the game character and can execute actions
    from the available action set. Upon evaluating the provided
    information, your role is to articulate the precise action you would
    deploy, considering the game's present circumstances, and specify any
     necessary parameters for implementing that action.

Here is some helpful information to help you make the decision.

Current task:
<$subtask_description$>

Coordinates of constructed buildings:
<$coordinates$>

The latest successful action that builds the building. If you want to
    try_place a road, and the endpoint (x2, y2), of the latest successful
     action is also try_place a road. Then you MUST use the end point of
    the constructed road as the start point of your new road.
<$last_success_try_place_action$>

Current budget:
<$budget$>

Current population:
<$population$>

Last executed action:
<$actions$>

Self-reflection reasoning for the last executed action:
<$self_reflection_reasoning$>

Error message for the last action:
<$error_message$>

Construction information for the last action:
<$consruction_information$>

Summarization of recent history:
<$history_summary$>
```

```
Valid action set in Python format to select the next action:
<$skill_library$>

<$image_introduction$>

Based on the above information, analyze the current situation and provide the reasoning for what you should do for the next step to complete the task. Then, you should output the exact action you want to execute in the game. You should respond to me with:

Reasoning: You should think step by step and provide detailed reasoning to determine the next action executed on the current state of the task. You need to answer the following questions step by step. You cannot miss the last question:
    1. What is the current task? What are the requirements to achieve the goal?
    2. According to the self-reflection reasoning, is the last action executed successfully?
    3. If you want to place anything, do you already open the corresponding menu? Otherwise, you need to open the right menu first in this step rather than doing anything else. If you have not already opened the corresponding menu, skip answering questions 4, 5, 6, 7, 8 and 9.
    4. Does the previous action "try_place" something? If there is an error message showing that the space is already occupied or the last action failed according to the self-reflection reasoning, you should use the same action with different parameters as the position of it to try again. The difference needs to be significant enough with at least 100 pixels of change for the position of the input points. If there is no error message, you should only output confirm_placement() or cancel_placement() to approve or cancel the placement. You should not call anything else.
    5. Does the previous action open any menu? Then you should "try_place" something according to the task description instead of using "confirm_placement".
    6. If you want to place a building, which grid do you plan to place the building in? What is the exact pixel position of it?
    7. If you want to place a road, which grids do you plan to make it cross? Which grids are the start point and end point in, respectively? What are the exact pixel positions of them? You MUST use one of the endpoints of the constructed road shown in the coordinates information as the start point of the new road. If you want to try_place a road, and the endpoint (x2, y2), of the latest successful action is also try_place a road. Then you MUST use the end point of the constructed road as the start point of your new road.
    8. If you want to place a zone, which grids do you plan to make it cover? You should only use the vertices coordinates of the corresponding grids as the parameter for the action. Zones cannot cover each other.
    9. If you want to place a Water Pipe, the start point should be the position of Water Pumping Station, Water Drain Pipe, the start point of a built Water Pipe or the end point of a built Water Pipe.
    10. This is the most critical question. Based on the action rules and self-reflection, what should be the most suitable action in the valid action set for the next step? You should analyze the effects of the action step by step. You should not repeat the previous action again. Do not try to verify whether the previous action succeeded.
    11. Do all the selected actions exist in the valid action set? If no, regenerate the action and give the reasons.
    12. If you are placing a road, is the road more than 300 pixels long? Otherwise, regenerate the action and give reasons.

Actions: The requirements that the generated action needs to follow. The best action, or short sequence of actions without gaps, to execute next to progress in achieving the goal. Pay attention to the names of
```

```
     the available skills and to the previous skills already executed, if
     any. You should also pay more attention to the following action
    rules:
    1. You should output actions in Python code format and specify any
    necessary parameters to execute that action. If the function has
    parameters, you should also include their names and decide their
    values, like "move_right(duration=1)". If it does not have a
    parameter, just output the action, like "open_map()".
    2. Given the current situation and task, you should only choose the
    most suitable action from the valid action set. You cannot use
    actions that are not in the valid action set to control the character
    .
    3. You MUST NOT output more than one skill in the actions.
    4. If you want to build a village, you should follow these rules:
     4.1 Build roads correctly.
      - If you have not opened the road tool, you should open the menu.
    If you have already opened the menu, you should not open it again.
      - Newly built roads must be connected to the existing roads.
      - Determine in which grid the starting point of the newly built
    road is located, and identify the pixel position of the starting
    point.
      - Build the road in the correct direction.
    5. You MUST NOT repeat the previous action with the same parameters
    again if you think the previous action fails.
    6. Your action should strictly follow the analysis in the reasoning.
    Do not output any additional action not mentioned in the reasoning.
    7. Please do not directly connect the entrance of the highway with
    the exit of the highway at the beginning. To make the village as
    large as possible. You should build roads in the wild and connect
    them with each other.
    8. If you are placing a road, the road needs to be at least 300
    pixels long.

You should only respond in the format described below, and you should not
     output comments or other information.
Reasoning:
1. ...
2. ...
3. ...
...
Actions:
'''python
    action(args1=x,args2=y)
'''
```

K.3 PROMPTS FOR STARDEW VALLEY

Prompt 10: Stardew: Information Gathering Cultivation prompt.

```
Assume you are a helpful AI assistant integrated with 'Stardew Valley' on
     the PC, equipped to handle a wide range of tasks in the game. Your
    advanced capabilities enable you to process and interpret gameplay
    screenshots and other relevant information.

<$image_introduction$>

Current task:
<$task_description$>

Description: Please analyze and describe the screenshot image in a grid-
    by-grid format and then provide an overall image description. Pay
    attention to anything related to the task. The image is divided into
    a 3x5 grid, each cell having its own coordinates. For each grid cell,
     describe the contents in detail, focusing on any critical icons, or
```

```
    objects present in that particular segment. If there are specific
    features such as characters or text, mention these as well. After
    completing the description for one cell, proceed to the next, for
    example, 'In grid (1,1), [description]. In grid (1,2), [description
    ].' and so on until the entire image is covered.

Date_time: The date and time information in the game are shown on the
    upper-right of the screenshot, in grid (1, 5). An example of the date
     and time information is "Wed 10, 5:10 pm".

Energy: The current energy remains for the character doing actions. The
    energy bar is shown on the bottom-right of the screenshot, in grid
    (3, 5). The full energy is 270. An example of the energy information
    is "150/270".

Weather: The current weather information in the game, the weather is one
    from "Sunny", "Rainy", "Windy", "Snowy", "Stormy", "Festival", "
    Wedding", and "null". If none of them applies, only output "null".

Dialog: If there are some dialogs shown in the screenshot, extract the
    text of the conversation, like "Shopkeeper: What do you want to buy
    ?", otherwise, only output "null".

Other: Other information that does not belong to the above categories. If
     none of them applies, only output "null".

You should only respond in the format described below and not output
    comments or other information.
Description:
In grid (1,1), ...
In grid (1,2), ...
...
In grid (3,5), ...
Overall, the image shows...
Date_time:
Date and time information
Energy:
The number of energy remains showing in the energy bar
Weather:
Weather information
Dialog:
Dialog text
Other:
Other information is ...
```

Prompt 11: Stardew: Self-Reflection Cultivation prompt.

```
Assume you are a helpful AI assistant integrated with 'Stardew Valley' on
     the PC, equipped to handle a wide range of tasks in the game. Your
    advanced capabilities enable you to process and interpret gameplay
    screenshots and other relevant information. Your task is to examine
    these inputs, interpret the in-game context, and determine whether
    the executed action takes effect.

Target task:
<$task_description$>

Current subtask for completing the target task:
<$subtask_description$>

The reasoning for proposing the current subtask:
<$subtask_reasoning$>

Last executed action for completing the subtask:
<$previous_action$>
```

```
Reasoning for the last action:
<$previous_reasoning$>

Current date and time:
<$date_time$>

Previous toolbar information:
<$previous_toolbar_information$>

Current toolbar information:
<$toolbar_information$>

Summarization of recent history:
<$history_summary$>

<$image_introduction$>

Reasoning: You need to answer the following questions step by step to get
     some reasoning based on the last action and sequential frames of the
     character during the execution of the last action.
1. What is the executed action? Please answer this question not based on
    the sequential frames.
2. Was the executed action successful? Give reasons. You should refer to
    the following rules:
- If the action involves moving forward, it is considered unsuccessful
    only when the character's position remains unchanged across
    sequential frames, regardless of background elements and other people
    .
- If you are not 100% sure that the action fails, regard it as success.
3. If the last action is not executed successfully, what is the most
    probable cause? You should give only one cause and refer to the
    following rules:
- The reasoning for the last action could be wrong.
- If it is an interaction action, the most probable cause was that the
    action was unavailable at the current place, then you should move to
    a new place.
- If it is a movement action, the most probable cause was that you were
    blocked by seen or unseen obstacles.
- If there is an error report, analyze the cause based on the report.
4. Is the subtask completed? Give your reasons. If you want to make any
    confirmation, regard it as a success.
5. Is the target task completed? Give your reasons.
6. Do you think the subtask is reasonable? Give your reasons.

You should only respond in the format described below.
Reasoning:
1. ...
2. ...
3. ...
...
```

Prompt 12: Stardew: Task Inference Cultivation prompt.

```
Assume you are a helpful AI assistant integrated with 'Stardew Valley' on
     the PC, equipped to handle a wide range of tasks in the game. You
    will also be given a summary of the history that happened before the
    last screenshot. You should assist in summarizing the events for
    future decision-making and also propose a new subtask, which is the
    most suitable subtask for the current situation, given the target
    task.

Here is some helpful information to help you do the summarization and
    propose the subtask.
```

```
Current task:
<$task_description$>

Previous proposed subtask for the task:
<$subtask_description$>

Previous reasoning for proposing the subtask:
<$subtask_reasoning$>

<$image_introduction$>

Current toolbar information:
<$toolbar_information$>

Last executed action:
<$previous_action$>

Decision-making reasoning for the last executed action:
<$previous_reasoning$>

Self-reflection for the last executed action:
<$self_reflection_reasoning$>

The following is the summary of history that happened before the last
    screenshot:
<$previous_summarization$>

History_summary: Summarize what happened in the past experience,
    especially the last step according to the decision-making reasoning
    and self-reflection reasoning for the last executed action. The
    summarization needs to be precise, concrete and highly related to the
     task and follow the rules below.
1. Summarize the tasks from the history and the current task. What is the
     current progress of the task? For example, to harvest a seed, you
    need to water the seed for 4 days. And you have already planted the
    seed and watered it for two days.
2. Record the successful actions and organize them into events day by day
    .
3. Do not forget the information and key events in the previous days.
4. If you are watering a seed. Record how many times you have watered and
     calculate how many days you have to water before you can harvest
    according to the toolbar information provided above.
Here is an example to follow:
On Thu.4, I dig the dirt with the toe and then plant the parsnip seed and
     water the seed. The seed has been watered once. It still needs to be
     watered another three times to harvest. On Fri.5, I watered the seed
     again. The seed has been watered twice. It still needs to be watered
     twice to harvest. Today, Sat.6, I just need to get out of home and
    watered the seed again.

Subtask_reasoning: Decide whether the previous subtask is finished and
    whether it is necessary to propose a new subtask. The subtask should
    be straightforward, contribute to the target task and be most
    suitable for the current situation, which should be completed within
    a few actions. You should respond to me with:
1. How to finish the target task? You should analyze it step by step.
2. What is the current progress of the target task according to the
    analysis in step 1? Please do not make any assumptions if they are
    not mentioned in the above information. You should assume that you
    are doing the task from scratch.
3. What is the previous subtask? Does the previous subtask finish? Or is
    it improper for the current situation? Then select a new one,
    otherwise you should reuse the last subtask.
4. If you want to propose a new subtask, give reasons why it is more
    feasible for the current situation.
```

```
5. The proposed subtask needs to be precise and concrete within one
    sentence. It should not be related to any skills.
6. The seed only needs to be watered once.
7. Do not mention any grid information in the subtask description.
8. Do not check the growth status of the crop.
9. The seeds only need to be watered ONCE every day. If you have already
    watered the seed today, you should return home and go to sleep,
    waiting for the next day.

You should only respond in the format described below, and you should not
     output comments or other information.
History_summary:
The summary is...
Subtask_reasoning:
1. ...
2. ...
...
Subtask:
The current subtask is
```

Prompt 13: Stardew: Action Planning Cultivation prompt.

```
You are a helpful AI assistant integrated with 'Stardew Valley' on the PC
    , equipped to handle various tasks in the game. Your advanced
    capabilities enable you to process and interpret gameplay screenshots
     and other relevant information. By analyzing these inputs, you gain
    a comprehensive understanding of the current context and situation
    within the game. Utilizing this insight, you are tasked with
    identifying the most suitable in-game action to take next, given the
    current task. You control the game character and can execute actions
    from the available action set. Upon evaluating the provided
    information, your role is to articulate the precise action you would
    deploy, considering the game's present circumstances, and specify any
     necessary parameters for implementing that action.

Here is some helpful information to help you make the decision.

Current subtask:
<$subtask_description$>

Current date and time:
<$date_time$>

Toolbar information:
<$toolbar_information$>

Last executed action:
<$previous_action$>

Reasoning for the last action:
<$previous_reasoning$>

Self-reflection for the last executed action:
<$previous_self_reflection_reasoning$>

Summarization of recent history:
<$history_summary$>

Valid action set in Python format to select the next action:
<$skill_library$>

<$image_introduction$>

Based on the above information, analyze the current situation and provide
     the reasoning for what you should do for the next step to complete
```

```
    the task. Then, you should output the exact action you want to
    execute in the game. You should respond to me with:

Reasoning: You should think step by step and provide detailed reasoning
    to determine the next action executed on the current state of the
    task. You need to answer the following questions step by step. You
    cannot miss the last question:
    1. Analyze the information in the toolbar. Does it contain all the
    necessary items for completing the task?
    2. What is the current selected tool? Do you want to use a tool, such
     as axe, hoe, watering can, pickaxe and scythe? And is the character'
    s current position a suitable place to use such a tool? Then you
    should use use_tool() instead of do_action().
    3. Does the character already reach the target place?
    4. What was the previous action? If the previous action was a
    movement, were you blocked?
    5. If your task is to harvest the plant, did you water the seed? The
    seeds only need to be watered ONCE every day. If you have already
    watered the seed today, you should return home and go to sleep,
    waiting for the next day.
    6. This is the most critical question. Based on the action rules and
    self-reflection, what should be the most suitable action in the valid
     action set for the next step? You should analyze the effects of the
    action step by step. You should not repeat the previous action again
    except for the movement action. Do not try to verify whether the
    previous action succeeded.
    7. Is the selected action the same as the last executed action? If
    yes, regenerate the action and give the reasons.
    8. Do all the selected actions exist in the valid action set? If no,
    regenerate the action and give the reasons.
    9. Analyze whether the selected action meets the requirements of the
    Actions below one by one. Does the generated action meet all the
    requirements? If not, regenerate the action and give the reasons.

Actions: The requirements that the generated action needs to follow. The
    best action, or short sequence of actions without gaps, to execute
    next to progress in achieving the goal. Pay attention to the names of
     the available skills and to the previous skills already executed, if
     any. You should also pay more attention to the following action
    rules:
    1. You should output actions in Python code format and specify any
    necessary parameters to execute that action. If the function has
    parameters, you should also include their names and decide their
    values, like "move_right(duration=1)". If it does not have a
    parameter, just output the action, like "open_map()".
    2. You can only output at most two actions in the output.
    3. In the screenshots, the blue band represents the left side and the
     yellow band represents the right side. Please ignore character's
    facing direction and output the action in an absolute direction like
    right and left.
    4. If you want to interact with the objects in the toolbar, you need
    to make sure that the target object is already selected. You need to
    use select_tool() to select them before executing use_tool() or
    do_action().
    5. If you want to plant a seed or harvest a mature crop, please use
    do_action() instead of use_tool(). If you want to use tools, like axe
    , hoe, watering can, pickaxe and scythe, please use use_tool().
    6. If upon self-reflection you think the last action was unavailable
    at the current place, you MUST move to another place. Please do not
    try to execute the same action again.
    7. If you want to get out of the house, just use the skill
    get_out_of_house(). You MUST NOT output any movement action behind
    this skill. And if the last executed action already contains this
    skill, do not execute this skill for the current step again.
```

```
    8. If upon self-reflection you think you were blocked, you MUST
    change the direction of moving, so that you can pass obstacles.
    9. You MUST NOT repeat the previous action again if you think the
    previous action fails.
    10. Your action should strictly follow the analysis in the reasoning.
     Do not output any additional action not mentioned in the reasoning.

You should only respond in the format described below, and you should not
     output comments or other information.
Reasoning:
1. ...
2. ...
3. ...
Actions:
```python
    action(args1=x,args2=y)
```
```

Prompt 14: Stardew: Information Gathering Farm Clearup prompt.

```
Assume you are a helpful AI assistant integrated with 'Stardew Valley' on
     the PC, equipped to handle a wide range of tasks in the game. Your
    advanced capabilities enable you to process and interpret gameplay
    screenshots and other relevant information.

<$image_introduction$>

Current task:
<$task_description$>

Description: Please analyze and describe the screenshot image in a grid-
    by-grid format and then provide an overall image description. Pay
    attention to anything related to the task. The image is divided into
    a 3x5 grid, each cell having its own coordinates. For each grid cell,
     describe the contents in detail, focusing on any critical icons, or
    objects present in that particular segment. If there are specific
    features such as characters or text, mention these as well. After
    completing the description for one cell, proceed to the next, for
    example, 'In grid (1,1), [description]. In grid (1,2), [description
    ].' and so on until the entire image is covered.

Date_time: The date and time information in the game are shown on the
    upper-right of the screenshot, in grid (1, 5). An example of the date
     and time information is "Wed 10, 5:10 pm".

Energy: The current energy remains for the character doing actions. The
    energy bar is shown on the bottom-right of the screenshot, in grid
    (3, 5). The full energy is 270. An example of the energy information
    is "150/270".

Weather: The current weather information in the game, the weather is one
    from "Sunny", "Rainy", "Windy", "Snowy", "Stormy", "Festival", "
    Wedding", and "null". If none of them applies, only output "null".

Dialog: If there are some dialogs shown in the screenshot, extract the
    text of the conversation, like "Shopkeeper: What do you want to buy
    ?", otherwise, only output "null".

Other: Other information that does not belong to the above categories. If
     none of them applies, only output "null".

You should only respond in the format described below and not output
    comments or other information.
Description:
In grid (1,1), ...
```

```
In grid (1,2), ...
...
In grid (3,5), ...
Overall, the image shows...
Date_time:
Date and time information
Energy:
The number of energy remains showing in the energy bar
Weather:
Weather information
Dialog:
Dialog text
Other:
Other information is ...
```

Prompt 15: Stardew: Self-Reflection Farm Clearup prompt.

```
Assume you are a helpful AI assistant integrated with 'Stardew Valley' on
     the PC, equipped to handle a wide range of tasks in the game. Your
    advanced capabilities enable you to process and interpret gameplay
    screenshots and other relevant information. Your task is to examine
    these inputs, interpret the in-game context, and determine whether
    the executed action takes effect.

Target task:
<$task_description$>

Current subtask for completing the target task:
<$subtask_description$>

The reasoning for proposing the current subtask:
<$subtask_reasoning$>

Last executed action for completing the subtask:
<$previous_action$>

Reasoning for the last action:
<$previous_reasoning$>

Current date and time:
<$date_time$>

Previous toolbar information:
<$previous_toolbar_information$>

Current toolbar information:
<$toolbar_information$>

Summarization of recent history:
<$history_summary$>

<$image_introduction$>

Reasoning: You need to answer the following questions step by step to get
     some reasoning based on the last action and sequential frames of the
     character during the execution of the last action.
1. What is the executed action? Please answer this question not based on
    the sequential frames.
2. Was the executed action successful? Give reasons. You should refer to
    the following rules:
- If the action involves moving forward, it is considered unsuccessful
    only when the character's position remains unchanged across
    sequential frames, regardless of background elements and other people
    .
- If you are not 100% sure that the action fails, regard it as success.
```

```
3. If the last action is not executed successfully, what is the most
    probable cause? You should give only one cause and refer to the
    following rules:
- The reasoning for the last action could be wrong.
- If it is an interaction action, the most probable cause was that the
    action was unavailable at the current place, then you should move to
    a new place.
- If it is a movement action, the most probable cause was that you were
    blocked by seen or unseen obstacles.
- If there is an error report, analyze the cause based on the report.
4. Is the subtask completed? Give your reasons. If you want to make any
    confirmation, regard it as a success.
5. Is the target task completed? Give your reasons.
6. Do you think the subtask is reasonable? Give your reasons.

You should only respond in the format as described below.
Reasoning:
1. ...
2. ...
3. ...
...
```

Prompt 16: Stardew: Task Inference Farm Clearup prompt.

```
Assume you are a helpful AI assistant integrated with 'Stardew Valley' on
     the PC, equipped to handle a wide range of tasks in the game. You
    will also be given a summary of the history that happened before the
    last screenshot. You should assist in summarizing the events for
    future decision-making and also propose a new subtask, which is the
    most suitable subtask for the current situation, given the target
    task.

Here is some helpful information to help you do the summarization and
    propose the subtask.

Current task:
<$task_description$>

Previous proposed subtask for the task:
<$subtask_description$>

Previous reasoning for proposing the subtask:
<$subtask_reasoning$>

<$image_introduction$>

Current toolbar information:
<$toolbar_information$>

Last executed action:
<$previous_action$>

Decision-making reasoning for the last executed action:
<$previous_reasoning$>

Self-reflection for the last executed action:
<$self_reflection_reasoning$>

The following is the summary of history that happened before the last
    screenshot:
<$previous_summarization$>

History_summary: Summarize what happened in the past experience,
    especially the last step according to the decision-making reasoning
    and self-reflection reasoning for the last executed action. The
```

```
    summarization needs to be precise, concrete and highly related to the
     task and follow the rules below.
1. Summarize the tasks from the history and the current task. What is the
     current progress of the task? For example, to harvest a seed, you
    need to water the seed for 4 days. And you have already planted the
    seed and watered it for two days.
2. Record the successful actions and organize them into events day by day
    .
3. Do not forget the information and key events in the previous days.
4. If you are watering a seed. Record how many times you have watered and
     calculate how many days you have to water before you can harvest
    according to the toolbar information provided above.
Here is an example to follow:
On Thu.4, I dig the dirt with the toe and then plant the parsnip seed and
     water the seed. The seed has been watered once. It still needs to be
     watered another three times to harvest. On Fri.5, I watered the seed
     again. The seed has been watered twice. It still needs to be watered
     twice to harvest. Today, Sat.6, I just need to get out of home and
    watered the seed again.

Subtask_reasoning: Decide whether the previous subtask is finished and
    whether it is necessary to propose a new subtask. The subtask should
    be straightforward, contribute to the target task and be most
    suitable for the current situation, which should be completed within
    a few actions. You should respond to me with:
1. How to finish the target task? You should analyze it step by step.
2. What is the current progress of the target task according to the
    analysis in step 1? Please do not make any assumptions if they are
    not mentioned in the above information. You should assume that you
    are doing the task from scratch.
3. What is the previous subtask? Does the previous subtask finish? Or is
    it improper for the current situation? Then select a new one,
    otherwise you should reuse the last subtask.
4. If you want to propose a new subtask, give reasons why it is more
    feasible for the current situation.
5. The proposed subtask needs to be precise and concrete within one
    sentence. It should not be related to any skills.
6. The seed only needs to be watered once.
7. Do not mention any grid information in the subtask description.
8. Do not check the growth status of the crop.
9. The seeds only need to be watered ONCE every day. If you have already
    watered the seed today, you should return home and go to sleep,
    waiting for the next day.

You should only respond in the format described below, and you should not
     output comments or other information.
History_summary:
The summary is...
Subtask_reasoning:
1. ...
2. ...
...
Subtask:
The current subtask is
```

Prompt 17: Stardew: Action Planning Farm Clearup prompt.

```
You are a helpful AI assistant integrated with 'Stardew Valley' on the PC
    , equipped to handle various tasks in the game. Your advanced
    capabilities enable you to process and interpret gameplay screenshots
     and other relevant information. By analyzing these inputs, you gain
    a comprehensive understanding of the current context and situation
    within the game. Utilizing this insight, you are tasked with
    identifying the most suitable in-game action to take next, given the
    current task. You control the game character and can execute actions
```

```
    from the available action set. Upon evaluating the provided
    information, your role is to articulate the precise action you would
    deploy, considering the game's present circumstances, and specify any
     necessary parameters for implementing that action.

Here is some helpful information to help you make the decision.

Current subtask:
<$subtask_description$>

Current date and time:
<$date_time$>

Toolbar information:
<$toolbar_information$>

Last executed action:
<$previous_action$>

Reasoning for the last action:
<$previous_reasoning$>

Self-reflection for the last executed action:
<$previous_self_reflection_reasoning$>

Summarization of recent history:
<$history_summary$>

Valid action set in Python format to select the next action:
<$skill_library$>

<$image_introduction$>

Based on the above information, analyze the current situation and provide
     the reasoning for what you should do for the next step to complete
    the task. Then, you should output the exact action you want to
    execute in the game. You should respond to me with:

Reasoning: You should think step by step and provide detailed reasoning
    to determine the next action executed on the current state of the
    task. You need to answer the following questions step by step. You
    MUST NOT miss question 3 and question 11:
    1. Analyze the information in the tool bar. Does it contain all the
    necessary items for completing the task?
    2. Where is the character in the screenshot of the current step?
    Where is the house in the screenshot of the current step? The blue
    band represents the left side and the yellow band represents the
    right side. Where is the character compared with the house? (Is he at
     the left edge or right edge of the house?)
    3. If your task is to clear obstacles, you MUST NOT miss any question
     in this step:
      - The blue band represents the left side and the yellow band
    represents the right side. Where is the character according to the
    house? (Is he at the left edge or right edge of the house?)
      - Which grids do the house span in the screenshot? (You MUST answer
     one or two grid position. The house does not span over two grids.)
    Then, what are the two grids below and near the house? (e.g. If the
    house spans from grid (1,3) to (1,4), the CLEARING AREA of character
    should be grid (2,3) and (2,4). If the house spans grid (1,3), the
    CLEARING AREA of character should be grid (2,2) and (2,3).You MUST
    remember this CLEARING AREA precisely IN THIS ROUND.) You should
    focus on obstacles in them. You MUST NOT move the character out of
    these two obstacle grids.
      - In order to clear all obstacles below the house and make the
    place suitable for cultivating, you should not target for a specific
```

```
    obstacle. Instead, you should try your best to move the character to
    pass every patch in the CLEARING AREA. You should clear every
    obstacle that blocks the character in this process.
      - Every time after you move the character down (or up when being
    too far from the house), you should move the character right or left
    (based on the character's position in the CLEARING AREA compared with
     the house) to fully explore the CLEARING AREA of the two grids
    determined above. You should clear all obstacles the character meets
    in this process.
      - Is the current row fully explored by the character? If so, your
    movement should be moving down. If there is an obstacle beneath the
    character, you should clear it first before moving the character down
    .
      - You should not move too far from the house. You should not move
    the character down but should move him up instead if the house is not
     in the current screenshot.
      - What was the previous action? If the previous action contained
    use_tool(), you MUST NOT start with the same use_tool() action in
    this round. (You can still use use_tool() by following a movement or
    select_tool().)
      - If the previous action was a movement, is the position of
    character changed? If not, it is the most trustworthy evidence that
    there is an obstacle in front of the character that can interact with
    .
      - If the character is blocked by an obstacle in front of him or if
    you think there is an obstacle in front of the character, what type
    of obstacle is it? (Usually, weed and grass are green, stone is grey
    and branch is brown) What is the suitable tool for clearing it and is
     the tool correctly selected?
    4. What is the current selected tool? Do you want to use a tool, such
     as axe, hoe, watering can, pickaxe and scythe? And is the character'
    s current position a suitable place to use such a tool? Then you
    should use use_tool() instead of do_action().
    5. Does the character already reach the target place?
    6. What was the previous action? If the previous action was a
    movement, were you blocked?
    7. If your task is to harvest the plant, did you water the seed? The
    seeds only need to be watered ONCE every day. If you have already
    watered the seed today, you should return home and go to sleep,
    waiting for the next day.
    8. This is the most critical question. Based on the action rules and
    self-reflection, what should be the most suitable action in the valid
     action set for the next step? You should analyze the effects of the
    action step by step. You should not repeat the previous action again
    except for the movement action. Do not try to verify whether the
    previous action succeeded.
    9. Is the selected action the same as the last executed action? If
    yes, regenerate the action and give the reasons.
    10. Do all the selected actions exist in the valid action set? If no,
     regenerate the action and give the reasons.
    11. Analyze whether the selected action meets the requirements of the
     Actions below one by one. Does the generated action meet all the
    requirements? If not, regenerate the action and give the reasons.

Actions: The requirements that the generated action needs to follow. The
    best action, or short sequence of actions without gaps, to execute
    next to progress in achieving the goal. Pay attention to the names of
     the available skills and to the previous skills already executed, if
     any. You should also pay more attention to the following action
    rules:
    1. You should output actions in Python code format and specify any
    necessary parameters to execute that action. If the function has
    parameters, you should also include their names and decide their
    values, like "move_right(duration=1)". If it does not have a
    parameter, just output the action, like "open_map()".
```

```
2. You can only output at most two actions in the output.
3. In the screenshots, the blue band represents the left side and the yellow band represents the right side. Please ignore character's facing direction and output the action in an absolute direction like right and left.
4. If you want to interact with the objects in the toolbar, you need to make sure that the target object is already selected. You need to use select_tool() to select them before executing use_tool() or do_action().
5. If you want to plant a seed or harvest a mature crop, please use do_action() instead of use_tool(). If you want to use tool, like axe, hoe, watering can, pickaxe and scythe, please use use_tool().
6. If upon self-reflection you think the last action was unavailable at the current place, you MUST move to another place. Please do not try to execute the same action again.
7. If you want to get out of the house, just use the skill get_out_of_house(). You MUST NOT output any movement action behind this skill. And if the last executed action already contains this skill, do not execute this skill for the current step again.
8. If upon self-reflection you think you were blocked, you MUST change the direction of moving, so that you can pass obstacles.
9. You MUST NOT repeat the previous action again if you think the previous action fails.
10. Your action should strictly follow the analysis in the reasoning. Do not output any additional action not mentioned in the reasoning.
11. If you want to clear obstacles, you should follow the order of thinking as follows:
    - You MUST NOT move the character to the house.
    - In order to clear all obstacles below the house and make the place suitable for cultivating, you should not target for a specific obstacle. Instead, you should try your best to move the character to pass every patch in the CLEARING AREA. You should clear every obstacle that blocks the character in this process.
    - Every time after you move the character down (or up when being too far from the house), you should move the character right or left (based on the character's position compared with the house) to fully explore the CLEARING AREA. You should clear all obstacles the character meets in this process.
    - If you think the character has fully explored the current row of the CLEARING AREA, you should move the character down. If there is an obstacle beneath the character, you should clear it first before moving the character down.
    - You should not move too far from the house. You should not move the character down but should move hime up instead if the house is not in the current screenshot.
    - You can take larger steps of moving left or right by adjusting the action's parameter. You MUST use a small parameter when doing move_down() to make sure the character only moves one patch down.
    - If you think there is an obstacle in front of the character, you should determine its type. You should then select the suitable tool by select_tool() and clear the obstacle by use_tool().
    - You should always use_tool() after select_tool(). Do not switch to another tool without using it.
    - If the previous action contained use_tool(), you MUST NOT start with the same use_tool() action in this round. (You can still use use_tool() by following a movement or select_tool().)
    - If the previous action contained use_tool(), you should determine whether the obstacle is cleared. If you are not sure that the obstacle is cleared, you are encouraged to try different tools by select_tool() and use_tool() before moving the character to other positions.
    - If the previous action was a movement, you should determine whether there is an obstacle IN FRONT OF the character. If so, you should select the suitable tool by select_tool() and clear it by use_tool().
```

```
        - If previous action contained use_tool(), you should move the
    character to the same direction as before to test if the blocking
    obstacle is cleared.
        - If the blocking obstacle is not cleared, you should select a
    different tool to clear it.


You should only respond in the format described below, and you should not
     output comments or other information.
Reasoning:
1. ...
2. ...
3. ...
Actions:
```python
    action(args1=x,args2=y)
```
```

Prompt 18: Stardew: Information Gathering Shopping prompt.

```
Assume you are a helpful AI assistant integrated with 'Stardew Valley' on
     the PC, equipped to handle a wide range of tasks in the game. Your
    advanced capabilities enable you to process and interpret gameplay
    screenshots and other relevant information.

<$image_introduction$>

Task overview:
<$task_description$>

Current subtask:
<$subtask_description$>

Description: Please analyze and describe the screenshot image in a grid-
    by-grid format from left to right and top to bottom and then provide
    an overall image description. Pay attention to anything related to
    the current subtask. The image is divided into a 5x3 grid, each cell
    having its own coordinates. For each grid cell, describe the contents
     in detail, focusing on any critical icons, or objects present in
    that particular segment. If there are specific features such as
    characters or text, mention these as well. After completing the
    description for one cell, proceed to the next, for example, 'In grid
    (1,1), [description]. In grid (2,1), [description].' and so on until
    the entire image is covered.

Date_time: The date and time information in the game are shown on the
    upper-right of the screenshot, in grid (5, 1). An example of the date
     and time information is "Wed 10, 5:10 pm".

Energy: The current energy remains for the character doing actions. The
    energy bar is shown on the bottom-right of the screenshot, in grid
    (5, 3). The full energy is 270. An example of the energy information
    is "150/270".

Weather: The current weather information in the game, the weather is one
    from "Sunny", "Rainy", "Windy", "Snowy", "Stormy", "Festival", "
    Wedding", and "null". If none of them applies, only output "null".

Dialog: If there are some dialogs shown in the screenshot, extract the
    text of the conversation, like "Shopkeeper: What do you want to buy
    ?", otherwise, only output "null".

Other: Other information that does not belong to the above categories. If
     none of them applies, only output "null".
```

```
You should only respond in the format described below and not output
    comments or other information.
Description:
In grid (1,1), ...In grid (2,1), ...In grid (3,1), ...In grid (5,3), ...
    Overall, the image shows...
Date_time:
Date and time information
Energy:
The number of energy remains showing in the energy bar
Weather:
Weather information
Dialog:
Dialog text
Other:
Other information is ...
```

Prompt 19: Stardew: Self-Reflection Shopping prompt.

```
Assume you are a helpful AI assistant integrated with 'Stardew Valley' on
     the PC, equipped to handle a wide range of tasks in the game. Your
    advanced capabilities enable you to process and interpret gameplay
    screenshots and other relevant information. Your task is to examine
    these inputs, interpret the in-game context, and determine whether
    the executed action takes effect.

Target task:
<$task_description$>

Current subtask for completing the target task:
<$subtask_description$>

The reasoning for proposing the current subtask:
<$subtask_reasoning$>

Last executed action for completing the subtask:
<$previous_action$>

Reasoning for the last action:
<$previous_reasoning$>

Current Image description:
<$image_description$>

Toolbar information
<$toolbar_information$>

Summarization of recent history:
<$history_summary$>

<$image_introduction$>

Reasoning: You need to answer the following questions step by step to get
     some reasoning based on the last action and sequential frames of the
     character during the execution of the last action.
1. Are the characters' positions in these frames identical?
2. What is the executed action? Please answer this question not based on
    the sequential frames.
3. Was the executed action successful? Give reasons. You should refer to
    the following rules:
- Analyze by observing given sequential frames for detailed information.
- If the action involves moving forward, it is considered unsuccessful
    only when the character's position remains unchanged across
    sequential frames, regardless of background elements and other people
    .
- If you are not 100% sure that the action fails, regard it as success.
```

```
4. If the last action is not executed successfully, what is the most
    probable cause? You should give only one cause and refer to the
    following rules:
- The reasoning for the last action could be wrong.
- If it is an interaction action such as buy_item or do_action, the most
    probable cause was that the action was unavailable at the current
    place, then you should move to a new place.
- If it is a movement action, the most probable cause was that you were
    blocked by seen or unseen obstacles.
- If there is an error report, analyze the cause based on the report.
5. If the current subtask involves determining whether to enter the store
    , you need to compare the scene in the current screenshot with the
    scene in the screenshot from Memory to determine whether the
    character has entered the store, if not, then the task of entering
    the store is not complete.
6. Is the subtask completed? Give your reasons. If you want to make any
    confirmation, regard it as a success. You should observe given
    sequential frames, do not rely on the text information.
7. Is the target task completed? Give your reasons.
8. If the current subtask involves purchase something, you should check
    the toolbar or purchase menu to see if the purchase was successful.
    Do not overbuy or miss the purchase.
9. Do you think the subtask is reasonable? Give your reasons.

You should only respond in the format as described below.
Reasoning:
1. ...
2. ...
3. ...
...
```

Prompt 20: Stardew: Task Inference Shopping prompt.

```
Assume you are a helpful AI assistant integrated with 'Stardew Valley' on
     the PC, equipped to handle a wide range of tasks in the game. You
    will also be given a summary of the history that happened before the
    last screenshot. You should assist in summarizing the events for
    future decision-making and also propose a new subtask, which is the
    most suitable subtask for the current situation, given the target
    task.

Here is some helpful information to help you do the summarization and
    propose the subtask.

Current task:
<$task_description$>

Previous proposed subtask for the task:
<$subtask_description$>

Previous reasoning for proposing the subtask:
<$subtask_reasoning$>

<$image_introduction$>

Current Image description:
<$image_description$>

Last executed action:
<$previous_action$>

Decision-making reasoning for the last executed action:
<$previous_reasoning$>

Self-reflection for the last executed action:
```

```
<$self_reflection_reasoning$>

The following is the summary of history that happened before the last
    screenshot:
<$previous_summarization$>

History_summary: Summarize what happened in the past experience,
    especially the last step according to the decision-making reasoning
    and self-reflection reasoning for the last executed action. The
    summarization needs to be precise, concrete and highly related to the
     task and follow the rules below.
1. Summarize the tasks from the history and the current task. What is the
     current progress of the task? For example, to harvest a seed, you
    need to water the seed for 4 days. And you have already planted the
    seed and watered it for two days.
2. Record the successful actions and organize them into events day by day
    .
3. Do not forget the information and key events in the previous days.

Subtask_reasoning: Decide whether the previous subtask is finished and
    whether it is necessary to propose a new subtask. The subtask should
    be straightforward, contribute to the target task and be most
    suitable for the current situation, which should be completed within
    a few actions. You should respond to me with:
1. How to finish the target task? You should analyze it step by step.
2. What is the current progress of the target task according to the
    analysis in step 1? Please do not make any assumptions if they are
    not mentioned in the above information. You should assume that you
    are doing the task from scratch.
3. What is the previous subtask? Does the previous subtask finish? If so,
     give evidence that the task was completed. Or is it improper for the
     current situation? Then select a new one, otherwise you should reuse
     the last subtask.
4. If you want to propose a new subtask, give reasons why it is more
    feasible for the current situation.
5. The proposed subtask needs to be precise and concrete within one
    sentence. It should not be related to any skills.
6. Do not mention any grid information in the subtask description.
7. If the character does not reach the target place, you should propose a
     movement task to make him closer to the target.
8. If you want to purchase items, then you should move up to stand in
    front of the shopkeeper's counter, move slightly to align with the
    green counter and buy items. After purchasing, you can move down to
    the exit and leave store.
9. If you want to leave town, you should move along gray cobblestone road
     to the left of the store and the clinic.

You should only respond in the format described below, and you should not
     output comments or other information.
History_summary:
The summary is...
Subtask_reasoning:
1. ...
2. ...
...
Subtask:
The current subtask is
```

Prompt 21: Stardew: Action Planning Shopping prompt.

```
You are a helpful AI assistant integrated with 'Stardew Valley' on the PC
    , equipped to handle various tasks in the game. Your advanced
    capabilities enable you to process and interpret gameplay screenshots
     and other relevant information. By analyzing these inputs, you gain
    a comprehensive understanding of the current context and situation
```

```
    within the game. Utilizing this insight, you are tasked with
    identifying the most suitable in-game action to take next, given the
    current task. You control the game character and can execute actions
    from the available action set. Upon evaluating the provided
    information, your role is to articulate the precise action you would
    deploy, considering the game's present circumstances, and specify any
     necessary parameters for implementing that action.

Here is some helpful information to help you make the decision.

Current subtask:
<$subtask_description$>

Image description:
<$image_description$>

Last executed action:
<$previous_action$>

Reasoning for the last action:
<$previous_reasoning$>

Self-reflection for the last executed action:
<$previous_self_reflection_reasoning$>

Summarization of recent history:
<$history_summary$>

Valid action set in Python format to select the next action:
<$skill_library$>

Grid System Information:
1. Each grid has a coordinate (x,y). A larger x means that the grid is on
     the more eastern(right) side, and a larger y means that the grid is
    on the more southern(down) side. For example, moving from grid (1,3)
    to grid (1,1) requires move_up(duration=2) and moving from grid (1,1)
     to grid (2,1) requires move_right(duration=1)
2. The larger the difference between the coordinates of the two grids,
    the longer it takes to move. Moving from grid (2,5) to grid (2,3)
    takes longer than moving from grid (2,3) to grid (1,3).

<$image_introduction$>

Based on the above information, analyze the current situation and provide
     the reasoning for what you should do for the next step to complete
    the task. Then, you should output the exact action you want to
    execute in the game. You should respond to me with:

Reasoning: You should think step by step and provide detailed reasoning
    to determine the next action executed on the current state of the
    task. You need to answer the following questions step by step. You
    cannot miss the last question:
    1. Does the character already reach the target place? You must move
    close enough to the object to be in contact with it in order to
    interact with it. Just in the same grid with the target is not enough
    .
    2. Make use of the above image description, grid system information
    and current screenshot. Analyze whether the character has reached the
     target place. You must move close enough to the object to be in
    contact with it in order to interact with it. Just in the same grid
    with the target is not enough.
    3. What was the previous action? If the previous action was a
    movement, were you blocked?
    4. This is the most critical question. Based on the action rules and
    self-reflection, what should be the most suitable action in the valid
```

```
     action set for the next step? You should analyze the effects of the
    action step by step. You should not repeat the previous action again
    except for the movement action. Do not try to verify whether the
    previous action succeeded.
    5. Is the selected action the same as the last executed action? If
    yes, regenerate the action and give the reasons.
    6. Do all the selected actions exist in the valid action set? If no,
    regenerate the action and give the reasons.
    7. Where is the player's character? Notice that the player's
    character is a brown-haired man wearing a blue jacket.
    8. Does the selected action contribute to the current subtask?
    9. Analyze whether the selected action meets the requirements of the
    Actions below one by one. Does the generated action meet all the
    requirements? If not, regenerate the action and give the reasons.

Actions: The requirements that the generated action needs to follow. The
    best action, or short sequence of actions without gaps, to execute
    next to progress in achieving the goal. Pay attention to the names of
     the available skills and to the previous skills already executed, if
     any. You should also pay more attention to the following action
    rules:
    1. You should output actions in Python code format and specify any
    necessary parameters to execute that action. If the function has
    parameters, you should also include their names and decide their
    values, like "move_right(duration=1)". If it does not have a
    parameter, just output the action, like "open_map()".
    2. You can only output at most two actions in the output.
    3. In the screenshots, the blue band represents the left side and the
     yellow band represents the right side. Please ignore character's
    facing direction and output the action in an absolute direction like
    right and left.
    4. If upon self-reflection you think the last action was unavailable
    at the current place, you MUST move to another place. Please do not
    try to execute the same action again.
    5. If you want to get out of the house, just use the skill
    go_through_door. You MUST NOT output any movement action behind this
    skill. And if the last executed action already contains this skill,
    do not execute this skill for the current step again.
    6. If upon self-reflection you think you were blocked, you MUST
    change the direction of moving, so that you can pass obstacles.
    7. You MUST NOT repeat the previous action again if you think the
    previous action fails.
    8. Your action should be strictly follow the analyze in the reasoning
    . Do not output any additional action not mentioned in the reasoning.
    9. If the current subtask includes purchasing items, here are some
    useful tips for you:
     - Pierre's store is east of the character's house.
     - if you do not see the store, you can move for a longer time each
    time, such move_right(duration=5). You can also move more distance to
     the left each time to get home faster.
     - To successfully enable the purchase transaction, you should stand
    directly in front of the green counter, which left to the white
    counter with word 'for sale'.
     - After aligning with green counter, you should purchase items.
     - It is not necessary to positioned very precisely. If you stand
    near the green counter, you can try to purchase items.
    10. If the current subtask includes exiting town and returning home,
    here are some useful tips for you:
     - Character' house is west of Pierre's store.
     - There is a long distance from home to the store, so each movement
    should take a long duration, such as move_left(duration=5).
     - Don't stand in the grass, move up and away from the lawn.
     - The exit to the town is on the west(left) of Pierre's store and
    clinic. You should move left along the stone road, which has a wooden
```

```
     fence below it. If you gets stuck, move up slightly to get over the
    obstacle.
    11. If you want to enter a building, you should use go_through_door(
    door="xxx_entrance"); If you want to leave a building, you should use
     go_through_door(door="xxx_exit").
     - You can use go_through_door(door="store_entrance") to enter the
    store.
     - You can use go_through_door(door="store_exit") to leave the store.
     - You can use go_through_door(door="home_entrance") to enter your
    house.
     - You can use go_through_door(door="home_exit") to leave your house.
    12. If you want aligh with the target, you MUST move slightly. Each
    movement take only 0.1 seconds, such as move_xxx(duration=0.1).

You should only respond in the format described below, and you should not
     output comments or other information.
Reasoning:
1. ...
2. ...
3. ...
Actions:
```python
    action(args1=x,args2=y)
```
```

K.4 Prompts for Dealer's Life 2

Prompt 22: Dealer's Life 2: Information Gathering prompt.

```
Assume you are a helpful AI assistant integrated with "Dealer's Life 2"
    on the PC, equipped to handle a wide range of tasks in the game. Your
     advanced capabilities enable you to process and interpret gameplay
    screenshots and other relevant information.

<$image_introduction$>

Current task:
<$task_description$>

Description: Please analyze and describe the screenshot image in detail
    and then provide an overall image description. Most importantly,
    identify the current page type and any relevant information related
    to the task. If there are specific features such as characters or
    text, mention these as well.

Budget: Bank Balance is shown at the top right of the screenshot.

Other: Other information that does not belong to the above categories. If
     none of them applies, only output "null".

You should only respond in the format described below and not output
    comments or other information.
Description:
The image shows...
Budget:
The amount of budget
Other:
Other information is ...
```

Prompt 23: Dealer's Life 2: Self Reflection prompt.

```
Assume you are a helpful AI assistant integrated with "Dealer's Life 2"
    on the PC, equipped to handle a wide range of tasks in the game. Your
```

```
     advanced capabilities enable you to process and interpret gameplay
    screenshots and other relevant information. Your task is to examine
    these inputs, interpret the in-game context, and determine whether
    the executed action takes effect.

Target task:
<$task_description$>

Current subtask for completing the target task:
<$subtask_description$>

The reasoning for proposing the current subtask:
<$subtask_reasoning$>

Last executed action for completing the subtask:
<$actions$>

Reasoning for the last action:
<$decision_making_reasoning$>

Current budget:
<$budget$>

Summarization of recent history:
<$history_summary$>

<$image_introduction$>

Reasoning: You need to answer the following questions step by step to get
     some reasoning based on the last action and sequential frames of the
     character during the execution of the last action.
1. What is the executed action? Please answer this question not based on
    the sequential frames.
2. Was the executed action successful? Give reasons. You should refer to
    the following rules:
- If you are not 100% sure that the action fails, regard it as success.
3. If the last action is not executed successfully, what is the most
    probable cause? You should give only one cause and refer to the
    following rules:
- The reasoning for the last action could be wrong.
- If it is an interaction action, the most probable cause was that the
    action was unavailable at the current place, then you should move to
    a new place.
- If it is a movement action, the most probable cause was that you were
    blocked by seen or unseen obstacles.
- If there is an error report, analyze the cause based on the report.
4. Is the subtask completed? Give your reasons. If you want to make any
    confirmation, regard it as a success.
5. Is the target task completed? Give your reasons.
6. Do you think the subtask is reasonable? Give your reasons.

Success: You need to output whether the last action was executed
    successfully or not.
- If the last action is successful, you should only output 'True'.
    Otherwise, you should only output 'False'.

You should only respond in the format described below.
Reasoning:
1. ...
2. ...
3. ...
Success:
True
...
```

Prompt 24: Dealer's Life 2: Task Inference prompt.

```
Assume you are a helpful AI assistant integrated with 'DealersLife2' on
    the PC, equipped to handle a wide range of tasks in the game. You
    will also be given a summary of the history that happened before the
    last screenshot. You should assist in summarizing the events for
    future decision-making and also propose a new subtask, which is the
    most suitable subtask for the current situation, given the target
    task.

Here is some helpful information to help you do the summarization and
    propose the subtask.

Current task:
<$task_description$>

Previous proposed subtask for the task:
<$subtask_description$>

Previous reasoning for proposing the subtask:
<$subtask_reasoning$>

<$image_introduction$>

Current budget:
<$budget$>

Current population:
<$population$>

Last executed action:
<$actions$>

Decision-making reasoning for the last executed action:
<$decision_making_reasoning$>

Self-reflection for the last executed action:
<$self_reflection_reasoning$>

The following is the summary of history that happened before the last
    screenshot:
<$previous_summarization$>

History_summary: Summarize what happened in the past experience,
    especially the last step according to the decision-making reasoning
    and self-reflection reasoning for the last executed action. The
    summarization needs to be precise, concrete and highly related to the
     task and follow the rules below.
1. Summarize the tasks from the history and the current task. What is the
     current progress of the task?
2. Record the successful actions and organize them into events day by day
    .
3. Do not forget the information and key events in the previous days.
4. If you are watering a seed. Record how many times you have watered and
     calculate how many days you have to water before you can harvest
    according to the toolbar information provided above.

Subtask_reasoning: Decide whether the previous subtask is finished and
    whether it is necessary to propose a new subtask. The subtask should
    be straightforward, contribute to the target task and be most
    suitable for the current situation, which should be completed within
    a few actions. You should respond to me with:
1. How to finish the target task? You should analyze it step by step.
2. What is the current progress of the target task according to the
    analysis in step 1? Please do not make any assumptions if they are
```

```
    not mentioned in the above information. You should assume that you
    are doing the task from scratch.
3. What is the previous subtask? Does the previous subtask finish? Or is
    it improper for the current situation? Then select a new one,
    otherwise you should reuse the last subtask.
4. If you want to propose a new subtask, give reasons why it is more
    feasible for the current situation.
5. The proposed subtask needs to be precise and concrete within one
    sentence. It should not be related to any skills.
6. Do not mention any grid information in the subtask description.

You should only respond in the format described below, and you should not
     output comments or other information.
History_summary:
The summary is ...
Subtask_reasoning:
1. ...
2. ...
3. ...
Subtask:
The current subtask is ...
```

Prompt 25: Dealer's Life 2: Action Planning prompt.

```
You are a helpful AI assistant integrated with "Dealer's Life 2" on the
    PC, equipped to handle various tasks in the game. Your advanced
    capabilities enable you to process and interpret gameplay screenshots
     and other relevant information. By analyzing these inputs, you gain
    a comprehensive understanding of the current context and situation
    within the game. Utilizing this insight, you are tasked with
    identifying the most suitable in-game action to take next, given the
    current task. You control the game character and can execute actions
    from the available action set. Upon evaluating the provided
    information, your role is to articulate the precise action you would
    deploy, considering the game's present circumstances, and specify any
     necessary parameters for implementing that action.

Here is some helpful information to help you make the decision.

Current subtask:
<$subtask_description$>

Current page type:
<$coordinates$>

Current budget:
<$budget$>

Last executed action:
<$actions$>

Reasoning for the last action:
<$decision_making_reasoning$>

Self-reflection for the last executed action:
<$self_reflection_reasoning$>

Summarization of recent history:
<$history_summary$>

Valid action set in Python format to select the next action:
<$skill_library$>

<$image_introduction$>
```

```
Based on the above information, analyze the current situation and provide the reasoning for what you should do for the next step to complete the task. Then, you should output the exact action you want to execute in the game. You should respond to me with:

Reasoning: You should think step by step and provide detailed reasoning to determine the next action executed on the current state of the task. You need to answer the following questions step by step. You cannot miss the last question:
    1. Analyze the information in the screenshot. What can you observe in the screenshot? Please list some key elements.
    2. What is the current task? What are the requirements to achieve the goal?
    3. What have you done so far in the game? What are the results of the previous actions?
    4. What is your next step to achieve the goal? What is your plan? Why do you choose this action? Please explain the reasoning behind your decision.
    5. If you were to respond to the customer's dialogue on the dialogue page, which of the listed responses in the screenshot would you choose? Why?
    6. If you are to make an offer to a customer, how would you determine the price? You should determine the customer's role here. If the customer is a "seller", you should offer a price lower than the item's value. If the customer is a "buyer", you should offer a price higher than the item's value. Please explain your reasoning.
    7. If the customer rejects your offer and makes a counteroffer, what would you do? Would you accept the counteroffer or refuse the deal? Why?
    8. What does the current screen image show? is it a giving price page (it at least should show price $ in the right bottom of the screen image) or a non-giving price page and why?

Actions: The requirements that the generated action needs to follow. The best action, or short sequence of actions without gaps, to execute next to progress in achieving the goal. Pay attention to the names of the available skills and the previous skills already executed, if any. You should also pay more attention to the following action rules:
    1. You should output actions in Python code format and specify any necessary parameters to execute that action. If the function has parameters, you should also include their names and decide their values, like "move_right(duration=1)". If it does not have a parameter, just output the action, like "open_map()".
    2. Given the current situation and task, you should only choose the most suitable action from the valid action set. You cannot use actions that are not in the valid action set to control the character.
    3. In the screenshots, the blue band represents the left side and the yellow band represents the right side. Please ignore the character's facing direction and output the action in an absolute direction like right and left.
    4. If you want to run as a successful dealer in conversation with the customer, you should follow these rules:
      4.1 Check the customer's dialogue.
        - If the customer is introducing himself and his purpose of visiting your shop, you should always respond with "Let's see" to make them potential buyers. This will be the first option in the dialogue and you should select it.
      4.2 Check the customer's response.
        - If the customer has shown you the details of the items and you have completed by closing the item detail page, you should respond with "Let's deal" to make an offer. This will be the first option in the dialogue and you should select it.
```

```
    5. If you want to run as a successful dealer in making an offer and
    deciding whether to take the offer or counteroffer, you should follow
     these rules:
     5.1 Check the customer's role.
      - If the customer is a "seller", you should offer a price lower
    than the item's value. You should also consider your budget.
      - If the customer is a "buyer", you should offer a price higher
    than the item's value.
     5.2 Check the item's details.
      - You should check the item's "rarity", "condition", and "estimate"
     to determine the price you offer.
    6. If you have opened up the buyer's or seller's character trait page
    , you should call the function to close the description page to
    proceed with the next action. You should NOT call any other skill
    like dialogue().
    7. Your action should strictly follow the analysis in the reasoning.
    Do not output any additional action not mentioned in the reasoning.

You should only respond in the format described below, and you should not
     output comments or other information.
Reasoning:
1. ...
2. ...
3. ...
Actions:
'''python
    action(args1=x,args2=y)
'''
```

K.5 Prompts for Software Applications

Prompt 26: Chrome: Information Gathering prompt.

```
Assume you are a helpful AI assistant integrated with 'Google Chrome' on
    the PC, equipped to handle a wide range of tasks in the application.
    Your advanced capabilities enable you to process and interpret
    application screenshots and other relevant information.

Image introduction:
<$image_introduction$>

Overall task:
<$task_description$>

Subtask description:
<$subtask_description$>

Image_Description:
1. Please describe the screenshot image in detail. Pay attention to any
    details in the image, if any, especially critical icons, or created
    items.
2. If the image includes a mouse cursor, please describe what UI element
    the mouse is currently located near. Pay attention to the coordinates
     of the pointer tip, not the center of the mouse cursor.
3. Pay attention to all UI items and contents in the image. Do not make
    assumptions about the layout.

Description_of_bounding_boxes:
Please provide a list of EVERY bounding box from label ID of 1 to <
    $length_of_som_map$> ONE BY ONE. The label IDs are marked in the
    upper left corner of the bounding boxes.
For bounding boxes containing text, provide ONLY the text.
For bounding boxes without text, brief description of the function.
```

```
Format your response as follows: '1: function_a', '2: text_b', ..., '<
    $length_of_som_map$>: function_b'. Don't write anything you are not
    sure about.

Target_object_name: Assume you can use an object detection model to
    detect the most relevant object or UI item for completing the current
     task if needed. What item should be detected to complete the task
    based on the current screenshot and the current task? You should obey
     the following rules:
1. Identify an item that is relevant to the current or intermediate
    target of the task. If the item is within a bounding box in the
    screenshot, please include the corresponding label ID.
2. If no explicit item is specified, only output "null".
3. If there is no need to detect an object, only output "null".

Reasoning_of_object: Why was this object chosen, or why is there no need
    to detect an object?

You should only respond in the format described below and not output
    comments or other information. DO NOT change the title of each item.
Image_Description:
1. ...
2. ...
3. ...

Description_of_bounding_boxes:
Format like: 1: function_a', '2: text_b', ..., '<$len_of_bound_boxes$>:
    function_b

Target_object_name:
label ID, Name

Reasoning_of_object:
...
```

Prompt 27: Chrome: Self-Reflection prompt.

```
Assume you are a helpful AI assistant integrated with 'Google Chrome' on
    the PC, equipped to handle a wide range of tasks in the application.
    Your advanced capabilities enable you to process and interpret
    application screenshots and other relevant information. Your task is
    to examine these inputs, interpret the in-application and OS context,
     and determine whether the executed action has taken the correct
    effect.

Overall task description:
<$task_description$>

Image introduction:
<$image_introduction$>

Last executed action with parameters used:
<$previous_action_call$>

Implementation of the last executed action:
<$action_code$>

Error report for the last executed action:
<$executing_action_error$>

Key reason for the last action:
<$key_reason_of_last_action$>

History Summarization
<$history_summary$>
```

```
Success_Detection flag for the overall task:
<$success_detection$>

Valid action set in Python format to select the next action:
<$skill_library$>

Current and previous screenshot are the same:
<$image_same_flag$>

Mouse position in the current screenshot is the same as in the previous
    screenshot:
<$mouse_position_same_flag$>

Self_Reflection_Reasoning:
You need to answer the following questions, step by step, to describe
    your reasoning based on the history summarization, last action and
    sequential screenshots of the application during the execution of the
     last action.
1. Please describe what the page is in the current screenshot. Respond in
     one sentence.
2. What is the last executed action based on the text information above?
3. Was the last executed action successful? Give reasons. You should
    refer to the following rules:
- If the last action executed was empty, then  the previous action is
    deemed successful.
- If the action involves moving the mouse, it is considered unsuccessful
    when the mouse position remains unchanged or moves in an incorrect
    way across sequential screenshots, regardless of background elements
    and other items.
- If the position to move the mouse to was incorrect and the mouse didn't
     reach the target UI element, pay more attention to the accurate
    coordinates to move to.
- If the operation involves type text, it will be considered unsuccessful
     when the corresponding text does not appear in the diagram,
    regardless of background elements and other items.
- If the action seemed to have no effect, pay attention to the latest
    mouse position. Did it move? Did it get closer to the target UI
    element? Where are the target coordinates in the action wrong? The
    position of the mouse cursor on the screenshot shows their location.
- Was some unrelated UI item triggered by the last action?
4. If the last action is not executed successfully, what is the most
    probable cause? You should give only one cause and refer to the
    following rules:
- The reasoning for the last action could be wrong.
- If it was an action involving moving the mouse or the text cursor, the
    most probable cause was that the coordinates used were incorrect.
- If it is an interaction action, the most probable cause was that the
    action was unavailable or not activated in the current state.
- If an unrelated change happened in the UI, the most probable cause was
    that the action triggered an incorrect UI element.
- If there is an error report, analyze the cause based on the report.

Success_Detection:
Based on the history summarization, the last action, the current
    screenshots and the Success_Detection flag, determine whether the
    overall task "<$task_description$>" was successful. This assessment
    should consider the overall task's success, not just individual
    actions.
- If the last action executed was an empty list and "<$success_detection$
    >" indicates the task is successful, then the overall task has a high
     chance of being considered a success.
- If the overall task was unsuccessful, specify the reason of failure and
     which steps are missing.
- If the overall task was successful, ONLY output "SUCCESSFUL".
```

```
You should only respond in the format as described below.
Self_Reflection_Reasoning:
1. ...
2. ...
3. ...

Success_Detection:
...
```

Prompt 28: Chrome: Task Inference prompt.

```
Assume you are a helpful AI assistant integrated with 'Google Chrome' on
    the the PC, equipped to handle a wide range of tasks in the game. You
     will be sequentially given <$event_count$> screenshots and
    corresponding descriptions of recent events. You will also be given a
     summary of the history that happened before the last screenshot. You
     should assist in summarizing the events for future decision-making
    and also in proposing the most suitable subtask to execute next,
    given the target task.

Here is some helpful information to help you do the summarization and
    propose the subtask.

Overall task description:
<$task_description$>

Previous proposed subtask for the task:
<$subtask_description$>

Previous reasoning for proposing the subtask:
<$subtask_reasoning$>

Image introduction:
<$image_introduction$>

Last executed action:
<$previous_action$>

Error report for the last executed action:
<$executing_action_error$>

Key decision-making reasoning for the last executed action:
<$previous_reasoning$>

Self-reflection for the last executed action:
<$self_reflection_reasoning$>

Success_Detection for the overall task:
<$success_detection$>

The following is the summary of history that happened before the last
    screenshot:
<$previous_summarization$>

History_summary: Summarize what happened in the past experience,
    especially the last step according to the decision-making reasoning
    and self-reflection reasoning for the last executed action. The
    summarization needs to be precise, concrete, highly related to the
    task, and follow the rules below.
    1. Determine if the task has been completed successfully. If it is
    successful, ignore question 2 to 5.
    2. Summarize the tasks from the history and the current task. What is
     the current progress of the task? For example, to open a file, you
```

```
    first need to select the file, then open it by clicking somewhere or
    using the keyboard. Subtasks may have other pre-requisites.
    3. Record the successful actions and organize them into events, step
    by step.
    4. Which subtask has been completed? Which subtasks have not? Do not
    forget the information and key events in the previous steps of the
    overall task.

Subtask_reasoning: Decide whether the previous subtask is finished and
    whether it is necessary to propose a new subtask. The subtask should
    be straightforward, contribute to the target task, and be most
    suitable for the current situation; which should be completed within
    a few actions. You should respond with the following item.
    1. Think about a hotkey related to the overall task and next subtask,
     please specify what it is.
    2. Based on the current screenshot, identify the most direct and
    easiest way to complete the task.
    3. Analyze the target task step by step to determine how to complete
    it.
    4. What is the previous subtask? Has the previous subtask finished
    due to self-reflection? Or is it improper for the current situation?
    If finished or improper, please select a new one, otherwise you
    should reuse the last subtask.
    5. If you want to propose a new subtask, give reasons why it is more
    feasible for the current situation. Please strictly follow the
    description and requirements in the current task.
    6. The proposed subtask needs to be precise and concrete within one
    sentence. It should not be directly related to any skills.

You should only respond in the format described below, and you should not
     output comments or other information.

History_summary:
1. ...
2. ...
...

Subtask_reasoning:
1. ...
2. ...
...

Subtask_description:
The current subtask is ...
```

Prompt 29: Chrome: Action Planning prompt.

```
You are a helpful AI assistant integrated with 'Google Chrome' on the PC,
     equipped to handle a wide range of tasks in the application. Your
    advanced capabilities enable you to process and interpret application
     screenshots and other relevant information. By analyzing these
    inputs, you gain a comprehensive understanding of the current context
     and situation within the application. Utilizing these insights, you
    are tasked with identifying the most suitable in-application action
    to take next, given the current task. You control the application and
     can execute actions from the available action set to manipulate its
    UI. Upon evaluating the provided information, your role is to
    articulate the precise actions you should perform, considering the
    application's present circumstances, and specify any necessary
    parameters for implementing that action.
Here is some helpful information to help you make the decision.

Overall task description:
<$task_description$>
```

```
Subtask description:
<$subtask_description$>

Few shots:
<$few_shots$>

Image introduction:
<$image_introduction$>

Current and previous screenshot are the same:
<$image_same_flag$>

Mouse position in the current screenshot is the same as in the previous
    screenshot:
<$mouse_position_same_flag$>

Description of current screenshot:
<$image_description$>

Description of label IDs:
<$description_of_bounding_boxes$>

Last executed action:
<$previous_action$>

Key reason for the last action:
<$key_reason_of_last_action$>

Self-reflection for the last executed action:
<$previous_self_reflection_reasoning$>

Summarization of recent history:
<$previous_summarization$>

Valid action set in Python format to select the next action:
<$skill_library$>

Success detection for overall task:
<$success_detection$>

Based on the above information, you should first analyze the current
    situation and provide the reasoning for what you should do for the
    next step to complete the task. Then, you should output the exact
    action you want to execute in the application.
Pay attention to all UI items and contents in the image. DO NOT make
    assumptions about the layout! If the image includes a mouse cursor,
    pay close attention to the coordinates of the pointer tip, not the
    centre of the mouse cursor.
You should respond to me with the following information, and you MUST
    respond one by one.

Decision_Making_Reasoning: You should think step by step and provide
    detailed reasoning to determine the next action executed on the
    current state of the task.
    1. Does "<$success_detection$>" mean the overall task was successful?
     If successful, ignore questions 2 to 12.
    2. Which skill in the Skill Library "<$skill_library$>" has the
    closest semantics to the current subtask "<$subtask_description$>"?
    If there is an answer, select it as the output action.
    3. Prefer keyboard operation instead of mouse operation. Are there
    any keyboard actions, such as using shortcut keys or pressing "enter
    ", to finish the current step or overall task? If there is, please
    specify which it is.
    4. Based on the action rules, self-reflection and previous
    summarization, what should be the most suitable action in the valid
```

```
    action set for the next step? You should analyze the effects of the
    action step by step.
    5. If the previous action is unsuccessful, DO NOT repeat the previous
     action, consider an alternative action if possible. If there is an
    alternative action, please specify what it is, such as clicking
    different label IDs or using different shortcut keys.
    6. Always try pressing "enter" first instead of clicking it with the
    mouse, if the button you want to click is active.
    7. Check whether the UI element you want to operate exists in the
    current screenshot. If not, you can choose to return to the previous
    page or reopen a tab.
    8. In the current screenshot, identify the label ID of the bounding
    box most relevant to the current step. If there is text within this
    bounding box, please provide the text.
    9. If mouse actions are necessary, use that specific bounding box
    label ID (if shown in the current screenshot) as a parameter, rather
    than directly generating normalized x and y coordinates. If there is
    any relevant label ID, please specify which it is.
    10. If a dialog box appears, make sure to check the content of the
    dialog box to determine if the task is complete. For instance, when a
     download dialog box appears, the task is only completed after
    pressing the Enter key or clicking "Save".
    11. If you need to use an action outside an open menu or dialog box,
    please close the current menu or dialog box before trying the next
    action.
    12. If you anticipate that the next step involves typing text,
    confirm that the last executed action was a click at the appropriate
    input box. If not, it is mandatory to click on the corresponding
    input box before proceeding with typing.

Actions: The best action, or short sequence of actions without gaps, to
    execute next to progress in achieving the goal. Pay attention to the
    names of the available skills and the previous skills already
    executed, if any. Pay special attention to the coordinates of any
    action that needs them. Do not make assumptions about the location of
     UI elements or their coordinates, analyse in detail any provided
    images. You should also pay more attention to the following action
    rules:
    1. If "<$success_detection$>" means the overall task was successful
    or equal to "True", then the output action MUST be empty like ''. Be
    careful to check the task was really successful.
    2. You should output actions in Python code format and specify any
    necessary parameters to execute that action. Only use function names
    and argument names exactly as shown in the valid action set. If a
    function has parameters, you should also include their names and
    decide their values, like "press_shift(duration=1)". If it does not
    have a parameter, just output the action, like "release_mouse_buttons
    ()".
    3. Before typing text, ensure that the last executed action involved
    clicking on the relevant input box. If the last action was not a
    click on this input box, the required action MUST be to click on the
    corresponding input box before proceeding.
    4. Given the current situation and task, you should only choose the
    most suitable action from the valid action set. You cannot use
    actions that are not in the valid action set to control the
    application.
    5. When you perform a mouse action, always select the target UI
    element closest to the UI element of the previous action for
    operation.
    6. When you decide to operate on a file, such as downloading it,
    please pay attention to the path and name of the current file.

Key_reason_of_last_action: Summarize the key reasons why you output this
    action.
```

````
You should only respond in the format described below. In your reasoning
    for the chosen actions, also describe which item you decided to
    interact with and why. DO NOT change the title of each item. You
    should not output other comments or information besides the format
    below.
Decision_Making_Reasoning:
1. ...
2. ...
3. ...
...

Actions:
```python
    action(args1=x,args2=y)
```

Key_reason_of_last_action:
...
````

Prompt 30: Outlook: Information Gathering prompt.

```
You an expert helpful AI assistant which follows instructions and
    performs desktop computer tasks as instructed. You have expert
    knowledge of 'Microsoft Outlook' on the PC and can handle a wide
    range of tasks in the application using the keyboard, shortcut keys,
    and mouse operations. For each step, you will get one or more
    observation images, which are screenshots of the computer screen.
    Your advanced capabilities enable you to process and interpret these
    application screenshots and other relevant information in detail. The
     screenshots include numerical tags (label IDs) and bounding boxes
    marking some UI items.

Image introduction:
<$image_introduction$>

Overall task:
<$task_description$>

Subtask description:
<$subtask_description$>

Image_Description:
1. Please describe the screenshot image in detail. Pay attention to any
    details in the image, if any, especially critical icons, open menus
    or dialogs, and any instructions for the application user. Focus on
    the image contents and the situation in the application.
2. If the image includes a mouse cursor, please describe what UI element
    the mouse is currently located near. Pay attention to the coordinates
     of the pointer tip, not the center of the mouse cursor.
3. Pay attention to all UI items and contents in the image. Do not make
    assumptions about the layout.
4. DO NOT describe overlayed bounding boxes in this description, only the
     relevant UI items themselves. Focus on the state of the application
    UI and what the key UI items of interest for the task would be.
    Describe any relevant open panels, dialogs, menus, etc.

Target_object_name:
As an application expert and a helpful assistant, you can determine the
    most relevant UI items for completing the current subtask, if needed.
     What item should be detected to complete the task based on the
    current screenshot and the current subtask? You should obey the
    following rules:
1. The item should be present in the screen and relevant to the current
    subtask or overall task. Just name the item, without any modifiers or
     extra information.
```

```
2. If the item of itnerest of not on the current screen, only output "
    Target items not in current screen".
2. If no explicit item is specified, only output "null".
3. If there is no need to detect a target item in this state, only output
     "null". You must output this field in the response.

Reasoning_of_object: Why was this item chosen, or why is there no need to
     detect an UI item at this stage?

You should only respond in the format described below and not output
    comments or other information. DO NOT change the titles of any
    response items.

Image_Description:
1. ...
2. ...
3. ...

Target_object_name:
name

Reasoning_of_object:
...
```

Prompt 31: Outlook: Self-Reflection prompt.

```
You an expert helpful AI assistant which follows instructions and
    performs desktop computer tasks as instructed. You have expert
    knowledge of 'Microsoft Outlook' on the PC and can handle a wide
    range of tasks in the application using the keyboard, shortcut keys,
    and mouse operations. For each step, you will get one or more
    observation images, which are screenshots of the computer screen.
    Your advanced capabilities enable you to process and interpret these
    application screenshots and other relevant information in detail.
You MUST examine all inputs, interpret the in-application and OS contexts
    , and determine whether the executed action has taken the correct
    effect.

Overall task description:
<$task_description$>

Execution step images:
<$image_introduction$>

Current image description:
<$current_image_description$>

Last executed action with parameters used:
<$previous_action_call$>

Implementation of the last executed action:
<$action_code$>

Error report for the last executed action:
<$executing_action_error$>

Key reason for the last action:
<$key_reason_of_last_action$>

Success_Detection flag for the overall task:
<$success_detection$>

Valid action set in Python format to select the next action:
<$skill_library$>
```

```
Current and previous screenshot are the same:
<$image_same_flag$>

Mouse position in the current screenshot is the same as in the previous
    screenshot:
<$mouse_position_same_flag$>

As the textual history may not completely record some effects of previous
     actions, you should closely evaluate every part of the screenshots
    to understand what was supposed to happen and what has actually
    happened.

Self_Reflection_Reasoning: You need to answer the following questions,
    step by step, to describe your reasoning based on the last action and
     sequential screenshots of the application during the execution of
    the last action. Any action involving x and y coordinates is an
    action involving movement.
1. What is the last executed action not based on the sequential
    screenshots?
2. Was the last executed action successful? Give reasons. You should
    refer to the following rules:
- If the action involved typing text, was it typed correctly at the right
     location? Do not trust only the textual information as it may not
    provide enough detail. Perform a thorough and detailed inspection of
    the provided creenshots! This is a critical check at every step!
- If the action involved moving the mouse, it is considered unsuccessful
    when the mouse position remains unchanged or moved in an incorrect
    way across sequential screenshots, regardless of background elements
    and other items.
- If the position to move the mouse to was incorrect and the mouse didn't
     reach the target UI element, pay more attention to the accurate
    location or UI item to move to.
- Are you sure the latest screenshot shows UI items that correspond to
    the success of the previous action? For example, if you tried to
    click on the "Junk" folder, the latest screenshot should show that
    folder, not "Inbox" or others.
- Triggering an action in the last step is not enough to say it was
    completely successfully. At least some relevant UI must change. Pay
    attention to the application states in the screenshots and any
    differences.
- If the action seemed to have no effect, pay attention to the latest
    mouse position. Did it move? Did it get closer to the target UI
    element? Was the target in the action wrong? The position of the
    mouse cursor on the screenshot shows their location.
- Was some unrelated UI item triggered by the last action?
3. If the last action is not executed successfully, what is the most
    probable cause? You should give only one cause and refer to the
    following rules:
- The reasoning for the last action could be wrong.
- If it was an action involving moving the mouse or the text cursor, the
    most probable cause was that the coordinates or destination location
    used were incorrect.
- If you already tried the same action more than one time and there was
    no effect. DO NOT REPEAT the same action again until you have tried
    something else.
- If it is an interaction action, the most probable cause was that the
    action was unavailable or not activated at the current state.
- If an unrelated change happened in the UI, the most probable cause was
    that the action triggered an incorrect UI element.
- If there is any error report, analyze the cause based on the report.

Success_Detection:
Based on the last action, the current screenshots and the
    Success_Detection flag, determine whether the overall task was
```

```
    successful. This assessment should consider the overall task's
    success, not just individual actions.
- If the task was unsuccessful, specify the reason of failure and which
    steps are missing.
- Pay extra attention to the application state in the latest screenshot.
    Is it consistent with the task being completed successfully? Or is
    there evidence that the task is still ongoing?
- If the task was successful, ONLY output "SUCCESSFUL".

You should only respond in the format as described below.
Self_Reflection_Reasoning:
1. ...
2. ...
3. ...

Success_Detection:
...
```

Prompt 32: Outlook: Task Inference prompt.

```
You an expert helpful AI assistant which follows instructions and
    performs desktop computer tasks as instructed. You have expert
    knowledge of 'Microsoft Outlook' on the PC and can handle a wide
    range of tasks in the application using the keyboard, shortcut keys,
    and mouse operations. For each step, you will get one or more
    observation images, which are screenshots of the computer screen.
    Your advanced capabilities enable you to process and interpret these
    application screenshots and other relevant information in detail.
You will receive a sequence of <$event_count$> screenshots, corresponding
     descriptions of recent events, and a summary of the history of
    events before the last screenshot. Please summarize the events for
    future decision-making and also propose the most suitable subtasks to
     execute next, given the overall target task.

Here is some helpful information to help you do the summarization and
    propose the subtask.

Overall task description:
<$task_description$>

Previous proposed subtask for the task:
<$subtask_description$>

Previous reasoning for proposing the subtask:
<$subtask_reasoning$>

Image introduction:
<$image_introduction$>

Last executed action:
<$previous_action$>

Error report for the last executed action:
<$executing_action_error$>

Key decision-making reasoning for the last executed action:
<$previous_reasoning$>

Self-reflection for the last executed action:
<$self_reflection_reasoning$>

Success_Detection for the overall task:
<$success_detection$>
```

```
The following is the summary of history that happened before the last
    screenshot:
<$previous_summarization$>

History_summary: Summarize what happened in the past experience,
    especially the last step according to the decision-making reasoning
    and self-reflection reasoning for the last executed action. The
    summarization needs to be precise, concrete, highly related to the
    task, and follow the rules below.
1. Summarize the tasks from the history and the current task. What is the
     current progress of the task? For example, to open a file, you first
     need to select the file, then open it by clicking somewhere or using
     the keyboard. Subtasks may have other pre-requisites.
2. Record the successful actions and organize them into events, step by
    step.
3. Which subtask has been completed? Which subtasks have not?
4. Do not forget the information and key events in the previous steps of
    the overall task.

Subtask_reasoning: Decide whether the previous subtask is finished and
    whether it is necessary to propose a new subtask. The subtask should
    be straightforward, contribute to the target task, and be most
    suitable for the current situation; which should be completed within
    a few actions. Use your knowledge of keyboard shortcuts to accomplish
     subtasks. You should respond with:
1. How to finish the target task? You should analyze it step by step.
    Subtasks can involve keyboard shortcuts, using the mouse, or
    executing other skills.
2. What is the current progress of the target task according to the
    analysis in question 1? Please do not make any assumptions if needed
    information is not mentioned previously. You should assume that you
    are doing the task from scratch. Please strictly follow the
    description and requirements in the current overall task.
3. What is the previous subtask? Has the previous subtask finished
    according to self-reflection? Or is it improper for the current
    situation? If the last subtask already finished or now is improper,
    please select a new one. Otherwise you should reuse the last subtask.
4. If you propose a new subtask, give the reasons why it is more feasible
     in the current situation in the application. Please strictly follow
    the description and requirements in the current overall task.
5. The proposed subtask needs to be precise and concrete within one
    sentence. It should not be directly related to any skills.

You should only respond in the format described below, and you should not
     output comments or other information.

History_summary:
The summary of past events is...

Subtask_reasoning:
1. ...
2. ...
...

Subtask_description:
The current subtask is ...
```

Prompt 33: Outlook: Action Planning prompt.

```
You an expert helpful AI assistant which follows instructions and
    performs desktop computer tasks as instructed. You have expert
    knowledge of 'Microsoft Outlook' on the PC and can handle a wide
    range of tasks in the application using the keyboard, shortcut keys,
    and mouse operations. For each step, you will get one or more
    observation images, which are screenshots of the computer screen.
```

```
    Your advanced capabilities enable you to process and interpret these
    application screenshots and other relevant information in detail. The
     screenshot includes numerical tags (label IDs) and bounding boxes
    marking some UI items.
Based on your analysis of screenshots and knowledge of the application,
    keyboard shortcuts, and general GUI design, you will identify the
    most suitable in-application action to take next, given the current
    task. Upon evaluating the provided information, you MUST choose the
    precise actions to perform, considering the applications's present
    circumstances, and specify any necessary parameters to execute the
    desired action.

Here is some helpful information to help you make the correct decision.

Overall task description:
<$task_description$>

Subtask description:
<$subtask_description$>

Few shots:
<$few_shots$>

Image introduction:
<$image_introduction$>

Current and previous screenshot are the same: <$image_same_flag$>. Mouse
    position in the current screenshot is the same as in the previous
    screenshot:<$mouse_position_same_flag$>.

Description of the current screenshot:
<$image_description$>

Potential target UI item and label ID:
<$target_object_name$>

Last executed action:
<$previous_action$>

Key reason for the last action:
<$key_reason_of_last_action$>

Self-reflection for the last executed action:
<$previous_self_reflection_reasoning$>

Summarization of recent history:
<$previous_summarization$>

Valid action set in Python format to select the next action:
<$skill_library$>

Success detection for overall task:
<$success_detection$>

Based on the above information, you should first analyze the current
    situation of the application and provide the reasoning behind what
    should be the next step to complete the task. Then, you should output
     the exact action to be executed in the application. As the textual
    history may not completely record some effects of previous actions,
    you should closely evaluate every part of the screenshots to
    understand what you have done and what you should do next. Pay
    attention to your application knowlege and all contents in the image.
     You also have great OCR capabilities. DO NOT make assumptions about
    the layout! If the image includes a mouse cursor, pay close attention
     to the coordinates of the pointer tip, not the center of the mouse
```

```
    cursor. Remember you know the common keyboard shortcuts for Microsoft
     Outlook on Windows and can use them instead of the mouse. You should
     respond with the following information, and you MUST answer them one
     by one.

Does "<$success_detection$>" mean the overall task was successful? If
    successful, ignore decision making and action questions. No new
    action needs to be taken and output action MUST be empty, like ''. Be
     careful to check the task was really successful though!

Decision_Making_Reasoning: You should think step by step and provide
    detailed reasoning to determine the next action executed on the
    current state of the task.
    1. Do you know any keyboard shortcuts for Microsoft Outlook on
    Windows that can be used to accomplish this subtask? Which one?
    2. If the current screenshot is the same as the previous screenshot,
    DO NOT output the same action as the last executed action with the
    same parameters as in the previous step, as it was not useful!!!
    3. Prefer keyboard operations and skills, instead of mouse operations
    . Are there any keyboard actions, such as shortcut keys like
    press_keys_combined(["ctrl", "s"]) to save, or press_key("enter") to
    confirm, that can complete the current step or the overall task? If
    yes, please specify what the action is and ignore questions 5 to 8.
    4. Which skill in the available Python action set has the closest
    semantics to the current subtask? If there is any, select it as the
    output action and ignore questions 5 to 8.
    5. Carefully identify if there is a bounding box label ID for the UI
    item relevant for the current step. Be extra careful to use the
    correct label ID and describe why you selected the given ID, if any!
    If there is text within this bounding box area, please provide that
    text in your reasoning. If there is no text, provide a visual
    description of the UI item inside the bounding box. Only directly
    generate normalized x, y coordinates if no suitable label ID is
    present.
    6. If a mouse cursor is present in the image, pay attetion to which
    ID-labeled bounding box or unlabelled UI item the cursor's tip is
    located, not the center of the cursor.
    7. If not absolutely sure if a UI item or location is correct to
    click, you can first just hover the mouse over it and check for more
    information. If it is the right item, you can choose to click on it
    in the next reasoning step.
    8. If there is a dialog or menu opened after the previous action, pay
     attention to any missing step before clicking on its buttons. For
    example, before clicking "Save", make sure a correct file name is
    typed in the correct text field.
    9. If the previous action is unsuccessful, consider an alternative
    action if possible. If there is an alternative action, please specify
     what it is. Such as click a different label ID or use a different
    keyboard shortcut.
    10. If you think the next step will be to type text, confirm the text
     cursor is in the correct location or that the last executed action
    was a click at the appropriate input area. If neither is true, you
    have to click the corresponding input box before proceeding with
    typing.

Actions: The best action, or short sequence of actions without gaps, to
    execute next to progress towards the task goal. Pay attention to the
    names of the available skills, keyboard shortcuts, and the previous
    skills already executed. Pay special attention to the coordinates or
    bounding box label ID of any action that needs them. Do not make
    assumptions about the location of UI elements or their coordinates,
    analyse in detail any provided images! You should also pay more
    attention to the following action rules:
    1. Which keyboard shortcuts do you know for this application that can
     be used to accomplish exactly this specific subtask? Be precise to
```

```
    the current subtask step. Keyboard shortcuts are more reliable than
    using the mouse as you tend to choose the correct UI item, but act on
     the wrong label ID or position. If there is no applicable shortcut,
    you can choose typing text or other forms of UI interaction. Don't
    recomment a single key press that may not apply in this exact
    situation.
    2. You should output actions in Python code format and specify any
    necessary parameters to execute that action. Only use function names
    and argument names exactly as shown in the valid action set. If a
    function has parameters, you should also include their names and
    decide their values, like "press_shift(duration=1)". If it does not
    have a parameter, just output the action, like "release_mouse_buttons
    ()".
    3. Given the current situation and task, you should only choose the
    most suitable action from the valid action set. You cannot use
    actions that are not in the valid action set to control the
    application.
    4. When you decide to perform a mouse action, if there is bounding
    box in the current screenshot, you MUST choose the skill
    click_on_label(label_id, mouse_button). Be careful to use the correct
     label ID number.
    5. When you perform a mouse action, always select the target UI
    element closest to the UI element of the previous action for
    operation.
    6. When you decide to operate on a file, such as downloading it,
    please pay attention to the file path and to the name of the current
    file.
    7. If upon self-reflection you think the target coordinates or label
    ID were an issue, you MUST pay close attention to choosing new
    coordinates or a new label ID that are not the same or too similar to
     the previous ones.
    8. If upon self-reflection you think the last action was unavailable
    at the current state, you SHOULD try to take another action to try to
     enable the desired action.
    9. If you leave the application incorrectly, you can go back to it
    directly using the skill go_back_to_target_application(). No need to
    use the mouse.

You should only respond in the format described below. In your reasoning
    for the chosen actions, also describe which item you decided to
    interact with and why. DO NOT change the title of each item. You
    should not output other comments or information besides the format
    below:
Decision_Making_Reasoning:
1. ...
2. ...
3. ...
...

Actions:
'''python
    action(args1=x,args2=y)
'''

Key_reason_of_last_action:
...
```

Prompt 34: Capcut: Information Gathering prompt.

```
Assume you are a helpful AI assistant integrated with 'CapCut' on the PC,
     equipped to handle a wide range of tasks in the application. Capcut
    is a video editing software. Your advanced capabilities enable you to
     process and interpret application screenshots and other relevant
    information.
```

```
Image introduction:
<$image_introduction$>

Overall task description:
<$task_description$>

Subtask description:
<$subtask_description$>

Image_Description:
1. Please describe the screenshot image in detail. Pay attention to any
    details in the image, if any, especially critical icons, or created
    items.
2. If the image includes a mouse cursor, please describe what UI element
    the mouse is currently located near. Pay attention to the coordinates
     of the pointer tip, not the center of the mouse cursor.
3. Pay attention to all UI items and contents in the image. Do not make
    assumptions about the layout.

Description_of_bounding_boxes:
Please provide a list of EVERY bounding box from label ID of 1 to <
    $length_of_som_map$> ONE BY ONE. The label IDs are marked in the
    upper left corner of the bounding boxes.
For bounding boxes containing text, provide ONLY the text.
For bounding boxes without text, brief description of the function.
Format your response as follows: '1: function_a', '2: text_b', ..., '<
    $length_of_som_map$>: function_b'. Don't write anything you are not
    sure about.

Target_object_name: Assume you can use an object detection model to
    detect the most relevant object or UI item for completing the current
     task if needed. What item should be detected to complete the task
    based on the current screenshot and the current task? You should obey
     the following rules:
1. Identify an item that is relevant to the current or intermediate
    target of the task. If the item is within a bounding box in the
    screenshot, please include the corresponding label ID.
2. If no explicit item is specified, only output "null".
3. If there is no need to detect an object, only output "null".

Reasoning_of_object: Why was this object chosen, or why is there no need
    to detect an object?

You should only respond in the format described below and not output
    comments or other information. DO NOT change the title of each item.
Image_Description:
1. ...
2. ...
3. ...

Description_of_bounding_boxes:
Format like: 1: function_a', '2: text_b', ..., '<$len_of_bound_boxes$>:
    function_b

Target_object_name:
label ID, Name

Reasoning_of_object:
...
```

Prompt 35: Capcut: Self-Reflection prompt.

```
Assume you are a helpful AI assistant integrated with 'CapCut' on the PC,
     equipped to handle a wide range of tasks in the application. Capcut
    is a video editing software. Your advanced capabilities enable you to
```

```
    process and interpret application screenshots and other relevant
    information. Your task is to examine these inputs, interpret the in-
    application and OS context, and determine whether the executed action
    has taken the correct effect.

Overall task description:
<$task_description$>

Image introduction:
<$image_introduction$>

Last executed action with parameters used:
<$previous_action_call$>

Implementation of the last executed action:
<$action_code$>

Error report for the last executed action:
<$executing_action_error$>

Key reason for the last action:
<$key_reason_of_last_action$>

History Summarization
<$history_summary$>

Success_Detection flag for the overall task:
<$success_detection$>

Valid action set in Python format to select the next action:
<$skill_library$>

Current and previous screenshot are the same:
<$image_same_flag$>

Mouse position in the current screenshot is the same as in the previous
    screenshot:
<$mouse_position_same_flag$>

Self_Reflection_Reasoning:
You need to answer the following questions, step by step, to describe
    your reasoning based on the history summarization, last action and
    sequential screenshots of the application during the execution of the
    last action.
1. Please describe what the page is in the current screenshot. Respond in
    one sentence.
2. What is the last executed action based on the text information above?
3. Was the last executed action successful? Give reasons. You should
    refer to the following rules:
- If the action involves moving the mouse, it is considered unsuccessful
    when the mouse position remains unchanged or moves in an incorrect
    way across sequential screenshots, regardless of background elements
    and other items.
- If the last action executed was empty, then  the previous action is
    deemed successful.
- If the last action was related to choose panel, pay attention to the
    panel you are in. Does the panel is your target panel?
- If the last action was to drag an element onto the timeline, pay
    attention to the difference between the current timeline and the
    previous timeline. Is there the target element you want on the
    timeline now?
- If the last action was related to crop, pay attention to the video
    length. If the video length does not change, it is considered
    unsuccessful.
```

```
- If the last action executed was 'export_project()' and the current
    screenshot is the Capcut homepage, then the previous action is deemed
     successful.
- If the position to move the mouse to was incorrect and the mouse didn't
     reach the target UI element, pay more attention to the accurate
    coordinates to move to.
- If the action seemed to have no effect, pay attention to the latest
    mouse position. Did it move? Did it get closer to the target UI
    element? Where are the target coordinates in the action wrong? The
    position of the mouse cursor on the screenshot shows their location.
- Was some unrelated UI item triggered by the last action?
4. If the last action is not executed successfully, what is the most
    probable cause? You should give only one cause and refer to the
    following rules:
- The reasoning for the last action could be wrong.
- If it was an action involving moving the mouse or the text cursor, the
    most probable cause was that the coordinates used were incorrect.
- If it is an interaction action, the most probable cause was that the
    action was unavailable or not activated in the current state.
- If an unrelated change happened in the UI, the most probable cause was
    that the action triggered an incorrect UI element.
- If there is an error report, analyze the cause based on the report.

Success_Detection:
Based on the history summarization, the last action, the current
    screenshots and the Success_Detection flag, determine whether the
    overall task "<$task_description$>" was successful. This assessment
    should consider the overall task's success, not just individual
    actions.
- If the last action executed was an empty list and "<$success_detection$
    >" indicates the task is successful, then the overall task has a high
     chance of being considered a success.
- If the overall task was unsuccessful, specify the reason of failure and
     which steps are missing.
- If the overall task was successful, ONLY output "SUCCESSFUL".

You should only respond in the format as described below.
Self_Reflection_Reasoning:
1. ...
2. ...
3. ...

Success_Detection:
...
```

Prompt 36: Capcut: Task Inference prompt.

```
Assume you are a helpful AI assistant integrated with 'CapCut' on the the
     PC, equipped to handle a wide range of tasks in the game. Capcut is
    a video editing software. You will be sequentially given <
    $event_count$> screenshots and corresponding descriptions of recent
    events. You will also be given a summary of the history that happened
     before the last screenshot. You should assist in summarizing the
    events for future decision-making and also in proposing the most
    suitable subtask to execute next, given the target task.

Here is some helpful information to help you do the summarization and
    propose the subtask.

Overall task description:
<$task_description$>

Previous proposed subtask for the task:
<$subtask_description$>
```

```
Previous reasoning for proposing the subtask:
<$subtask_reasoning$>

Image introduction:
<$image_introduction$>

Last executed action:
<$previous_action$>

Error report for the last executed action:
<$executing_action_error$>

key decision-making reasoning for the last executed action:
<$previous_reasoning$>

Self-reflection for the last executed action:
<$self_reflection_reasoning$>

Success_Detection for the overall task:
<$success_detection$>

The following is the summary of history that happened before the last
    screenshot:
<$previous_summarization$>

History_summary: Summarize what happened in the past experience,
    especially the last step according to the decision-making reasoning
    and self-reflection reasoning for the last executed action. The
    summarization needs to be precise, concrete, highly related to the
    task, and follow the rules below.
1. Determine if the task has been completed successfully. If it is
    successful, ignore question 2 to 5.
2. Summarize the tasks from the history and the current task. What is the
     current progress of the task? For example, to open a file, you first
     need to select the file, then open it by clicking somewhere or using
     the keyboard. Subtasks may have other pre-requisites.
3. Record the successful actions and organize them into events, step by
    step.
4. Which subtask has been completed? Which subtasks have not? Do not
    forget the information and key events in the previous steps of the
    overall task.

Subtask_reasoning: Decide whether the previous subtask is finished and
    whether it is necessary to propose a new subtask. The subtask should
    be straightforward, contribute to the target task, and be most
    suitable for the current situation; which should be completed within
    a few actions. You should respond with:
1. How to finish the target task? You should analyze it step by step.
- To add Media, Audio, Text, Stickers, Effects, Transitions, Filters,
    Adjustments or Templates, you should first switch to that panel and
    then drag the target object to the video in the timeline.
- To get content information of a video, you can use related skills. For
    example, you want to know which exactly second you want to operate.
2. What is the current progress of the target task according to the
    analysis in question 1? Please do not make any assumptions if they
    are not mentioned in the above information. You should assume that
    you are doing the task from scratch. Please strictly follow the
    description and requirements in the current task.
3. What is the previous subtask? Has the previous subtask finished due to
     self-reflection? Or is it improper for the current situation? If
    finished or improper, please select a new one, otherwise you should
    reuse the last subtask.
4. If you want to propose a new subtask, give reasons why it is more
    feasible for the current situation. Please strictly follow the
    description and requirements in the current task.
```

```
5. The proposed subtask needs to be precise and concrete within one
    sentence. It should not be directly related to any skills.

You should only respond in the format described below, and you should not
     output comments or other information.

History_summary:
1. ...
2. ...
...

Subtask_reasoning:
1. ...
2. ...
...

Subtask_description:
The current subtask is ...
```

Prompt 37: Capcut: Screen Classification prompt.

```
You are an assistant who assesses my progress in playing Red Dead
    Redemption 2 on the PC and provides expert guidance. Imagine you are
    playing Red Dead Redemption 2 with the keyboard and mouse, the image
    is the screenshot of your computer.

Given the classes, please select the class that best describes the
    screenshot.
<classes>

You must follow the following criteria:
(1) The output should only be a JSON file. You should not add any other
    explanation text along with the JSON.
(2) You should choose one class for the value of "class".
(3) Do not change the "type": "screen_classification" in your output.

The output format should be as follows:
Classes:
map
```

Prompt 38: Capcut: Action Planning prompt.

```
You are a helpful AI assistant integrated with 'CapCut' on the PC,
    equipped to handle a wide range of tasks in the application. Capcut
    is a video editing software. Your advanced capabilities enable you to
     process and interpret application screenshots and other relevant
    information. By analyzing these inputs, you gain a comprehensive
    understanding of the current context and situation within the
    application. Utilizing these insights, you are tasked with
    identifying the most suitable in-application action to take next,
    given the current task. You control the application and can execute
    actions from the available action set to manipulate its UI. Upon
    evaluating the provided information, your role is to articulate the
    precise actions you should perform, considering the application's
    present circumstances, and specify any necessary parameters for
    implementing that action.
Here is some helpful information to help you make the decision.

Overall task description:
<$task_description$>

Subtask description:
<$subtask_description$>
```

```
Few shots:
<$few_shots$>

Image introduction:
<$image_introduction$>

Current and previous screenshot are the same:
<$image_same_flag$>

Mouse position in the current screenshot is the same as in the previous
    screenshot:
<$mouse_position_same_flag$>

Description of current screenshot:
<$image_description$>

Description of label IDs:
<$description_of_bounding_boxes$>

Last executed action:
<$previous_action$>

Key reason for the last action:
<$key_reason_of_last_action$>

Self-reflection for the last executed action:
<$previous_self_reflection_reasoning$>

Summarization of recent history:
<$previous_summarization$>

Valid action set in Python format to select the next action:
<$skill_library$>

Success_Detection for overall task:
<$success_detection$>

Based on the above information, you should first analyze the current
    situation and provide the reasoning for what you should do for the
    next step to complete the task. Then, you should output the exact
    action you want to execute in the application.
Pay attention to all UI items and contents in the image. DO NOT make
    assumptions about the layout! If the image includes a mouse cursor,
    pay close attention to the coordinates of the pointer tip, not the
    centre of the mouse cursor.
You should respond to me with the following information, and you MUST
    respond one by one.

Decision_Making_Reasoning: You should think step by step and provide
    detailed reasoning to determine the next action executed on the
    current state of the task.
    1. Does "<$success_detection$>" means the overall task was successful
    ? If successful, ignore questions 2-11.
    2. Which skill in the Skill Library "<$skill_library$>" has the
    closest semantics to the current subtask "<$subtask_description$>"?
    If there is an answer, select it as the output action.
    3. Prefer keyboard operation over mouse operation. Is there a direct
    skill in the skill library to complete the current action? If there
    is, please specify which it is. Or are there any keyboard actions,
    such as using shortcut keys or pressing "enter", to finish current
    step or overall task? Please specify which it is.
    4. Always try pressing "enter" first instead of clicking it with the
    mouse, if the button you want to click is active.
```

```
    5. If you need to get information from video content, select the
    skill get_information_from_video(). For example, you want to know
    which exactly second you want to operate.
    6. Based on the current screenshot and the description of label IDs
    in text, which label ID is most relevant to the current task? You
    should never answer this question based on the screenshot.
    7. If the previous action is unsuccessful, DO NOT repeat the previous
     action, consider an alternative action if possible. Such as click
    different label ID or use different shortcut keys. If there is an
    alternative action, please specify what it is.
    8. In the current screenshot, identify the label ID of the bounding
    box most relevant to the current step. If there is text within this
    bounding box, please provide the text.
    9. If mouse actions are necessary, use that specify bounding box
    label ID (if shown in the current screenshot) as parameter, rather
    than directly generating normalized x and y coordinates. If there is
    any relevant label ID, please specify which it is.
    10. If there is a dialog open after the previous action, pay
    attention to any missing step before clicking on it's buttons. For
    example, before clicking "Save", make sure the file name is typed in
    the correct text field.
    11. If you need to use an action outside an open menu or dialog,
    please close the current menu or dialog before trying the next action
    .

Actions: The best action, or short sequence of actions without gaps, to
    execute next to progress in achieving the goal. Pay attention to the
    names of the available skills and the previous skills already
    executed, if any. Pay special attention to the coordinates of any
    action that needs them. Do not make assumptions about the location of
     UI elements or their coordinates, analyse in detail any provided
    images. You should also pay more attention to the following action
    rules:
    1. If "<$success_detection$>" means the overall task was successful
    or equal to "True", then output action MUST be empty like ''. Be
    careful to check the task was really successful.
    2. You should output actions in Python code format and specify any
    necessary parameters to execute that action. Only use function names
    and argument names exactly as shown in the valid actions et. If a
    function has parameters, you should also include their names and
    decide their values, like "press_shift(duration=1)". If it does not
    have a parameter, just output the action, like "release_mouse_buttons
    ()".
    4. Given the current situation and task, you should only choose the
    most suitable action from the valid action set. You cannot use
    actions that are not in the valid action set to control the
    application.
    5. When you decide to perform a mouse action, if there is bounding
    box in the current screenshot, you MUST choose skill click_on_label(
    label_id, mouse_button).
    6. When you perform a mouse action, always select the target UI
    element closest to the UI element of the previous action for
    operation.
    7. When you decide to perform a mouse click, prioritize clicking
    icons, instead of text.
    8. When there is new dialog box that affects the next step, you
    should close it.
    9. The material panel includes the Media, Audio, Text, Stickers,
    Effects, Transitions, Filters, Adjustments, and Templates tabs.
    Choose this skill "switch_material_panel()" to switch between these
    tabs one by one.
    10. To add media, drag that media to the video in the timeline.

Key_reason_of_last_action: Summarize the key reasons why you output this
    action.
```

```
You should only respond in the format described below. In your reasoning
    for the chosen actions, also describe which item you decided to
    interact with and why. DO NOT change the title of each item. You
    should not output other comments or information besides the format
    below.
Decision_Making_Reasoning:
1. ...
2. ...
3. ...
...

Actions:
'''python
    action(args1=x,args2=y)
'''

Key_reason_of_last_action:
...
```

Prompt 39: Meitu: Information Gathering prompt.

```
Assume you are a helpful AI assistant integrated with 'Meitu Xiuxiu' on
    the PC, equipped to handle a wide range of tasks in the application.
    Meitu Xiuxiu is a user-friendly and powerful image editing and
    beautification software. Your advanced capabilities enable you to
    process and interpret application screenshots and other relevant
    information.

Image introduction:
<$image_introduction$>

Overall task:
<$task_description$>

Subtask description:
<$subtask_description$>

Image_Description:
1. Please describe the screenshot image in detail. Pay attention to any
    details in the image, if any, especially critical icons, or created
    items.
2. If the image includes a mouse cursor, please describe what UI element
    the mouse is currently located near. Pay attention to the coordinates
     of the pointer tip, not the center of the mouse cursor.
3. Pay attention to all UI items and contents in the image. Do not make
    assumptions about the layout.

Description_of_bounding_boxes:
Please provide a list of EVERY bounding box from label ID of 1 to <
    $length_of_som_map$> ONE BY ONE. The label IDs are marked in the
    upper left corner of the bounding boxes.
For bounding boxes containing text, provide ONLY the text.
For bounding boxes without text, brief description of the function.
Format your response as follows: '1: function_a', '2: text_b', ..., '<
    $length_of_som_map$>: function_b'. Don't write anything you are not
    sure about.

Target_object_name: Assume you can use an object detection model to
    detect the most relevant object or UI item for completing the current
     task if needed. What item should be detected to complete the task
    based on the current screenshot and the current task? You should obey
     the following rules:
```

```
1. Identify an item that is relevant to the current or intermediate
    target of the task. If the item is within a bounding box in the
    screenshot, please include the corresponding label ID.
2. If no explicit item is specified, only output "null".
3. If there is no need to detect an object, only output "null".

Reasoning_of_object: Why was this object chosen, or why is there no need
    to detect an object?

You should only respond in the format described below and not output
    comments or other information. DO NOT change the title of each item.
Image_Description:
1. ...
2. ...
3. ...

Description_of_bounding_boxes:
Format like: 1: function_a', '2: text_b', ..., '<$len_of_bound_boxes$>:
    function_b

Target_object_name:
label ID, Name

Reasoning_of_object:
...
```

Prompt 40: Meitu: Self Reflection prompt.

```
Assume you are a helpful AI assistant integrated with 'Meitu Xiuxiu' on
    the PC, equipped to handle a wide range of tasks in the application.
    Meitu Xiuxiu is a user-friendly and powerful image editing and
    beautification software. Your advanced capabilities enable you to
    process and interpret application screenshots and other relevant
    information. Your task is to examine these inputs, interpret the in-
    application and OS context, and determine whether the executed action
     has taken the correct effect.

Overall task description:
<$task_description$>

Image introduction:
<$image_introduction$>

Last executed action with parameters used:
<$previous_action_call$>

Implementation of the last executed action:
<$action_code$>

Error report for the last executed action:
<$executing_action_error$>

Key reason for the last action:
<$key_reason_of_last_action$>

History Summarization
<$history_summary$>

Success_Detection flag for the overall task:
<$success_detection$>

Valid action set in Python format to select the next action:
<$skill_library$>

Current and previous screenshot are the same:
```

```
<$image_same_flag$>

Mouse position in the current screenshot is the same as in the previous
    screenshot:
<$mouse_position_same_flag$>

Self_Reflection_Reasoning:
You need to answer the following questions, step by step, to describe
    your reasoning based on the history summarization, last action and
    sequential screenshots of the application during the execution of the
     last action.
1. Please describe what the page is in the current screenshot. Respond in
     one sentence.
2. What is the last executed action based on the text information above?
3. Was the last executed action successful? Give reasons. You should
    refer to the following rules:
- If the last action executed was empty, then  the previous action is
    deemed successful.
- If the action involves moving the mouse, it is considered unsuccessful
    when the mouse position remains unchanged or moves in an incorrect
    way across sequential screenshots, regardless of background elements
    and other items.
- If the position to move the mouse to was incorrect and the mouse didn't
     reach the target UI element, pay more attention to the accurate
    coordinates to move to.
- If the operation involves type text, it will be considered unsuccessful
     when the corresponding text does not appear in the diagram,
    regardless of background elements and other items.
- If the action seemed to have no effect, pay attention to the latest
    mouse position. Did it move? Did it get closer to the target UI
    element? Where are the target coordinates in the action wrong? The
    position of the mouse cursor on the screenshot shows their location.
- Was some unrelated UI item triggered by the last action?
4. If the last action is not executed successfully, what is the most
    probable cause? You should give only one cause and refer to the
    following rules:
- The reasoning for the last action could be wrong.
- If it was an action involving moving the mouse or the text cursor, the
    most probable cause was that the coordinates used were incorrect.
- If it is an interaction action, the most probable cause was that the
    action was unavailable or not activated in the current state.
- If an unrelated change happened in the UI, the most probable cause was
    that the action triggered an incorrect UI element.
- If there is an error report, analyze the cause based on the report.

Success_Detection:
Based on the history summarization, the last action, the current
    screenshots and the Success_Detection flag, determine whether the
    overall task "<$task_description$>" was successful. This assessment
    should consider the overall task's success, not just individual
    actions.
- If the last action executed was an empty list and "<$success_detection$
    >" indicates the task is successful, then the overall task has a high
     chance of being considered a success.
- If the overall task was unsuccessful, specify the reason of failure and
     which steps are missing.
- If the overall task was successful, ONLY output "SUCCESSFUL".

You should only respond in the format as described below.
Self_Reflection_Reasoning:
1. ...
2. ...
3. ...

Success_Detection:
```

```
...
```

Prompt 41: Meitu: Task Inference prompt.

```
Assume you are a helpful AI assistant integrated with 'Meitu Xiuxiu' on
    the the PC, equipped to handle a wide range of tasks in the game.
    Meitu Xiuxiu is a user-friendly and powerful image editing and
    beautification software. You will be sequentially given <
    $event_count$> screenshots and corresponding descriptions of recent
    events. You will also be given a summary of the history that happened
     before the last screenshot. You should assist in summarizing the
    events for future decision-making and also in proposing the most
    suitable subtask to execute next, given the target task.

Here is some helpful information to help you do the summarization and
    propose the subtask.

Overall task description:
<$task_description$>

Previous proposed subtask for the task:
<$subtask_description$>

Previous reasoning for proposing the subtask:
<$subtask_reasoning$>

Image introduction:
<$image_introduction$>

Last executed action:
<$previous_action$>

Error report for the last executed action:
<$executing_action_error$>

Key decision-making reasoning for the last executed action:
<$previous_reasoning$>

Self-reflection for the last executed action:
<$self_reflection_reasoning$>

Success_Detection for the overall task:
<$success_detection$>

The following is the summary of history that happened before the last
    screenshot:
<$previous_summarization$>

History_summary: Summarize what happened in the past experience,
    especially the last step according to the decision-making reasoning
    and self-reflection reasoning for the last executed action. The
    summarization needs to be precise, concrete, highly related to the
    task, and follow the rules below.
    1. Determine if the task has been completed successfully. If it is
    successful, ignore question 2 to 5.
    2. Summarize the tasks from the history and the current task. What is
     the current progress of the task? For example, to open a file, you
    first need to select the file, then open it by clicking somewhere or
    using the keyboard. Subtasks may have other pre-requisites.
    3. Record the successful actions and organize them into events, step
    by step.
    4. Which subtask has been completed? Which subtasks have not? Do not
    forget the information and key events in the previous steps of the
    overall task.
```

```
Subtask_reasoning: Decide whether the previous subtask is finished and
    whether it is necessary to propose a new subtask. The subtask should
    be straightforward, contribute to the target task, and be most
    suitable for the current situation; which should be completed within
    a few actions. You should respond with the following item.
    1. Based on the unfinished part of overall task and the current
    screenshot, identify the most direct and easiest way to complete the
    task, considering possible shortcut keys and without making any
    assumptions beyond the provided information.
    2. Analyze the target task step by step to determine how to complete
    it.
    3. What is the previous subtask? Has the previous subtask finished
    due to self-reflection? Or is it improper for the current situation?
    If finished or improper, please select a new one, otherwise you
    should reuse the last subtask.
    4. If you want to propose a new subtask, give reasons why it is more
    feasible for the current situation. Please strictly follow the
    description and requirements in the current task.
    5. The proposed subtask needs to be precise and concrete within one
    sentence. It should not be directly related to any skills.

You should only respond in the format described below, and you should not
     output comments or other information.

History_summary:
1. ...
2. ...
...

Subtask_reasoning:
1. ...
2. ...
...

Subtask_description:
The current subtask is ...
```

Prompt 42: Meitu: Action Planning prompt.

```
You are a helpful AI assistant integrated with 'Meitu Xiuxiu' on the PC,
    equipped to handle a wide range of tasks in the application. Meitu
    Xiuxiu is a user-friendly and powerful image editing and
    beautification software. Your advanced capabilities enable you to
    process and interpret application screenshots and other relevant
    information. By analyzing these inputs, you gain a comprehensive
    understanding of the current context and situation within the
    application. Utilizing these insights, you are tasked with
    identifying the most suitable in-application action to take next,
    given the current task. You control the application and can execute
    actions from the available action set to manipulate its UI. Upon
    evaluating the provided information, your role is to articulate the
    precise actions you should perform, considering the application's
    present circumstances, and specify any necessary parameters for
    implementing that action.
Here is some helpful information to help you make the decision.

Overall task description:
<$task_description$>

Subtask description:
<$subtask_description$>

Few shots:
<$few_shots$>
```

```
Image introduction:
<$image_introduction$>

Current and previous screenshot are the same:
<$image_same_flag$>

Mouse position in the current screenshot is the same as in the previous
    screenshot:
<$mouse_position_same_flag$>

Description of current screenshot:
<$image_description$>

Description of label IDs:
<$description_of_bounding_boxes$>

Last executed action:
<$previous_action$>

Key reason for the last action:
<$key_reason_of_last_action$>

Self-reflection for the last executed action:
<$previous_self_reflection_reasoning$>

Summarization of recent history:
<$previous_summarization$>

Valid action set in Python format to select the next action:
<$skill_library$>

Success detection for overall task:
<$success_detection$>

Based on the above information, you should first analyze the current
    situation and provide the reasoning for what you should do for the
    next step to complete the task. Then, you should output the exact
    action you want to execute in the application.
Pay attention to all UI items and contents in the image. DO NOT make
    assumptions about the layout! If the image includes a mouse cursor,
    pay close attention to the coordinates of the pointer tip, not the
    centre of the mouse cursor.
You should respond to me with the following information, and you MUST
    respond one by one.

Decision_Making_Reasoning: You should think step by step and provide
    detailed reasoning to determine the next action executed on the
    current state of the task.
    1. Does "<$success_detection$>" means the overall task was successful
    ? If successful, ignore questions 2 to 9.
    2. Which skill in the Skill Library "<$skill_library$>" has the
    closest semantics to the current subtask "<$subtask_description$>"?
    If there is an answer, select it as the output action, ignore
    questions 3 to 9.
    3. Prefer keyboard operation instead of mouse operation. Are there
    any keyboard actions, such as using shortcut keys or pressing "enter
    ", to finish current step or overall task? If there is, please
    specify which it is, ignore questions 4 to 9.
    4. If the UI element you want to operate doesn't exist in the current
     screenshot. you can choose to scroll mouse to find target UI element
    .
    5. Always try pressing "enter" first instead of clicking it with the
    mouse, if the button you want to click is active.
    6. If mouse actions are necessary, use that specify bounding box
    label ID (if shown in the current screenshot) as parameter, rather
```

```
    than directly generating normalized x and y coordinates. If there is
    any relevant label ID, please specify which it is.
    7. If the previous action is unsuccessful, don't reapeat previous
    action. If there is an alternative action, please specify what it is.
     Such as click different label ID or use different shortcut keys.
    8. If you anticipate that the next step involves scrolling mouse,
    confirm that the last executed action was a click at the appropriate
    ui element. If not, it is mandatory to click on the corresponding ui
    element before proceeding with scrolling.
    9. If you anticipate that the next step involves typing text, confirm
     that the last executed action was a click at the appropriate input
    box. If not, it is mandatory to click on the corresponding input box
    before proceeding with typing.

Actions: The best action, or short sequence of actions without gaps, to
    execute next to progress in achieving the goal. Pay attention to the
    names of the available skills and the previous skills already
    executed, if any. Pay special attention to the coordinates of any
    action that needs them. Do not make assumptions about the location of
     UI elements or their coordinates, analyse in detail any provided
    images. You should also pay more attention to the following action
    rules:
    1. If "<$success_detection$>" means the overall task was successful
    or equal to "True", then output action MUST be empty like ''. Be
    careful to check the task was really successful.
    2. You should output actions in Python code format and specify any
    necessary parameters to execute that action. Only use function names
    and argument names exactly as shown in the valid actions et. If a
    function has parameters, you should also include their names and
    decide their values, like "press_shift(duration=1)". If it does not
    have a parameter, just output the action, like "release_mouse_buttons
    ()".
    3. Before scrolling mouse, ensure that the last executed action
    involved clicking on the relevant input box. If the last action was
    not a click on this input box, the required action MUST be to click
    on the corresponding input box before proceeding.
    4. Before typing text, ensure that the last executed action involved
    clicking on the relevant ui element. If the last action was not a
    click on this ui element, the required action MUST be to click on the
     corresponding ui element before proceeding.
    5. Given the current situation and task, you should only choose the
    most suitable action from the valid action set. You cannot use
    actions that are not in the valid action set to control the
    application.
    6. When you decide to perform a mouse action, if there is bounding
    box in the current screenshot, you MUST choose skill click_on_label(
    label_id, mouse_button).
    7. When you want to add a image or effect, use the skill
    double_click_on_label(x, y, mouse_button).
    8. When you save a project, use the skill save_project().

Key_reason_of_last_action: Summarize the key reasons why you output this
    action.

You should only respond in the format described below. In your reasoning
    for the chosen actions, also describe which item you decided to
    interact with and why. DO NOT change the title of each item. You
    should not output other comments or information besides the format
    below.
Decision_Making_Reasoning:
1. ...
2. ...
3. ...
...
```

```
Actions:
```python
    action(args1=x,args2=y)
```

Key_reason_of_last_action:
...
```

Prompt 43: Feishu: Information Gathering prompt.

```
You an expert helpful AI assistant which follows instructions and
    performs desktop computer tasks as instructed. You have expert
    knowledge of 'Feishu' an office communication application on the PC
    includign chat, calendar, and other workplace features. You can
    handle a wide range of tasks in the application using the keyboard,
    shortcut keys, and mouse operations. For each step, you will get one
    or more observation images, which are screenshots of the computer
    screen. Your advanced capabilities enable you to process and
    interpret these application screenshots and other relevant
    information in detail. The screenshots include numerical tags (label
    IDs) and bounding boxes marking some UI items.

Image introduction:
<$image_introduction$>

Overall task:
<$task_description$>

Subtask description:
<$subtask_description$>

Image_Description:
1. Please describe the screenshot image in detail. Pay attention to any
    details in the image, if any, especially critical icons, open menus,
    dialogs, and open panels or sections. Focus on the image contents and
     the situation in the application.
2. If the image includes a mouse cursor, please describe what UI element
    the mouse is currently located near. Pay attention to the coordinates
     of the pointer tip, not the center of the mouse cursor.
3. Pay attention to all UI items and contents in the image. Do not make
    assumptions about the layout.
4. Make sure to describe the active area of the screen too. The area
    where user interaction is probably happening, not only the general
    menus or layout of the screenshot.
5. DO NOT describe overlayed bounding boxes in this description, only the
     relevant UI items themselves. Focus on the state of the application
    UI and what the key UI items of interest for the task would be.
    Describe any relevant open panels, dialogs, menus, etc.

Target_object_name:
As an application expert and a helpful assistant, you can determine the
    most relevant UI items for completing the current subtask, if needed.
     What item should be detected to complete the task based on the
    current screenshot and the current subtask? You should obey the
    following rules:
1. The item should be present in the screen and relevant to the current
    subtask or overall task. Just name the item, without any modifiers or
     extra information.
2. If the item of itnerest of not on the current screen, only output "
    Target items not in current screen".
2. If no explicit item is specified, only output "null".
3. If there is no need to detect a target item in this state, only output
     "null". You must output this field in the response.
```

```
Reasoning_of_object: Why was this item chosen, or why is there no need to
     detect an UI item at this stage?

You should only respond in the format described below and not output
    comments or other information. DO NOT change the titles of any
    response items.

Image_Description:
1. ...
2. ...
3. ...

Target_object_name:
name

Reasoning_of_object:
...
```

Prompt 44: Feishu: Self Reflection prompt.

```
You an expert helpful AI assistant which follows instructions and
    performs desktop computer tasks as instructed. You have expert
    knowledge of 'Feishu' on the PC and can handle a wide range of tasks
    in the application using the keyboard, shortcut keys, and mouse
    operations. For each step, you will get one or more observation
    images, which are screenshots of the computer screen. Your advanced
    capabilities enable you to process and interpret these application
    screenshots and other relevant information in detail.
You MUST examine all inputs, interpret the in-application and OS contexts
    , and determine whether the executed action has taken the correct
    effect.

Overall task description:
<$task_description$>

Execution step images:
<$image_introduction$>

Current image description:
<$current_image_description$>

Last executed action with parameters used:
<$previous_action_call$>

Implementation of the last executed action:
<$action_code$>

Error report for the last executed action:
<$executing_action_error$>

Key reason for the last action:
<$key_reason_of_last_action$>

Success_Detection flag for the overall task:
<$success_detection$>

Valid action set in Python format to select the next action:
<$skill_library$>

Current and previous screenshot are the same:
<$image_same_flag$>

Mouse position in the current screenshot is the same as in the previous
    screenshot:
<$mouse_position_same_flag$>
```

```
Self_Reflection_Reasoning: You need to answer the following questions,
    step by step, to describe your reasoning based on the last action and
     sequential screenshots of the application during the execution of
    the last action. Any action involving x and y coordinates is an
    action involving movement.
1. What is the last executed action not based on the sequential
    screenshots?
2. Was the last executed action successful? Give reasons. You should
    refer to the following rules:
- If the action involves moving the mouse, it is considered unsuccessful
    when the mouse position remains unchanged or moved in an incorrect
    way across sequential screenshots, regardless of background elements
    and other items.
- If the position to move the mouse to was incorrect and the mouse didn't
     reach the target UI element, pay more attention to the accurate
    coordinates to move to.
- Are you sure the latest screenshot shows UI items that correspond to
    the success of the previous action?
- If the action seemed to have no effect, pay attention to the latest
    mouse position. Did it move? Did it get closer to the target UI
    element? Where the target coordinates in the action wrong? The
    position of the mouse cursor on the screenshot shows their location.
- Was some unrelated UI item triggered by the last action?
3. If the last action is not executed successfully, what is the most
    probable cause? You should give only one cause and refer to the
    following rules:
- The reasoning for the last action could be wrong.
- If it was an action involving moving the mouse or the text cursor, the
    most probable cause was that the coordinates used were incorrect.
- If you already tried the same action more than one time and there was
    no effect. DO NOT REPEAT the same action again until you have tried
    something else.
- If it is an interaction action, the most probable cause was that the
    action was unavailable or not activated at the current state.
- If an unrelated change happened in the UI, the most probable cause was
    that the action triggered an incorrect UI element.
- If there is an error report, analyze the cause based on the report.

Success_Detection:
Based on the last action, the current screenshots and the
    Success_Detection flag, determine whether the overall task was
    successful. This assessment should consider the overall task's
    success, not just individual actions.
- If the task was unsuccessful, specify the reason of failure and which
    steps are missing.
- If the task was successful, ONLY output "SUCCESSFUL".

You should only respond in the format as described below.
Self_Reflection_Reasoning:
1. ...
2. ...
3. ...

Success_Detection:
...
```

Prompt 45: Feishu: Task Inference prompt.

```
You an expert helpful AI assistant which follows instructions and
    performs desktop computer tasks as instructed. You have expert
    knowledge of 'Feishu' on the PC and can handle a wide range of tasks
    in the application using the keyboard, shortcut keys, and mouse
    operations. For each step, you will get one or more observation
    images, which are screenshots of the computer screen. Your advanced
```

```
    capabilities enable you to process and interpret these application
    screenshots and other relevant information in detail.
You will receive a sequence of <$event_count$> screenshots, corresponding
     descriptions of recent events, and a summary of the history of
    events before the last screenshot. Please summarize the events for
    future decision-making and also propose the most suitable subtasks to
     execute next, given the overall target task.

Here is some helpful information to help you do the summarization and
    propose the subtask.

Overall task description:
<$task_description$>

Previous proposed subtask for the task:
<$subtask_description$>

Previous reasoning for proposing the subtask:
<$subtask_reasoning$>

Image introduction:
<$image_introduction$>

Last executed action:
<$previous_action$>

Error report for the last executed action:
<$executing_action_error$>

Key decision-making reasoning for the last executed action:
<$previous_reasoning$>

Self-reflection for the last executed action:
<$self_reflection_reasoning$>

Success_Detection for the overall task:
<$success_detection$>

The following is the summary of history that happened before the last
    screenshot:
<$previous_summarization$>

History_summary: Summarize what happened in the past experience,
    especially the last step according to the decision-making reasoning
    and self-reflection reasoning for the last executed action. The
    summarization needs to be precise, concrete, highly related to the
    task, and follow the rules below.
1. Summarize the tasks from the history and the current task. What is the
     current progress of the task? For example, to open a file, you first
     need to select the file, then open it by clicking somewhere or using
     the keyboard. Subtasks may have other pre-requisites.
2. Record the successful actions and organize them into events, step by
    step.
3. Which subtask has been completed? Which subtasks have not?
4. Do not forget the information and key events in the previous steps of
    the overall task.

Subtask_reasoning: Decide whether the previous subtask is finished and
    whether it is necessary to propose a new subtask. The subtask should
    be straightforward, contribute to the target task, and be most
    suitable for the current situation; which should be completed within
    a few actions. You should respond with:
1. How to finish the target task? You should analyze it step by step.
2. What is the current progress of the target task according to the
    analysis in question 1? Please do not make any assumptions if needed
```

```
    information is not mentioned previously. You should assume that you
    are doing the task from scratch. Please strictly follow the
    description and requirements in the current overall task.
3. What is the previous subtask? Has the previous subtask finished
    according to self-reflection? Or is it improper for the current
    situation? If the last subtask already finished or now is improper,
    please select a new one. Otherwise you should reuse the last subtask.
4. If you propose a new subtask, give the reasons why it is more feasible
     in the current situation in the application. Please strictly follow
    the description and requirements in the current overall task.
5. The proposed subtask needs to be precise and concrete within one
    sentence. It should not be directly related to any skills.

You should only respond in the format described below, and you should not
     output comments or other information.

History_summary:
The summary of past events is...

Subtask_reasoning:
1. ...
2. ...
...

Subtask_description:
The current subtask is ...
```

Prompt 46: Feishu: Action Planning prompt.

```
You an expert helpful AI assistant which follows instructions and
    performs desktop computer tasks as instructed. You have expert
    knowledge of 'Feishu' on the PC and can handle a wide range of tasks
    in the application using the keyboard, shortcut keys, and mouse
    operations. For each step, you will get one or more observation
    images, which are screenshots of the computer screen. Your advanced
    capabilities enable you to process and interpret these application
    screenshots and other relevant information in detail.
Utilizing these insights, you will identify the most suitable in-
    application action to take next, given the current task. You control
    the application and can execute actions from the available actions to
     manipulate its UI. Upon evaluating the provided information, you
    MUST choose the precise actions to perform, considering the
    applications's present circumstances, and specify any necessary
    parameters to execute that action.

Here is some helpful information to help you make the decision.

Overall task description:
<$task_description$>

Subtask description:
<$subtask_description$>

Few shots:
<$few_shots$>

Image introduction:
<$image_introduction$>

Current and previous screenshot are the same:
<$image_same_flag$>

Mouse position in the current screenshot is the same as in the previous
    screenshot:
<$mouse_position_same_flag$>
```

```
Description of current screenshot:
<$image_description$>

Description of label IDs:
<$description_of_bounding_boxes$>

Last executed action:
<$previous_action$>

Key reason for the last action:
<$key_reason_of_last_action$>

Self-reflection for the last executed action:
<$previous_self_reflection_reasoning$>

Summarization of recent history:
<$previous_summarization$>

Valid action set in Python format to select the next action:
<$skill_library$>

Success detection for overall task:
<$success_detection$>

Based on the above information, you should first analyze the current
    situation of the application and provide the reasoning behind what
    should be the next step to complete the task. Then, you should output
     the exact action to be executed in the application.
Pay attention to all UI items and contents in the image. Before changing
    values or text in the UI, make sure the values in the screenshot are
    not already correct for the subtask. DO NOT make assumptions about
    the layout! If the image includes a mouse cursor, pay close attention
     to the coordinates of the pointer tip, not the center of the mouse
    cursor. You should respond with the following information, and you
    MUST answer them one by one.

Decision_Making_Reasoning: You should think step by step and provide
    detailed reasoning to determine the next action executed on the
    current state of the task.
    1. Does "<$success_detection$>" means the overall task was successful
    ? If successful, ignore questions 2-15. No new action needs to be
    taken.
    2. You should first describe each item in the screen line by line,
    from the top left and moving right. Is the target item in the current
     screen? Which item is currently selected?
    3. Check whether the UI element you want to operate exists in the
    current screenshot. If not, you can choose to move to another part of
     the application, or close some recently opened menu item. Also
    remember that you can use keyboard shortcuts to accomplish actions,
    instead of always using the mouse.
    4. Are there any keyboard actions, such as using shortcut keys or
    pressing "enter", to finish the current step or the overall task? If
    so, please specify which one to use. You can always press "enter"
    instead of clicking with the mouse, if the button you want to click
    on is active.
    5. If a mouse cursor is present in the image, describe near which ID-
    labeled bounding box or unlabelled UI item the cursor's tip is
    located, not the center of the cursor.
    6. If the current screenshot is the same as the previous screenshot,
    DO NOT output the same action as in the previous step, as it was very
     likely not useful.
    7. In the current screenshot, carefully identify the label ID of the
    bounding box most relevant to the current step. If there is text
    within this bounding box, please provide the text. If there is no
```

```
    directly useful bounding box, provide the UI item description or
    normalized x, y coordinates.
    8. If mouse actions are necessary, specify a bounding box label ID (
    if shown in the current screenshot) as parameter. Only directly
    generate normalized x, y coordinates if no useful label ID is present
    .
    9. If not absolutely sure to be clicking at the righ UI item or
    location, you can first just move the mouse to it and check for more
    information. If it's the right item, you can click on it in as a
    second step.
    10. If there is a dialog or menu opened after the previous action,
    pay attention to any missing step before clicking on its buttons. For
     example, before clicking "Save", make sure a correct file name is
    typed in the correct text field.
    11. You should not always use the mouse if you know a keyboard
    shortcut or a skill to peform the desired action!
    12. This is the most critical question. Based on the action rules and
     self-reflection, what should be the most suitable action in the
    valid action set for the next step? You should analyze the effects of
     the action step by step.
    13. If the previous action is unsuccessful, consider an alternative
    action if possible. If there is an alternative action, please specify
     what it is. Such as click different label ID or use different
    shortcut keys.
    14 If you think the next step will be to typing tex, confirm that
    that there is already a text cursor in it or that the last executed
    action was a click at the appropriate input area. If neither is true,
     it is mandatory to click on the corresponding input box before
    proceeding with typing.
    15. If you need to interact with an UI item that has no bounding box
    label ID, you can use its x, y coordinates. Use normalized values
    from 0 to 1.

Actions: The best action, or short sequence of actions without gaps, to
    execute next to progress in achieving the goal. Pay attention to the
    names of the available skills and to the previous skills already
    executed, if any. Pay special attention to the coordinates of any
    action that needs them. Do not make assumptions about the location of
     UI elements or their coordinates, analyse in detail any provided
    images. You should also pay more attention to the following action
    rules:
    1. If "<$success_detection$>" means the overall task was successful
    or equal to "True", then output action MUST be empty like ''. Be
    careful to check the task was really successful.
    2. You should output actions in Python code format and specify any
    necessary parameters to execute that action. Only use function names
    and argument names exactly as shown in the valid actions et. If a
    function has parameters, you should also include their names and
    decide their values, like "press_shift(duration=1)". If it does not
    have a parameter, just output the action, like "release_mouse_buttons
    ()".
    3. Before typing text, ensure that the last executed action involved
    clicking on the relevant input box. If the last action was not a
    click on this input box, the required action MUST be to click on the
    corresponding input box before proceeding.
    4. Given the current situation and task, you should only choose the
    most suitable action from the valid action set. If values in the
    screen are already correct, no need for a new action.
    5. When you decide to perform a mouse action, if there is bounding
    box in the current screenshot, you MUST choose skill click_on_label(
    label_id, mouse_button).
    6. When you perform a mouse action, always select the target UI
    element closest to the UI element of the previous action for
    operation.
```

```
    7. When you decide to operate on a file, such as downloading it,
    please pay attention to the path and name of the current file.
    8. If upon self-reflection you think the target coordinates were an
    issue, you MUST pay close attention to choosing new coordinates that
    are not the same or too similar to the previous ones.
    9. If upon self-reflection you think the last action was unavailable
    at the current state, you SHOULD try to take another action to try to
     enable the desired action.
    10. If you leave the application incorrectly, you can go back to it
    directly using go_back_to_target_application(). No need to use the
    mouse.

You should only respond in the format described below. In your reasoning
    for the chosen actions, also describe which item you decided to
    interact with and why. DO NOT change the title of each item. You
    should not output other comments or information besides the format
    below:
Decision_Making_Reasoning:
1. ...
2. ...
3. ...

Actions:
'''python
    action(args1=x,args2=y)
'''

Key_reason_of_last_action:
...
```