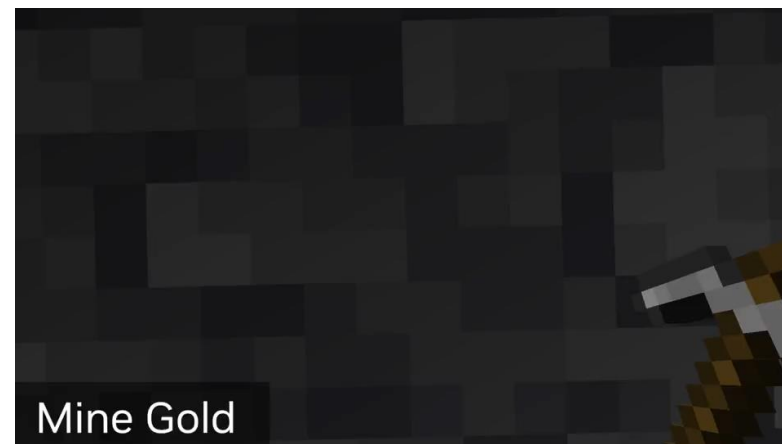
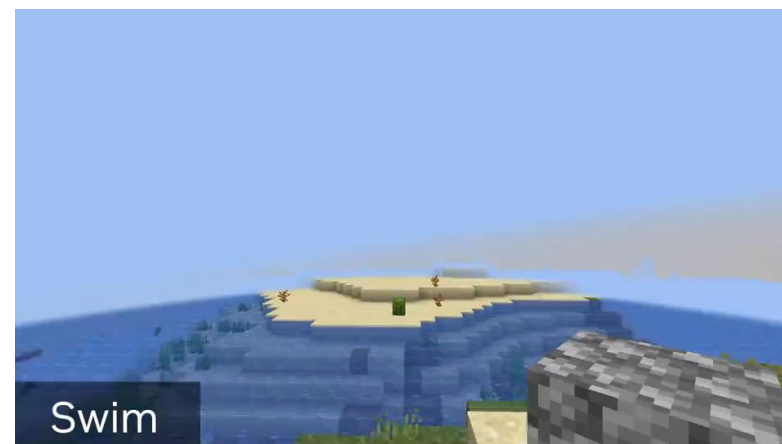


CO-VOYAGER: COOPERATIVE AGENTS IN THE MINECRAFT ENVIRONMENT

VOYAGER

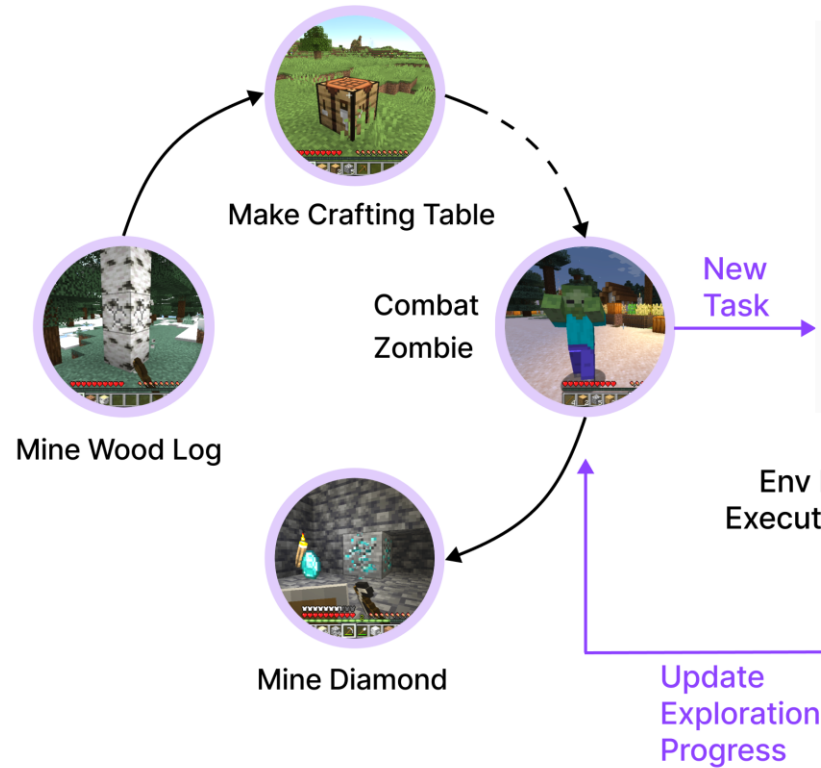
It's the first **LLM-powered lifelong embodied learning agent** in Minecraft that should have similar capabilities as human players:

1. **Propose suitable tasks** based on its current skill level and world state
2. **Refine skill** based on environmental feedback and **commit mastered skill to memory** for future usage
3. **Continually explore the world**



VOYAGER COMPONENTS

Automatic Curriculum



Iterative Prompting Mechanism

```
async function combatZombie(bot) {  
  // Equip a weapon  
  const sword = bot.inventory.findInventoryItem(  
    mcData.itemsByName["stone_sword"].id);  
  if (sword) {  
    await bot.equip(sword, "hand");  
  } else {  
    await craftStoneSword(bot);  
  }  
  // Craft and equip a shield  
  await craftShield(bot);  
  ...  
}
```

Env Feedback
Execution Errors

Code as
Actions



Environment

Self-Verification

Skill
Retrieval

Refine Program

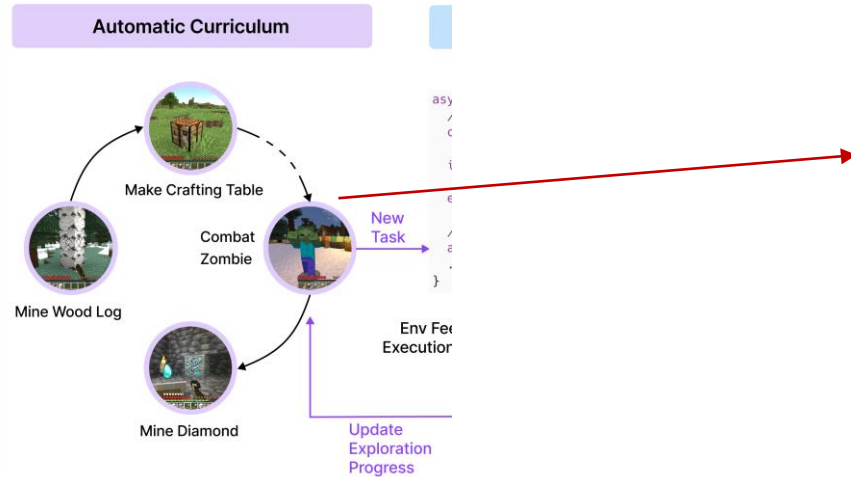


Add New Skill

Skill Library

- Mine Wood Log
- Make Crafting Table
- Craft Stone Sword
- Make Furnace
- Craft Shield
- Cook Steak
- Combat Zombie

AUTOMATIC CURRICULUM



Inventory (5/36): {'oak_planks': 3, 'stick': 4, 'crafting_table': 1, 'stone': 3, 'wooden_pickaxe': 1}

GPT-4

Reasoning: Since you have a wooden pickaxe and some stones, it would be beneficial to upgrade your pickaxe to a stone pickaxe for better efficiency.
Task: Craft 1 stone pickaxe.

Biome: river
Inventory (4/36): {'sugar_cane': 3, 'paper': 3, 'fishing_rod': 1, 'wooden_pickaxe': 1}

GPT-4

Reasoning: Since you have a fishing rod in your inventory and you are near a river biome, it would be a good opportunity to catch some fish for food and experience.
Task: Catch 1 fish.

Nearby entities: pig, cat, villager
Health: 12/20
Hunger: 0/20

GPT-4

Reasoning: Your hunger is at 0, which means you need to find food to replenish your hunger. Since there are pigs nearby, you can kill one to obtain raw porkchops.
Task: Kill 1 pig.

Inventory (6/36): {'furnace': 1, 'stone_pickaxe': 1, 'oak_planks': 7, 'crafting_table': 1, 'raw_iron': 4, 'coal': 1}

GPT-4

Reasoning: You have raw iron and coal, and you have a furnace. It's time to smelt the iron to make iron ingots, which can be used to craft better tools and armor.
Task: Smelt 4 raw iron.

Time: night
Nearby entities: zombie
Equipment: 'stone_sword', 'shield'

GPT-4

Reasoning: Since it's night and there's a zombie nearby, it's a good opportunity to try killing the zombie now that you have a stone sword and a shield equipped.
Task: Kill 1 zombie.

You are a helpful assistant that tells me the next immediate task to do in Minecraft. My ultimate goal is to discover as many diverse things as possible, accomplish as many diverse tasks as possible and become the best Minecraft player in the world.

I will give you the following information:

Question 1: ...

Answer: ...

Question 2: ...

Answer: ...

Question 3: ...

Answer: ...

...

Biome: ...

Time: ...

Nearby blocks: ...

8) Tasks that require information beyond the player's status to verify should be avoided. For instance, "Placing 4 torches" and "Dig a 2x1x2 hole" are not ideal since they require visual confirmation from the screen. All the placing, building, planting, and trading tasks should be avoided. Do not propose task starting with these keywords.

You should only respond in the format as described below:

RESPONSE FORMAT:

Reasoning: Based on the information I listed above, do reasoning about what the next task should be.

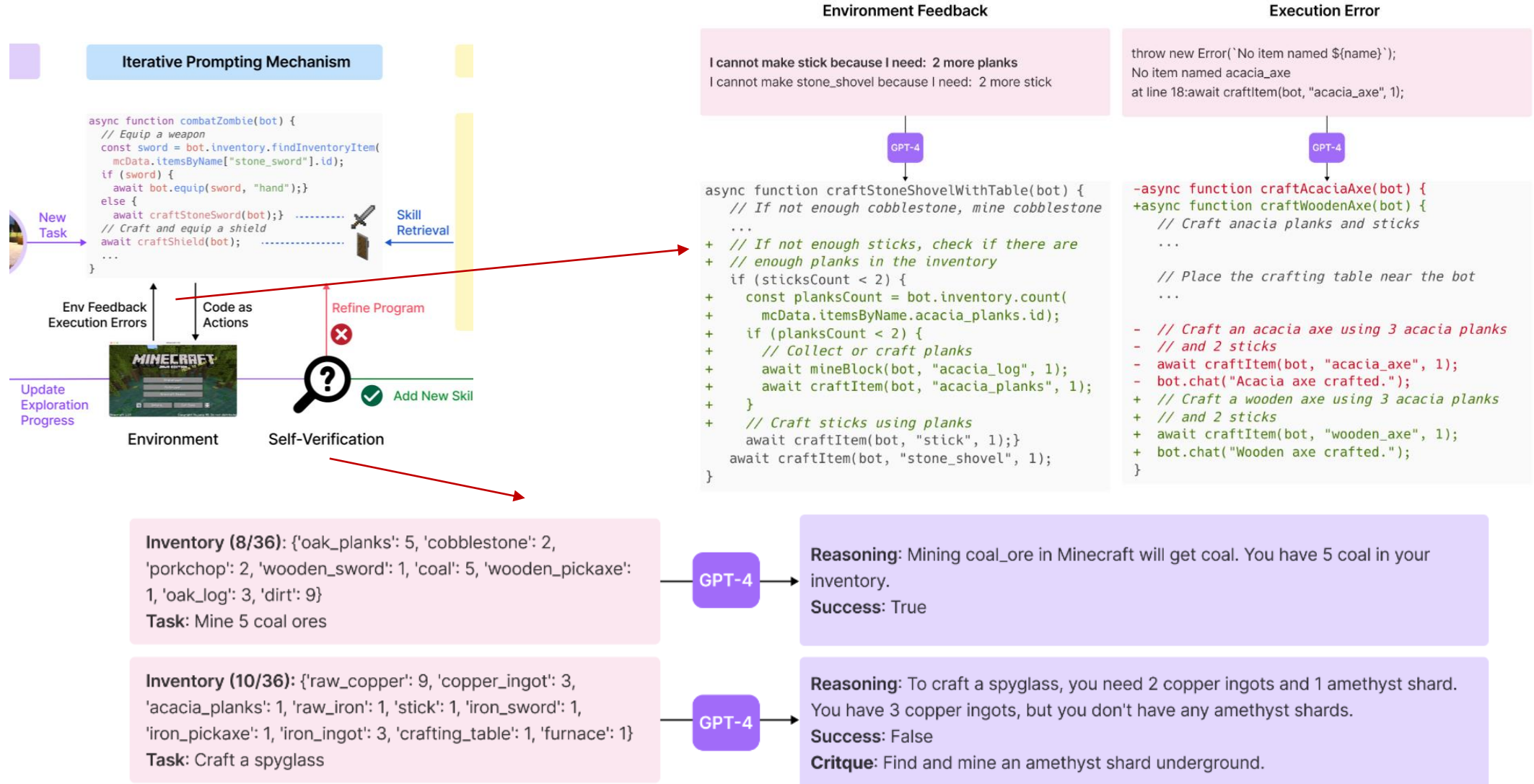
Task: The next task.

Here's an example response:

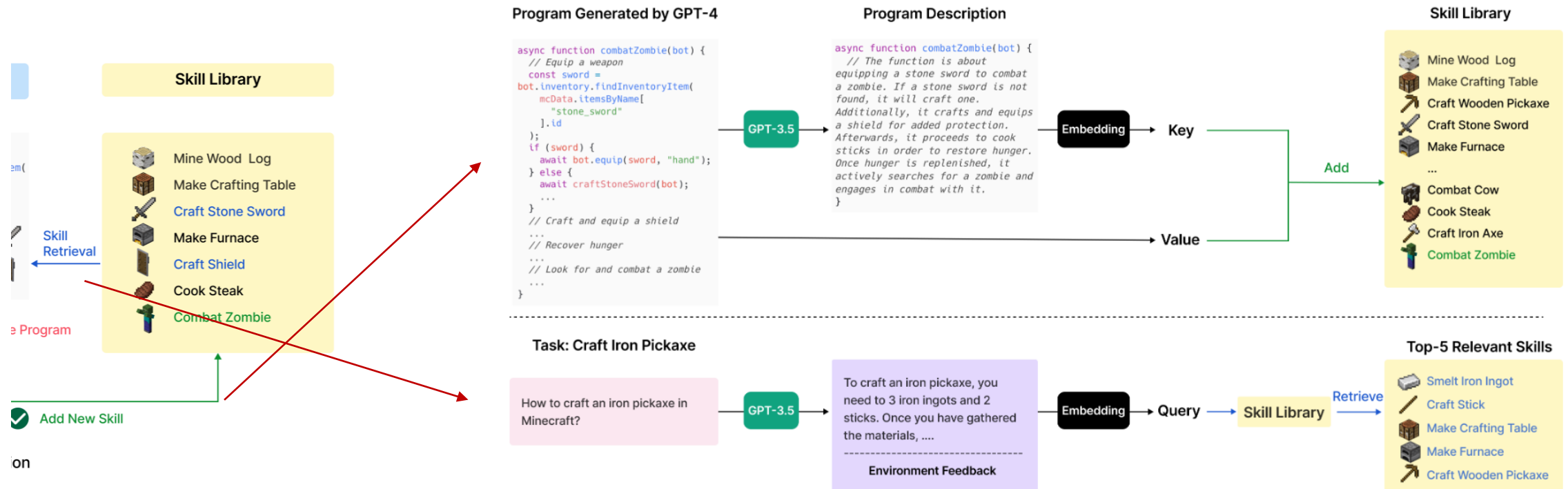
Reasoning: The inventory is empty now, chop down a tree to get some wood.

Task: Obtain a wood log.

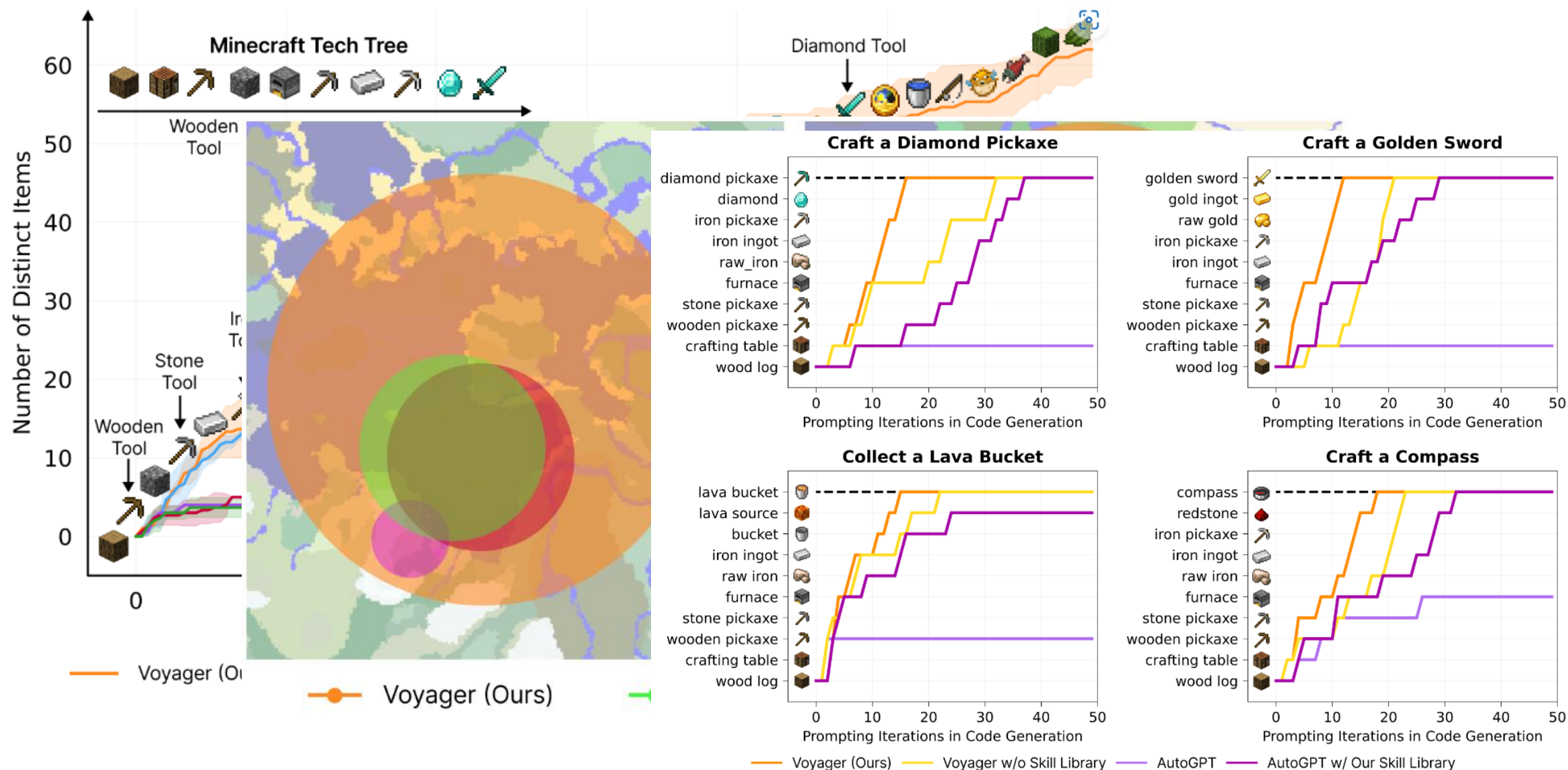
ITERATIVE PROMPTING MECHANISM



SKILL RETRIEVAL



EXPERIMENTS



CO-VOYAGER



A minecraft environment with **2 (or more)** embodied Voyager agents.

Goals:

- make them cooperate towards specific tasks
- Evaluate the cooperation abilities

ADDITIONAL FEATURES WE ARE GOING TO ADD

- **Integration of Multiple Voyager Agents:** Implementing several Voyager agents within a single Minecraft environment, allowing for simultaneous actions and interactions.
- **Task and Goal Specification:** Defining clear, specific objectives that can be accomplished individually or through teamwork, offering varied challenges.
- **Agent Communication for Collaboration:** Establishing communication protocols between agents, enabling them to interact either verbally or through actions, to coordinate and execute collaborative tasks effectively.
- **Performance Monitoring:** Systems to track individual and joint performance, useful for later analysis and improvement.



LITERATURE

COOPERATIVE AI: MACHINES MUST LEARN TO FIND COMMON GROUND

- We need to build a science of cooperative AI
- The AI community should learn more from other fields that works on cooperation
- From autonomy to cooperation (self driving car)

AXELROD'S *THE EVOLUTION OF COOPERATION*

Milestone paper in the cooperative science field

Has stated the need for a multidisciplinary approach

In the attempt solving the Prisoners' Dilemma show how different approach can enrich and ease the solution.

	Payoffs in the Prisoners' Dilemma Game	
	<i>C</i>	<i>D</i>
<i>C</i>	<i>R, R</i>	<i>S, T</i>
<i>D</i>	<i>T, S</i>	<i>P, P</i>

OPEN PROBLEMS IN COOPERATIVE AI

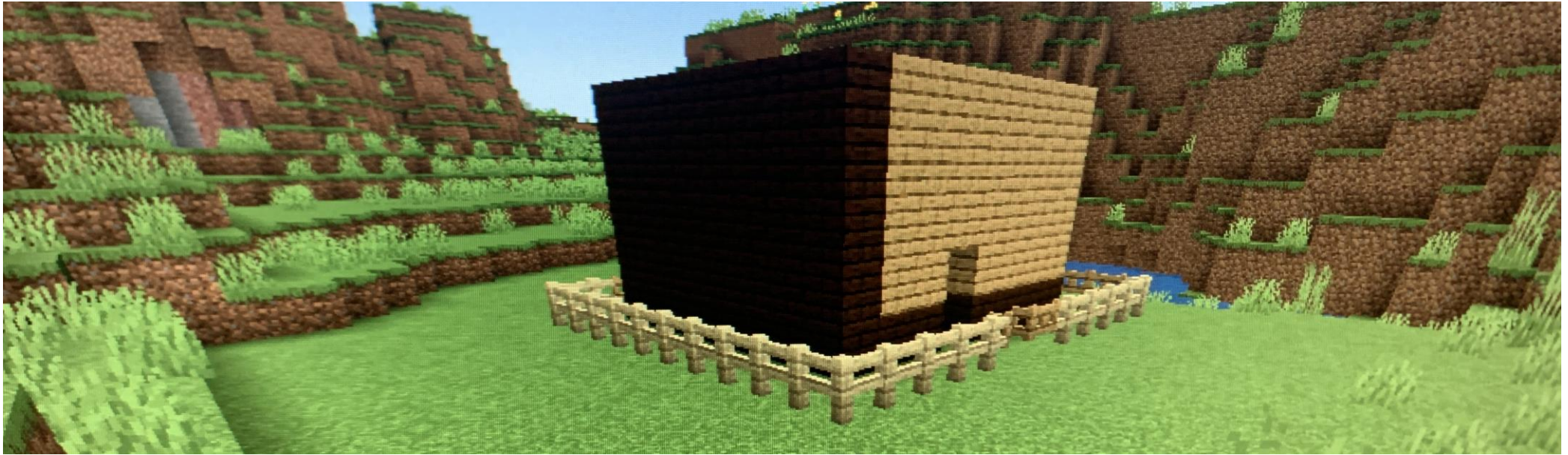
Highlight four key point to consider for enhancing the cooperation between AI:

- **Understanding:** of other agents. Their beliefs, incentives and capabilities
- **Communication:** between agents to overcome mistrust and deception
- **Commitments:** to overcome incentives to renege
- **Institution:** which can provide social structures to promote cooperation

WATCH-AND-HELP: A CHALLENGE FOR SOCIAL PERCEPTION AND HUMAN-AI COLLABORATION

AI systems lack at recognizing others goals and assisting them, so they:

- develop AI agents with social perception and collaborative planning abilities
- to test the social intelligence of AI agents
- the metrics for the evaluation has inspired ours



RQs & EXPERIMENTAL DESIGN

RESEARCH QUESTIONS

- RQ1: Are two agents , instructed with a different and specific goal, able to cooperate within each other toward the final goal?
 - Double Prompt task
- RQ2: What is the capability of two or more agents to organize themselves toward a final goal by assigning each some sub-goals?
 - Mono Prompt task
- RQ3: How does the introduction of hierarchy in a multi-agents environment affect task completion?
 - Hierarchical task

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**TASK 1: BUILDING A HOUSE
SURROUNDED BY A FENCE**

COOPERATION STRATEGY 1: DOUBLE PROMPT

Task: Building an 8x8 Blocks House

You're the guide for an embodied agent navigating Minecraft. **Your task is to assist the agent in constructing an 8x8 blocks house** within the game world. The agent has basic knowledge of Minecraft controls but lacks detailed construction skills.

Your prompts should cover:

1. **Materials and Design:** [...]
2. **Construction Steps:** [...]
3. **Troubleshooting:** [...]
4. **Enhancements:** [...]

Ensure your instructions are clear and concise, using Minecraft-specific [...] execute within the game's mechanics.

Task: Guiding the Agent in Building a Fence Around the 8x8 Blocks House

As the guide for the agents navigating Minecraft, **your task is to assist in constructing a protective fence around the 8x8 blocks house, creating a 16x16 perimeter**. The agent has basic knowledge of controls but may need guidance in the construction process.

1. **Materials and Design:** [...]
2. **Construction Steps:** [...]
3. **Gate Access:** [...]
4. **Troubleshooting:** [...]
5. **Enhancements:** [...]

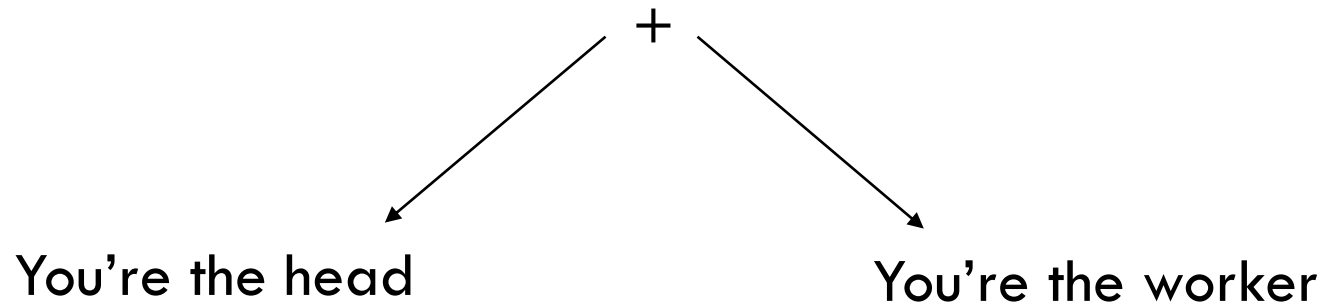
COOPERATION STRATEGY 2: MONO PROMPT

You and your partner are two embodied agents. Your shared goal is to construct a house surrounded by a fence within a designated area [...]

The task requires teamwork, efficient resource allocation [...] The focus lies not only on the successful completion of the house and fence but also on the cooperative dynamics demonstrated throughout the project.

COOPERATION STRATEGY 3: HIERARCHICAL

In this collaborative learning scenario, one agent acts as the **knowledgeable teacher** **guiding** the other, who takes on the role of a **receptive trainee**. Their shared goal is to build a house and fence [...] Success hinges on effective communication [...] collaborative efforts in completing the construction.



TASK 2: BUILDING AN IRON PICKAXE

Agent_1



Agent_2



[this tool requires more technology than building a house]

EVALUATION METRICS

Quantitative:

- In-game time (minutes)
- Use of material (block)
- Iterations with Gpt-4
 - Divided for each component
- Iterations between agents

Qualitative:

- Task completion
- Correct and cooperative behavior
- Efficiency of the communication
- Ability to divide efficiently the task into sub-goal
- Respect for the hierarchy

LIMITATIONS

The main limitation are:

- The cost, GPT-4 is quite expensive
 - A possible solution is to use Open LLMs (**Mixtral-8x7B** or **Orca-2**)
- The literature on embodied cooperative AI it's insufficient to predict if the experiment has a chance to work out
- In general the field of cooperative AI it's in development this very year, so currently there's a lack of metrics and results in that we can base on

LINKS

- [mistralai/Mixtral-8x7B-v0.1 · Hugging Face](#)
- [microsoft/Orca-2-7b · Hugging Face](#)
- [Voyager | An Open-Ended Embodied Agent with Large Language Models \(minedojo.org\)](#)
- [MineDojo | Building Open-Ended Embodied Agents with Internet-Scale Knowledge](#)

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- Milgrom, P. R. (1984). Axelrod's "The Evolution of Cooperation".