

VOYAGER: An Open-Ended Embodied Agent with Large Language Models

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What is necessary for an embodied agent?

World Knowledge



Continuous Exploration

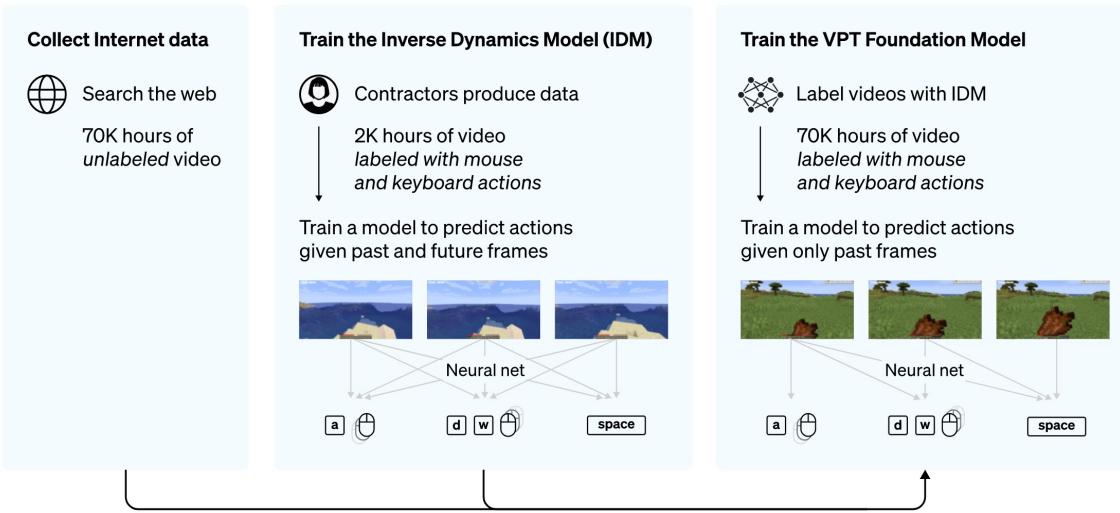


Open-Ended Objectives



Video-Pretraining (VPT)

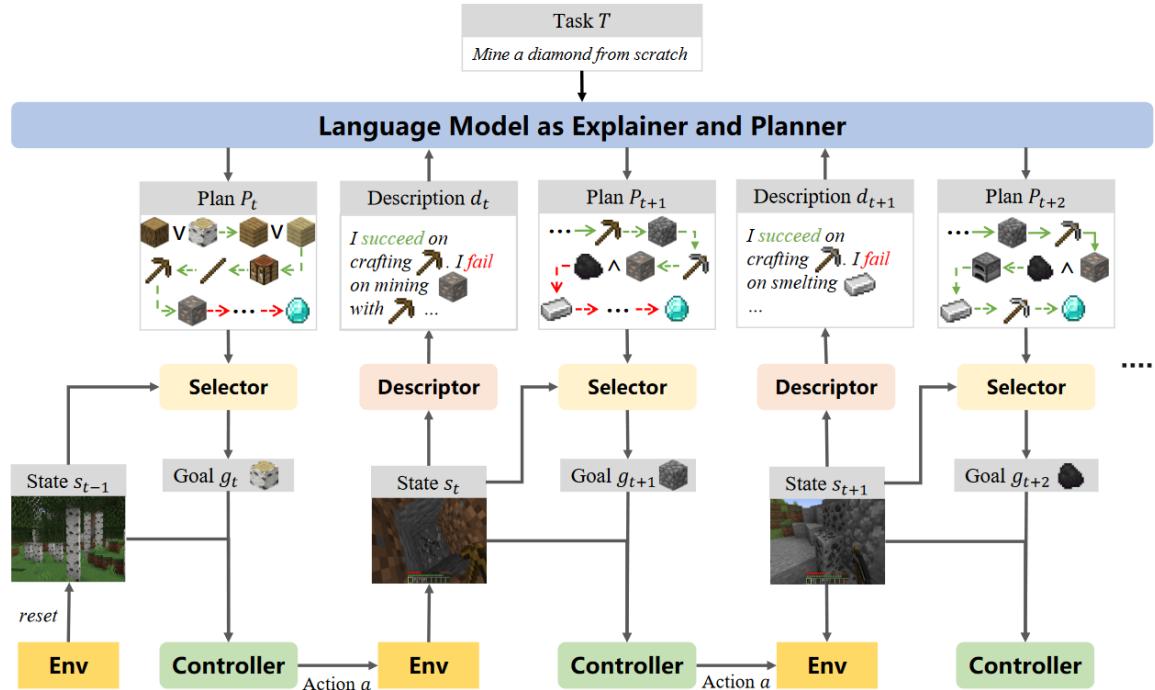
- OpenAI VPT: Extract policies from human-play videos
 - Use keyboard and mouse control
 - Internet-scale data
 - Continuous exploration
 - Do not have any objectives



B. Baker et al., "Video PreTraining (VPT): Learning to Act by Watching Unlabeled Online Videos." arXiv, Jun. 23, 2022. doi: [10.48550/arXiv.2206.11795](https://doi.org/10.48550/arXiv.2206.11795).

Describe, Explain, Plan and Select

- DEPS: Use LLM as explainer and planner
 - Task driven
 - Top-down decomposition
 - Not continuous



Z. Wang, S. Cai, A. Liu, X. Ma, and Y. Liang, "Describe, Explain, Plan and Select: Interactive Planning with Large Language Models Enables Open-World Multi-Task Agents," arXiv, Feb. 03, 2023. doi: [10.48550/arXiv.2302.01560](https://doi.org/10.48550/arXiv.2302.01560).

Minecraft AI NPC



In game Q&A



Task Completion using code

R. Volum et al., "Craft an Iron Sword: Dynamically Generating Interactive Game Characters by Prompting Large Language Models Tuned on Code," in Association of Computational Linguistics, Microsoft, Jul. 2022. [Online]. Available: <https://www.microsoft.com/en-us/research/publication/craft-an-iron-sword-dynamically-generating-interactive-game-characters-by-prompting-large-language-models-tuned-on-code/>

Finish task with supervision



Why not let the agent propose the task itself?

Automatic Curriculum

Curriculum
(GPT-4)



Wood Log



Crafting Table



Wooden Pickaxe



Stone Sword



Make Furnace



Make Shield



Hunt Cow



Cook Steak



Combat Zombie



Make Clock



Diamond Sword



Beat Enderman

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.

Action-Critic Loop Overview

Actor (GPT-4)

```
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);
  ...
  // Look for and combat a zombie
  ...
}
```

Code as Action Space



Environment Feedback
Execution Errors



Agent's State

Critic (GPT-4)

Self-Critic Success Check

Inventory (10/36): {'raw_copper': 9, 'copper_ingot': 3,

'acacia_planks': 1, 'raw_iron': 1, 'stick': 1, 'iron_sword': 1,

'iron_pickaxe': 1, 'iron_ingot': 3, 'crafting_table': 1, 'furnace': 1}

Task: Craft a spyglass

GPT-4

Reasoning: To craft a spyglass, you need 2 copper ingots and 1 amethyst shard. You have 3 copper ingots, but you don't have any amethyst shards.

Success: False

Critique: Find and mine an amethyst shard underground.

Inventory (7/36): {'oak_log': 5, 'oak_planks': 1,

'wooden_pickaxe': 1, 'wooden_sword': 1, 'porkchop': 2,

'white_wool': 2, 'mutton': 6}

Task: Kill 3 sheep

GPT-4

Reasoning: You have 2 white_wool and 6 mutton in your inventory, which indicates that you killed 2 sheep. You needed to kill 3 sheep.

Success: False

Critique: Find and kill one more sheep to complete the task.

Inventory (9/36): {'string': 4, 'coal': 1, 'rotten_flesh': 1,

'iron_sword': 1, 'furnace': 1, 'dirt': 6, 'stone_shovel': 1,

'wooden_pickaxe': 1, 'granite': 5}

Task: Kill 1 zombie

GPT-4

Reasoning: You have 1 rotten_flesh in your inventory, which means you have killed at least 1 zombie.

Success: True

Environment and Error Feedback

Environment Feedback

I cannot make stick because I need: 2 more planks
I cannot make stone_shovel because I need: 2 more stick

Actor
(GPT-4)

```
async function craftStoneShovelWithTable(bot) {
    // If not enough cobblestone, mine cobblestone
    ...
    + // If not enough sticks, check if there are
    + // enough planks in the inventory
    if (sticksCount < 2) {
        + const planksCount = bot.inventory.count(
        +     mcData.itemsByName.acacia_planks.id);
        + if (planksCount < 2) {
        +     // Collect or craft planks
        +     await mineBlock(bot, "acacia_log", 1);
        +     await craftItem(bot, "acacia_planks", 1);
        + }
        + // Craft sticks using planks
        await craftItem(bot, "stick", 1);
        await craftItem(bot, "stone_shovel", 1);
    }
}
```

Execution Error

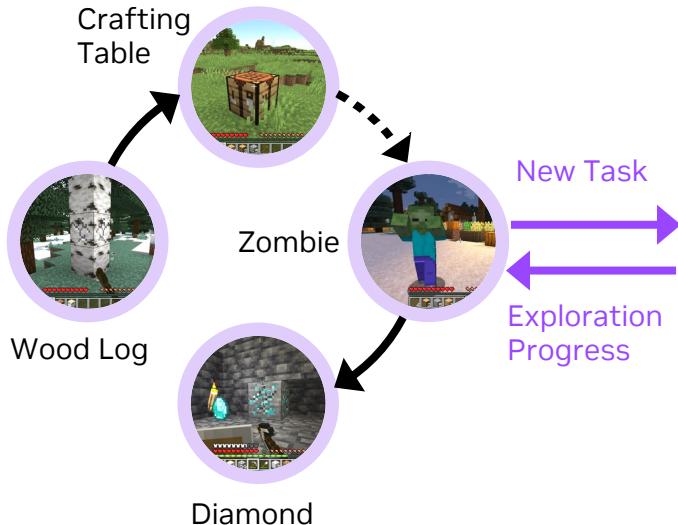
```
throw new Error(`No item named ${name}`);
No item named acacia_axe
at line 18:await craftItem(bot, "acacia_axe", 1);
```

Actor
(GPT-4)

```
-async function craftAcaciaAxe(bot) {
+async function craftWoodenAxe(bot) {
    // Craft anacia planks and sticks
    ...
    // Place the crafting table near the bot
    ...
    - // Craft an acacia axe using 3 acacia planks
    - // and 2 sticks
    - await craftItem(bot, "acacia_axe", 1);
    - bot.chat("Acacia axe crafted.");
    + // Craft a wooden axe using 3 acacia planks
    + // and 2 sticks
    + await craftItem(bot, "wooden_axe", 1);
    + bot.chat("Wooden axe crafted.");
}
```

Structure Overview

Automatic Curriculum



Iterative Prompting Mechanism

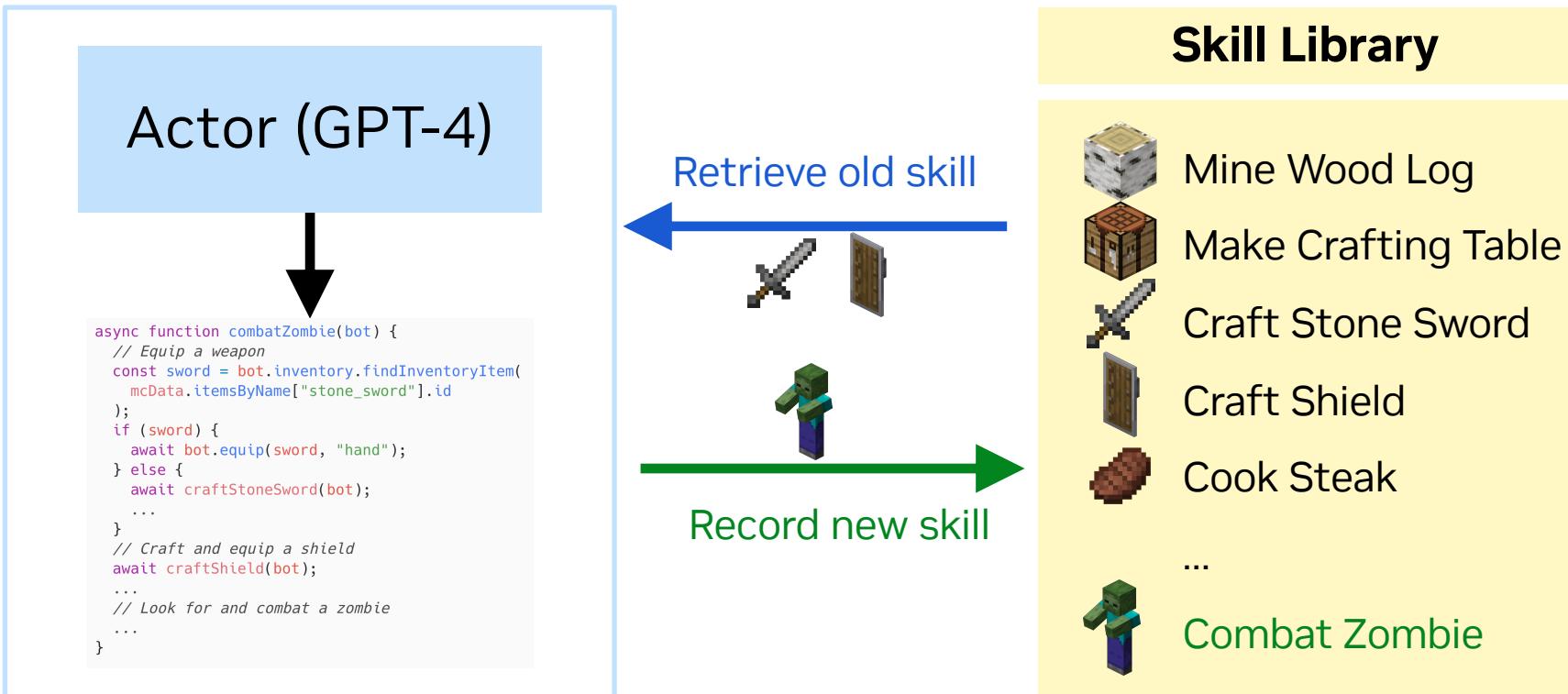
```
async function combatZombie(bot) {  
    // Equip a weapon  
    if (sword) {  
        await bot.equip(sword, "hand");  
    } else {  
        await craftStoneSword(bot);  
        ...  
    }  
    // Craft and equip a shield  
    await craftShield(bot);  
    ...  
    // Look for and combat a zombie  
    ...  
}
```



Skill Library

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

Skill Library



Adding new skills

Program Generated by GPT-4

```
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);  
    ...  
    // Look for and combat a zombie  
    ...  
}
```

GPT-3.5

Program Description

```
async function combatZombie(bot) {  
    // The function is about  
    // equipping a stone sword to combat  
    // a zombie. If a stone sword is not  
    // found, it will craft one.  
    // Additionally, it crafts and equips  
    // a shield for added protection.  
    // Afterwards, it actively searches  
    // for a zombie and engages in combat  
    // with it.  
}
```

Embedding

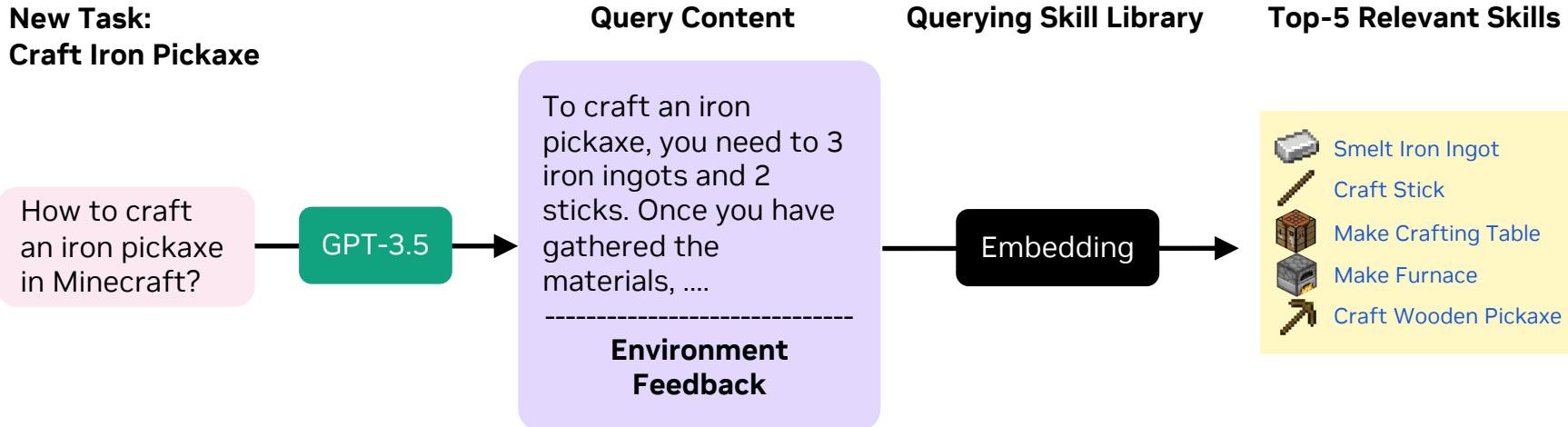
Key

Value

Skill Library

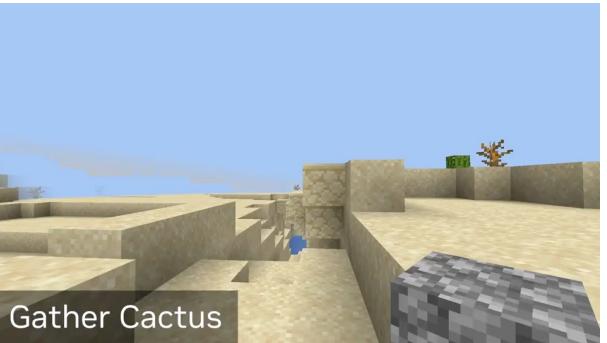
	Mine Wood Log
	Make Crafting Table
	Craft Stone Sword
	Craft Shield
	Cook Steak
...	...
	Combat Zombie

Retrieving skills





Mine Amethyst



Gather Cactus



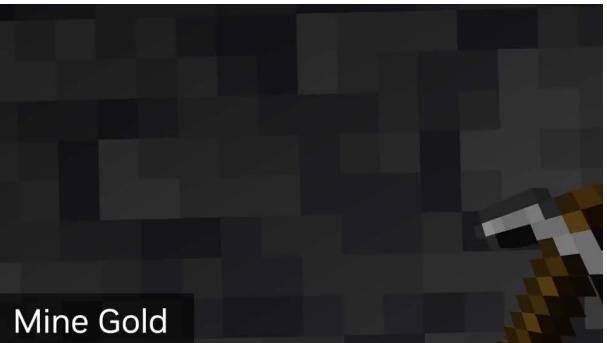
Build Base



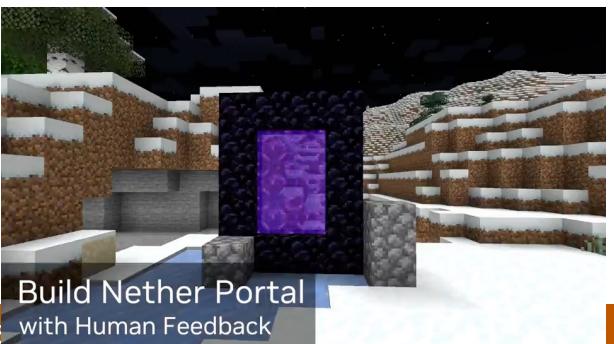
Fight Enderman



Build House
with Human Feedback



Mine Gold



Build Nether Portal
with Human Feedback



Hunt Pig



Swim

Baseline: ReAct

- Reason before Act
 - Just like “Let’s think step by step”
- Experiment setting:
 - No curriculum
 - No error feedback
 - No critic
 - No skill library

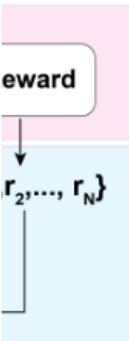
(2b) ReAct (Reason + Act)

```
Act 1: Think[First I need to find a pepper shaker...more likely to appear in cabinets (1-6), countertops (1-3), ... ]  
Act 2: Go to cabinet 1  
Obs 2: On the cabinet 1, you see a vase 2.  
(Here the agent go to cabinet 1, then cabinet 2, 3, then countertop 1 and 2)  
Act 6: Go to countertop 3  
Obs 6: On the countertop 3, you see a apple 1, a bread 1, ..... a pepper shaker 1, and a vase 3.  
  
Act 7: Take pepper shaker 1 from countertop 3  
Obs 7: You pick up the pepper shaker 1 from the countertop 3.  
  
Act 8: Think[Now I find a pepper shaker 1. Next, I need to put it in/on drawer 1. ]  
Act 9: Go to drawer 1  
Obs 9: Drawer 1 is closed.  
  
Act 10: Open drawer 1  
Obs 10: You open Drawer 1 ...  
  
Act 11: Put pepper shaker 1 in/on drawer 1  
Obs 11: You put pepper shaker 1 in/on the drawer 1.
```



Baseline: Reflexion

- A > go to desk 1
Nothing happens.
> go to desk 2
On the desk 2, you see a alarmclock 1, a bowl 1, a mug 3, a pencil 3, and a pencil 2.
> think: Now I find a desklamp (1). Next, I need to use it.
OK.
> use desklamp 1
Nothing happens.
> use desklamp 1
Nothing happens.
Status: Fail



Reflection: In this environment, my plan was to find a mug then find and use a desklamp. However, the task says to examine the mug with the desklamp. I should have looked for the desklamp first, then looked for the mug. I noticed that the desklamp was found on desk 1. In the next trial, I will go to desk 1, find the lamp, then look for the mug and examine it with the desklamp.

Baseline: AutoGPT (April 16th)

- AI agent for complex tasks
- Experiment setup:
 - Task decomposition
 - Replanning over iterations
 - No curriculum
 - No critic

The screenshot shows a terminal window with the following text:

April 16, 2023 - Blake Werlinger

With thanks to Blake Werlinger for this demo!

All other choices can be kept at "...". ("title": "Autonomous agents Auto-GPT and BabyAI are bringing AI to the masses", "url": "https://www.fastcompany.com/9888824/auto-gpt-and-babyai-how-autonomous-agents-are-bringing-generative-ai-to-the-masses", "body": "Developed by Tocan Bruce Richards, Auto-GPT is described on GitHub as a GPT-4-powered agent that can search the internet in structured ways. It can create subtasks and launch new agents to...")

AUTOGPT-DEMO THOUGHTS: The next step would be to browse the GitHub repository of Auto-GPT. This will help us to gather more information about the project and understand it better.

REASONING: Browsing the GitHub repository is the best way to gather more detailed information about the project and understand its functionality.

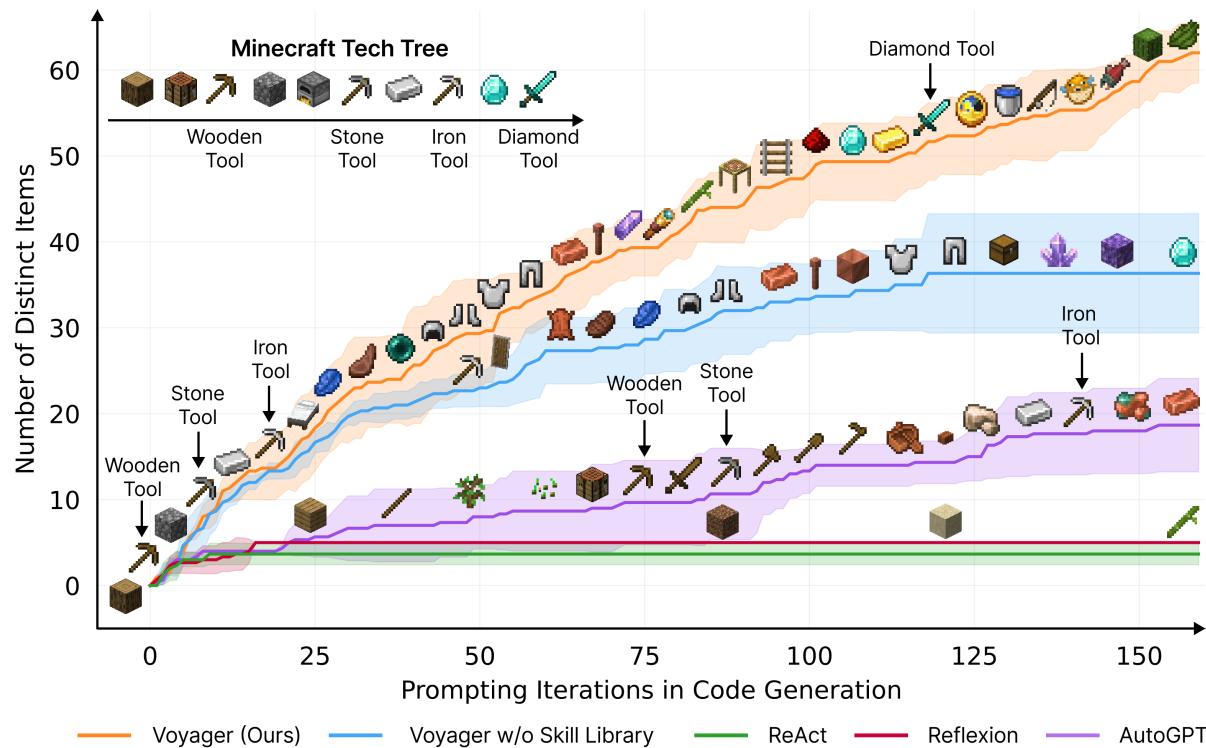
PLAN:

- Browse the GitHub repository of Auto-GPT. Explore the repository to understand the project better.
- Write a document explaining Auto-GPT.

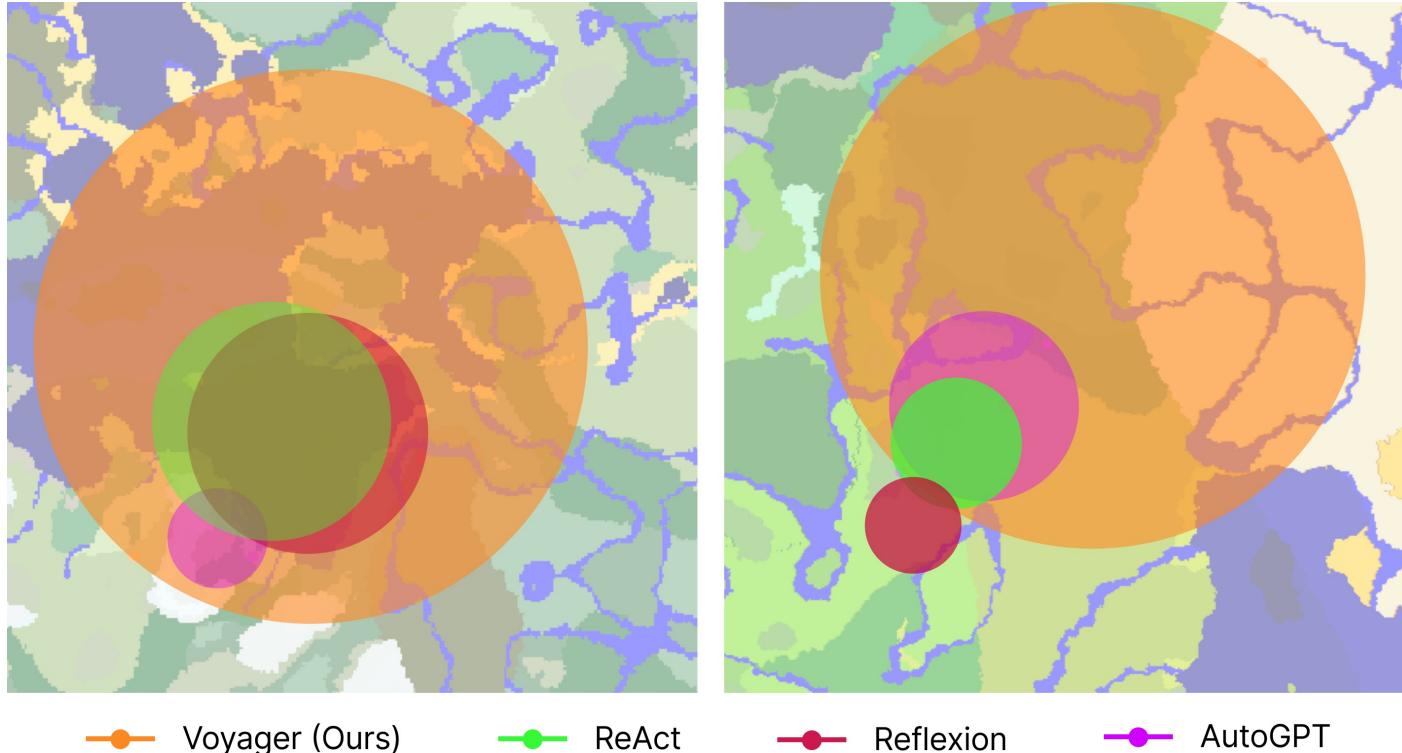
Attempting to fix JSON by finding outermost brackets
Apparently JSON was fixed.
NEXT ACTION: COMMAND = browser_website ARGUMENTS = ["url"], "https://github.com/TocanBruce/Auto-GPT", "question": "Closely examine and gather features of Auto-GPT")

DevTools listening on ws://127.0.0.1:8114/devtools/browser/8edfa01-1a09-486e-8402-42d302f6b1aa
Text length: 35953 characters
Summarizing chunk 1 / 4
Summarizing chunk 2 / 4
Summarizing chunk 3 / 4
Summarizing chunk 4 / 4
Summarized 4 chunks.

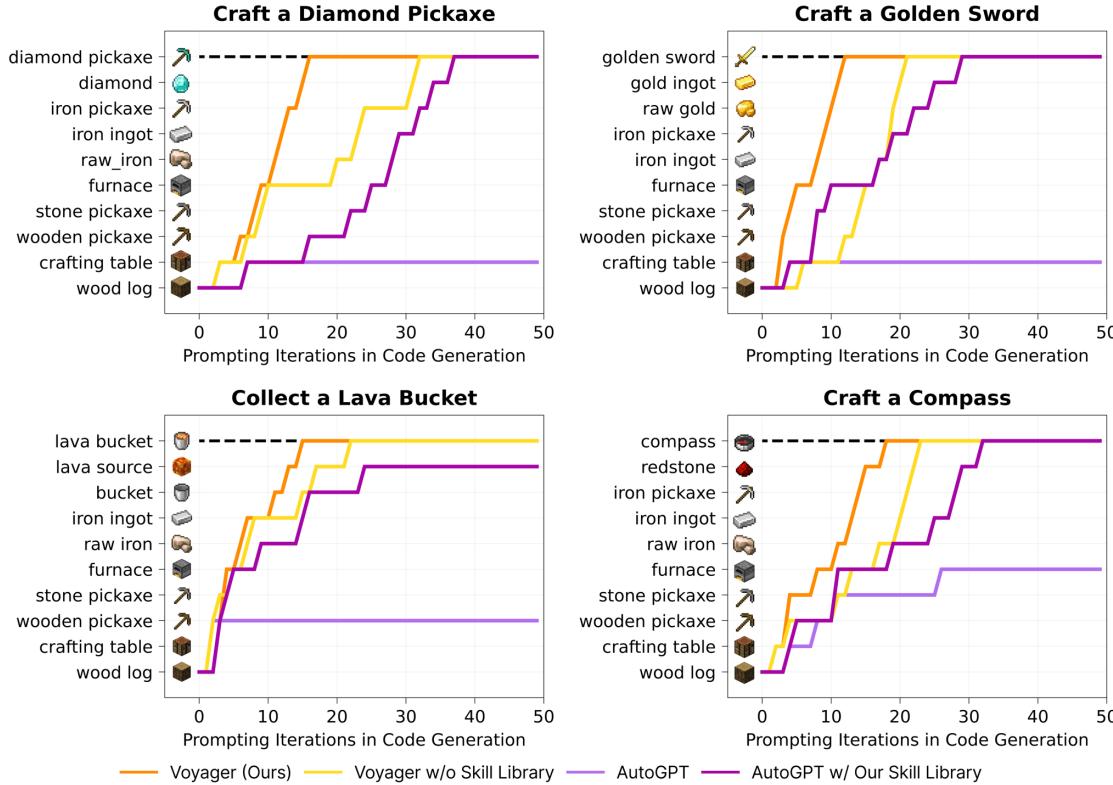
Open-Ended Exploration



Map Coverage



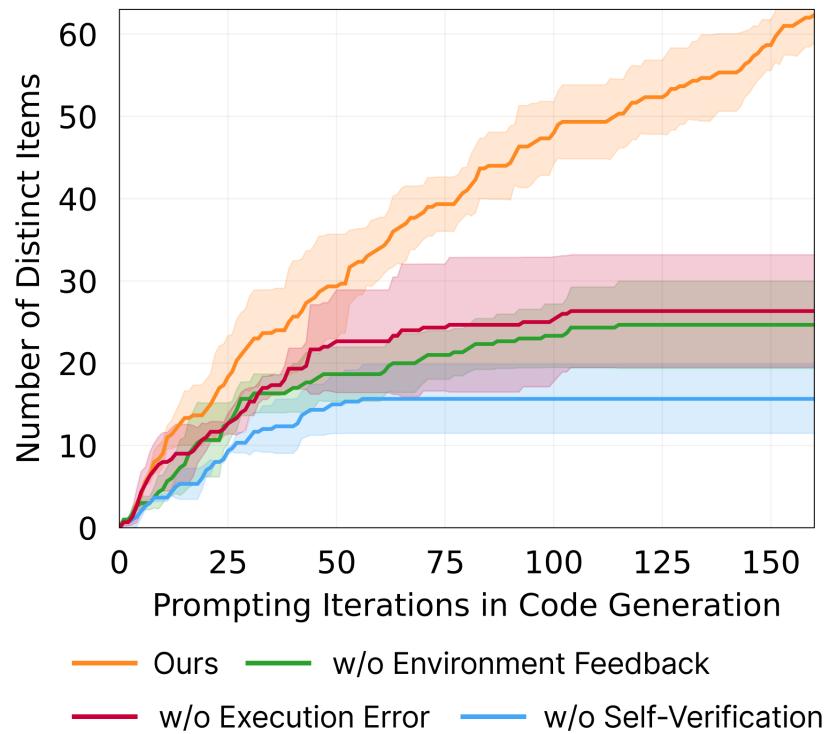
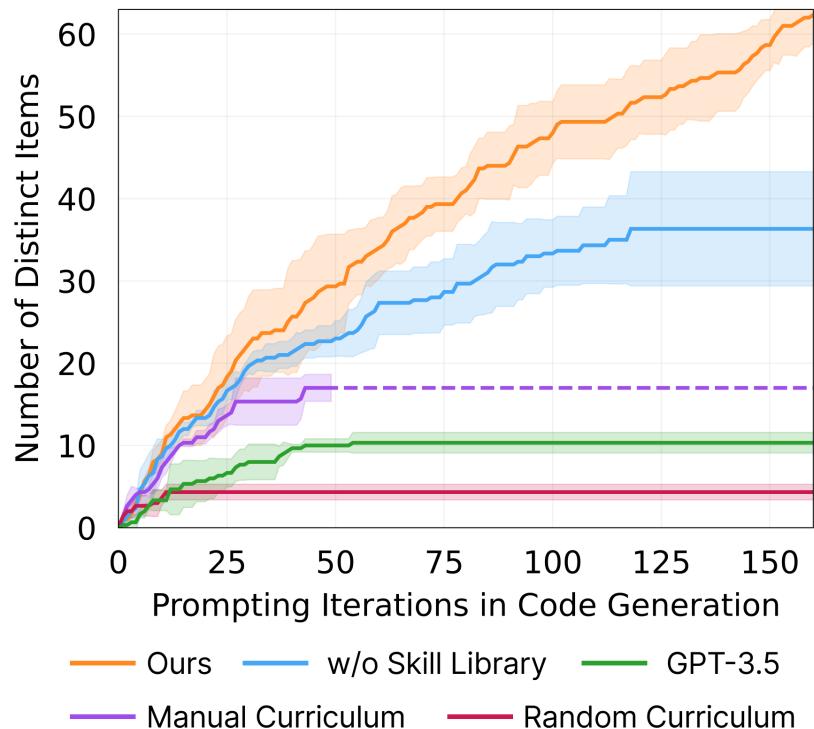
Zero-shot Generalization to Unseen Tasks



Human as Multimodal Feedback



Ablation Studies



Q&A