OS-Genesis Automating GUI Agent Trajectory Construction via Reverse Task Synthesis

Qiushi Sun*, Kanzhi Cheng*, Zichen Ding*, Chuanyang Jin*, Yian Wang
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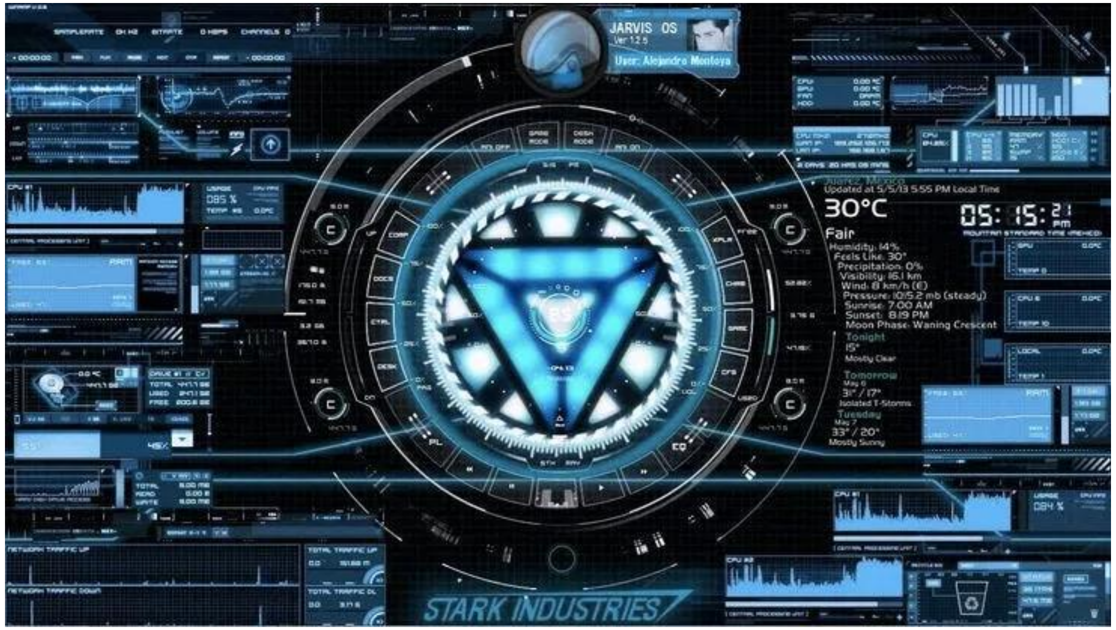
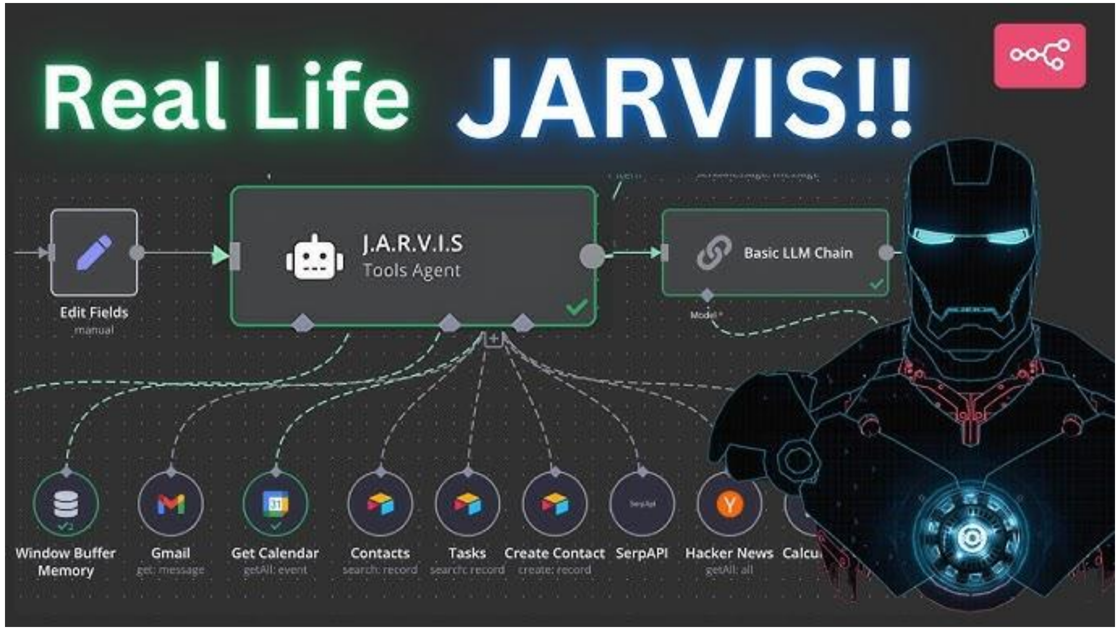
Computer Use Agents





The Feasibility of Jarvis AI from Marvel in Real Life

[1] OS-Copilot: Towards Generalist Computer Agents with Self-Improvement

Computer Use Agents

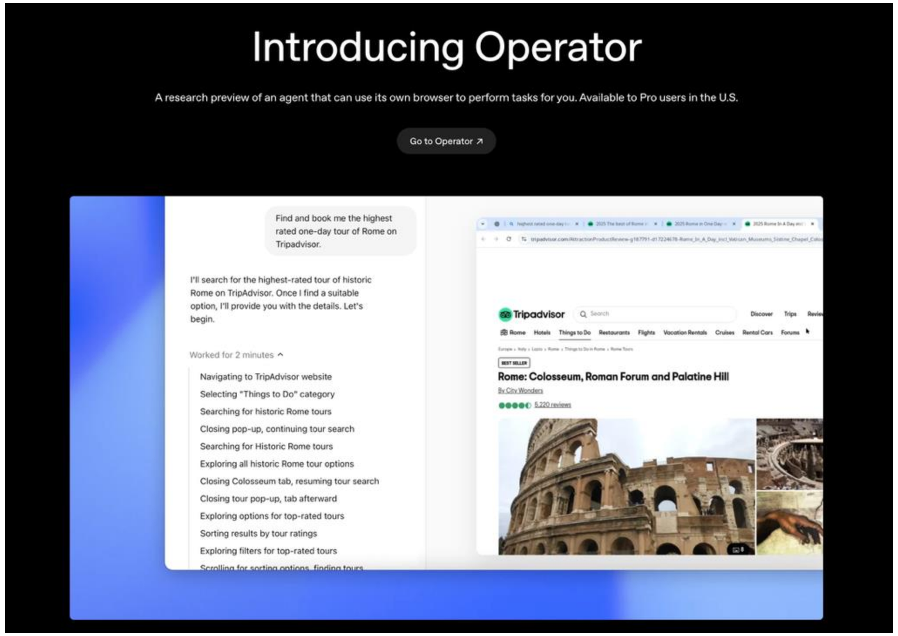
Both academia and industry are building computer use agents

Claude Computer Use

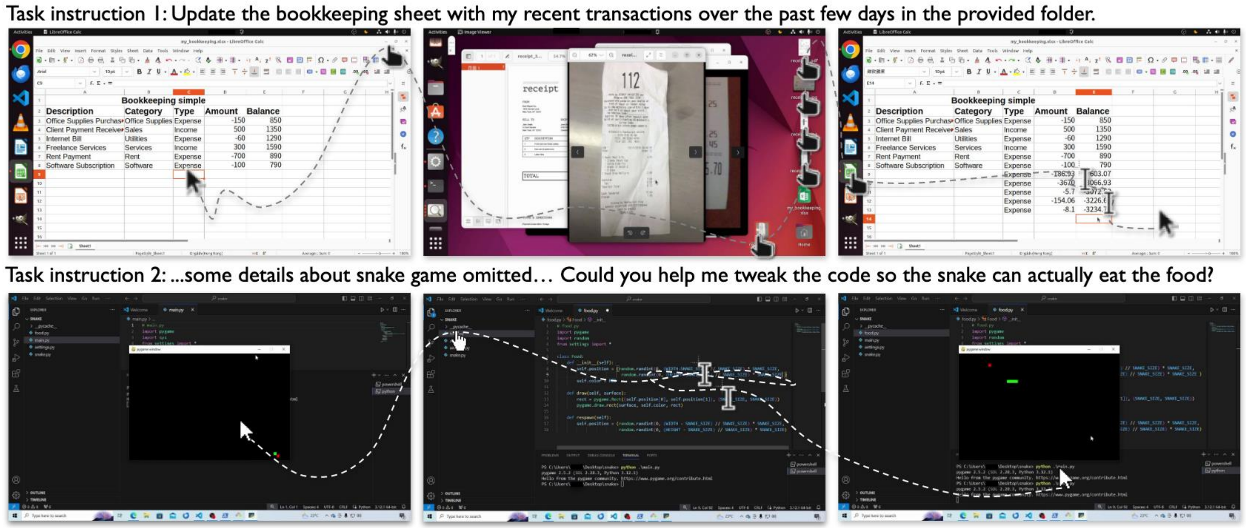
[2] *Introducing computer use, a new Claude 3.5 Sonnet, and Claude 3.5 Haiku, 22 Oct 2024*

Computer Use Agents

Automating daily computer tasks



OpenAI Operator



Daily Computer Use

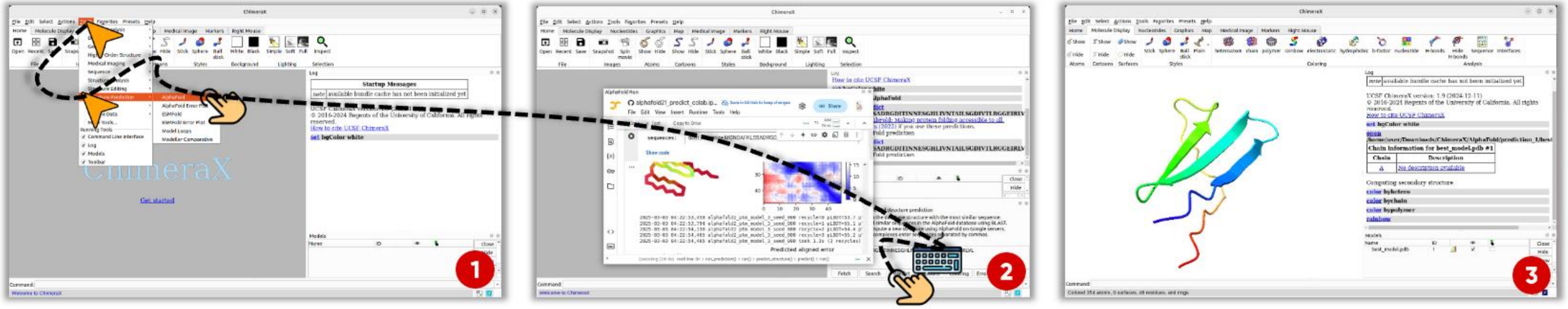
[3] Introducing Operator: A research preview of an agent that can use its own browser to perform tasks for you., Jan 23, 2025

[4] OSWorld: Benchmarking Multimodal Agents for Open-Ended Tasks in Real Computer Environments

Computer Use Agents

Automate scientific workflows

Instruction: Predict the protein structure for the amino acid sequence of 'MGND…' via AlphaFold in ChimeraX.

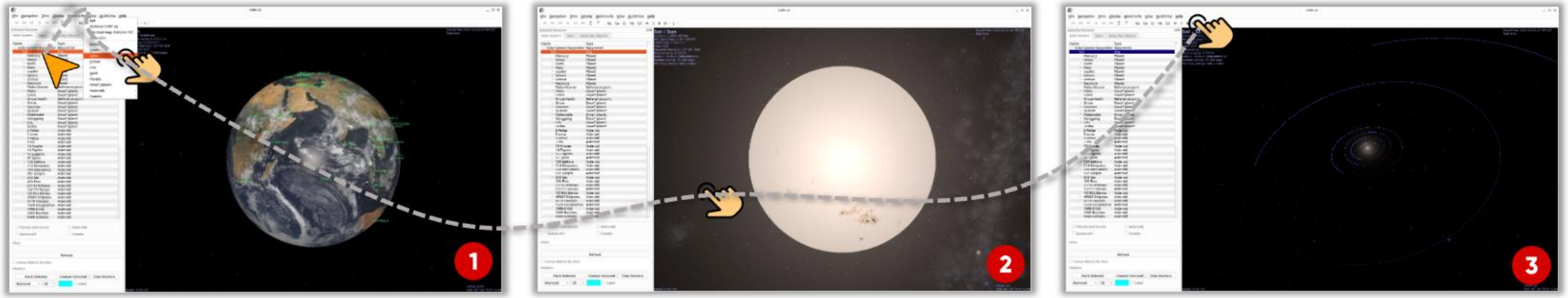


Step1: Toggle the widget of AlphaFold.

Step2: Input the given sequence and call out AlphaFold for structure prediction.

Step3: Wait until the prediction finished.

Instruction: Show planets' orbits of Solar System in Celestia.



Step1: Select the Sol and click 'Goto' in contect menu.

Step2: Slide the mouse wheel to move the camera away from Sol.

Step3: Click to show orbits of planets.

[5] ScienceBoard: Evaluating Multimodal Autonomous Agents in Realistic Scientific Workflows

Some Typical & Recent works

- SeeClick: Harnessing GUI Grounding for Advanced Visual GUI Agents, ACL 2024
- OS-ATLAS: A Foundation Action Model for Generalist GUI Agents , ICLR 2025 Spotlight
- OS-Genesis: Automating GUI Agent Trajectory Construction via Reverse Task Synthesis , ACL 2025
- Breaking the Data Barrier -- Building GUI Agents Through Task Generalization
- AgentStore: Scalable Integration of Heterogeneous Agents As Specialized Generalist Computer Assistant , ACL 2025
- ScienceBoard: Evaluating Multimodal Autonomous Agents in Realistic Scientific Workflows

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ScienceBoard: Evaluating Multimodal Autonomous Agents in Realistic Scientific Workflows

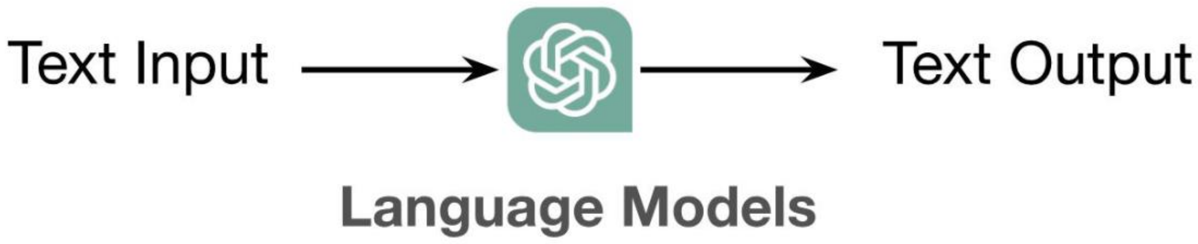
Build Computer Use Agents

They are quite promising for achieving Digital Automation through CLI or GUI.

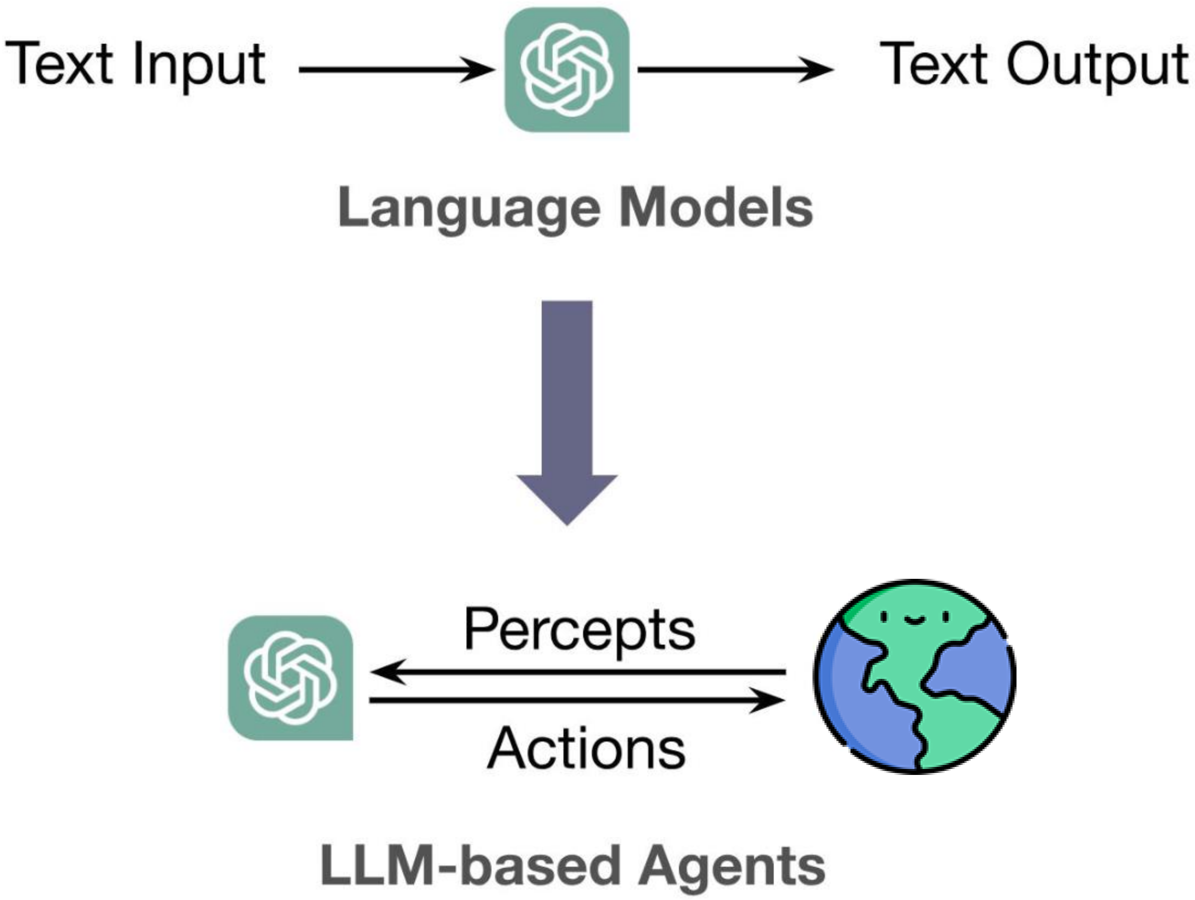
Can we transform a (V)LM into such GUI agents?

Of course! But it is a non-trivial job!

Recap: Language Agents



Recap: Language Agents



But this is not enough for Computer Use / GUI Agents.

Computer Use Agents

Agents are promising, but building powerful agents is challenging.

1. Agents need to follow human instructions.
2. Agents need to perform planning and action.
3. Agents need to perceive envs. and the applications they are interacting with.

Best Way to build Computer Use Agents

Behavioral Cloning / Imitation Learning.

Sounds good, but where is our data?

Data Problems

Human annotation for GUI data is much more expensive than you think.

Not to mention scenario/domain - specific data.

How about having the machine collect data?

1. Pre-defined tasks are required, but they may not align with the environment.
2. Limited diversity and a poor success rate.

Data Scarcity

So, our goals are as follows:

1. Eliminate human involvement.
2. Obtain high-quality Trajectory data.
3. Diversity and Scalability.

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GUI Trajectory Data

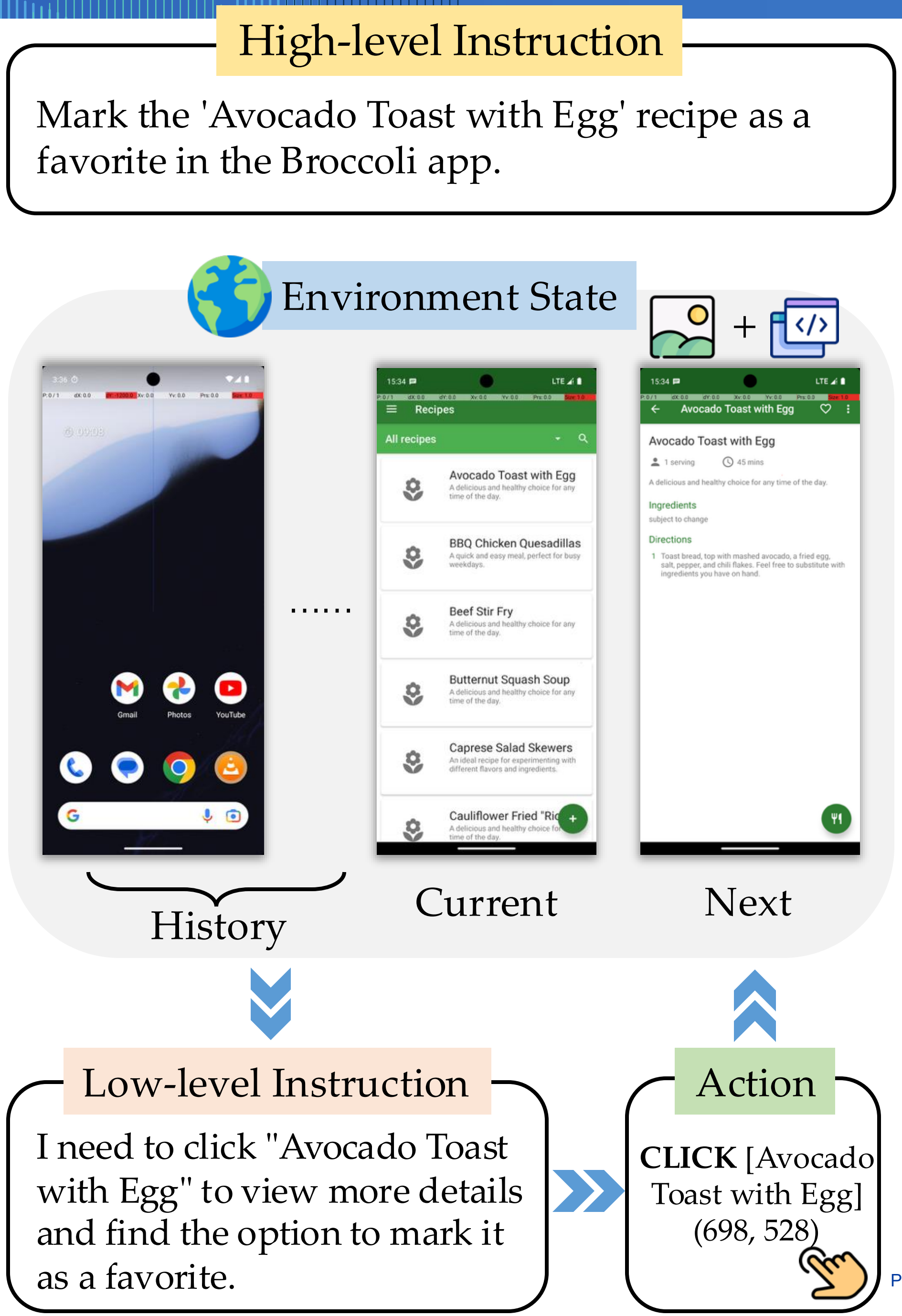
The best data format for GUI agents

1. A high-level instruction that defines the overall goal the agent aims to accomplish

2. A series of low-level instructions that each describe specific steps required

3. Actions (e.g., CLICK, TYPE)

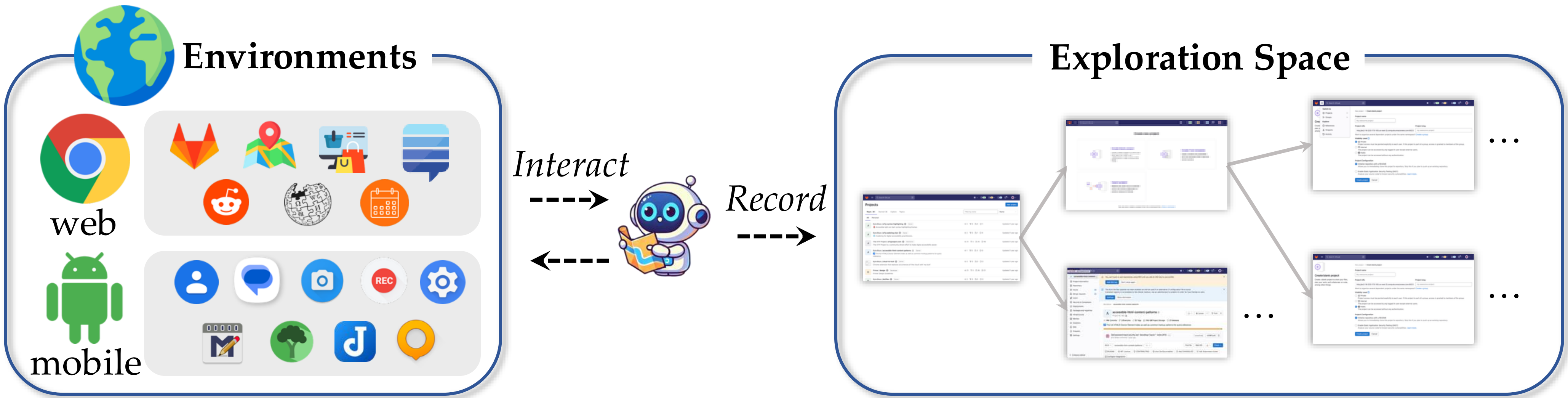
4. States, which include visual representations like screenshots and textual representations such as a11ytree



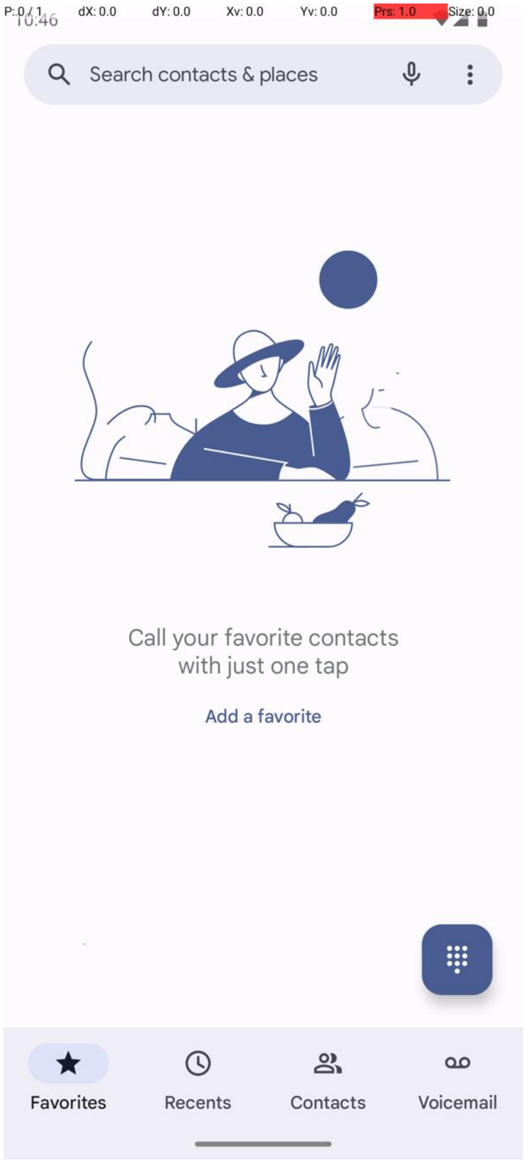
Reverse Task Synthesis

Interaction-Driven Functional Discovery is a rule-based process that explores dynamic GUI environments by interacting with UI elements. It uncovers functionalities through interaction triples

We collect: <Screen1, action, Screen2>

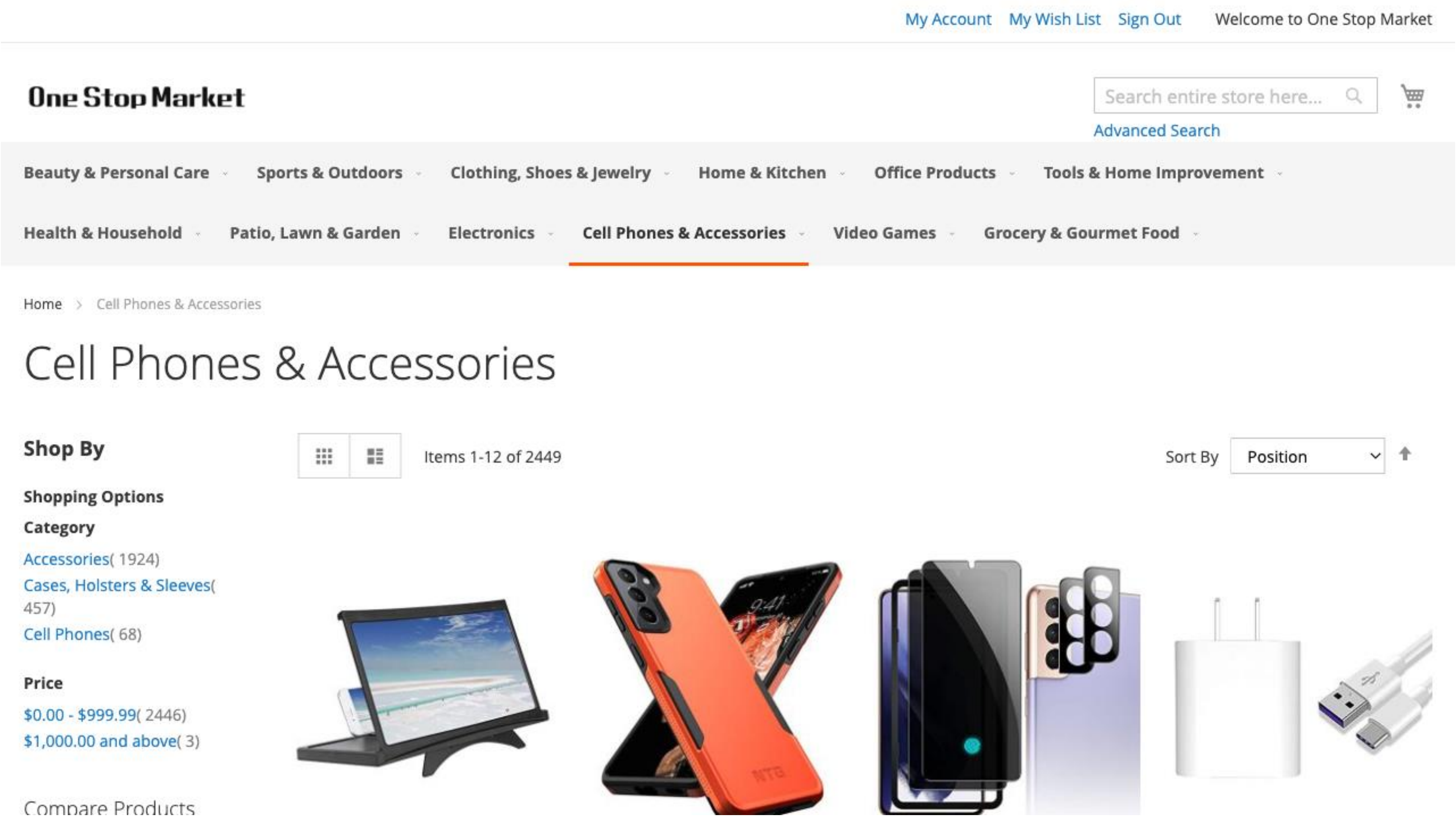


Dynamic Environments



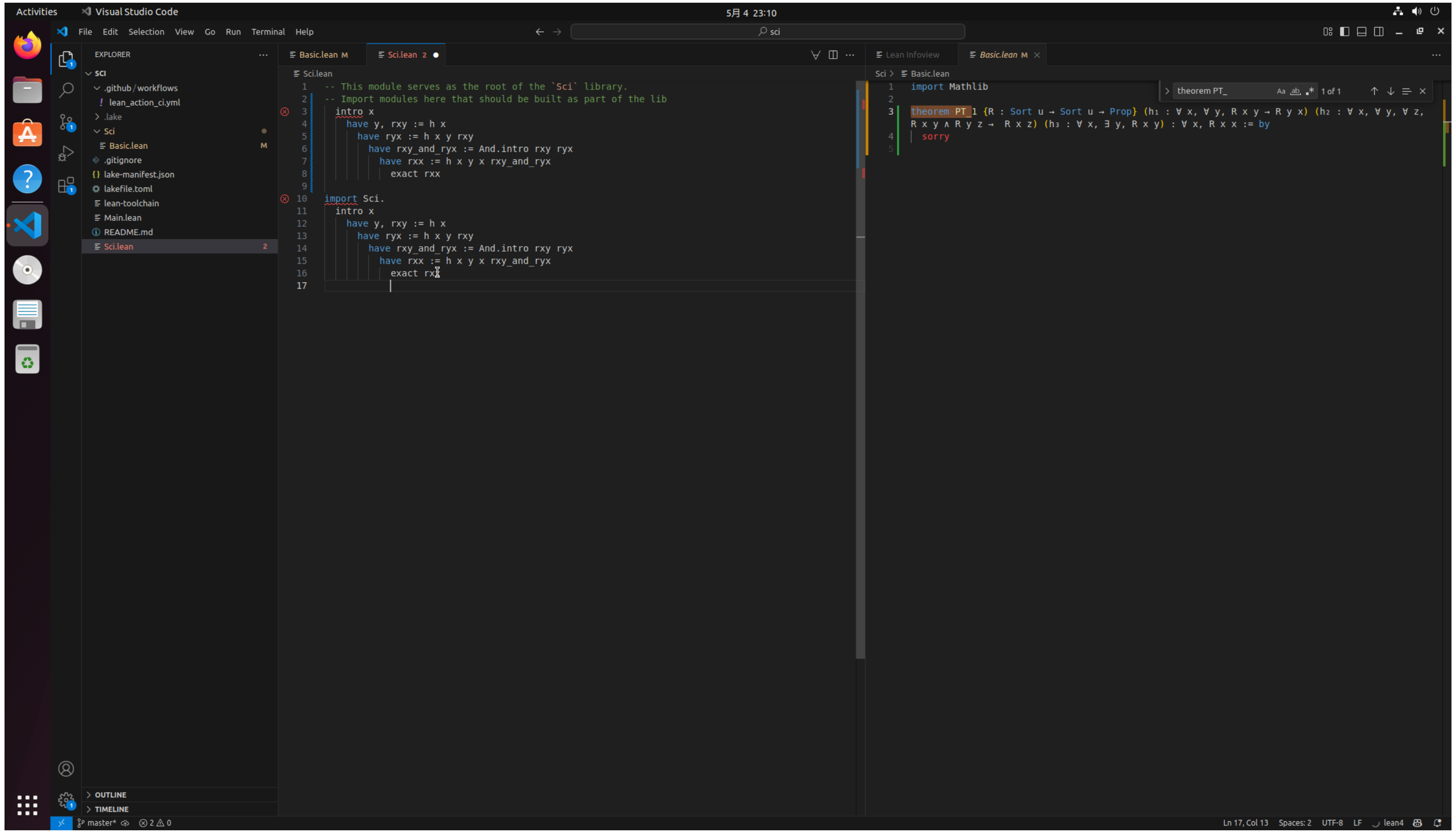
[6] AndroidWorld: A Dynamic Benchmarking Environment for Autonomous Agents, ICLR 2025

Dynamic Environments



[7] *WebArena: A Realistic Web Environment for Building Autonomous Agents, ICLR 2024*

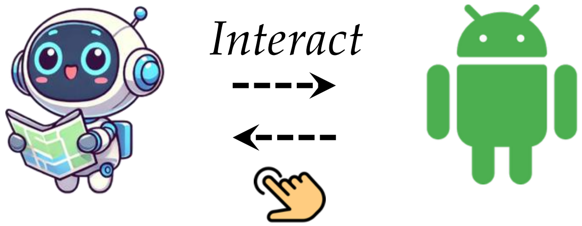
Dynamic Environments

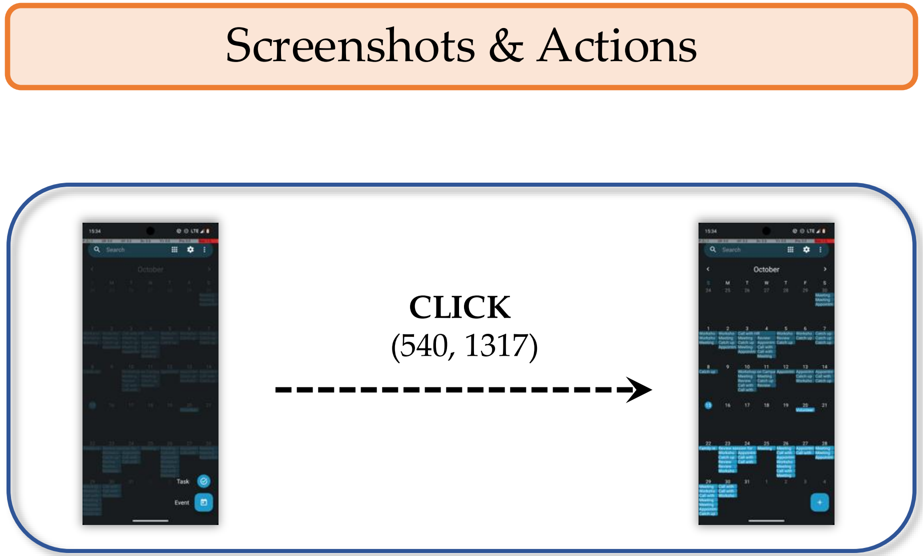


[5] *ScienceBoard: Evaluating Multimodal Autonomous Agents in Realistic Scientific Workflows*

Reverse Task Synthesis

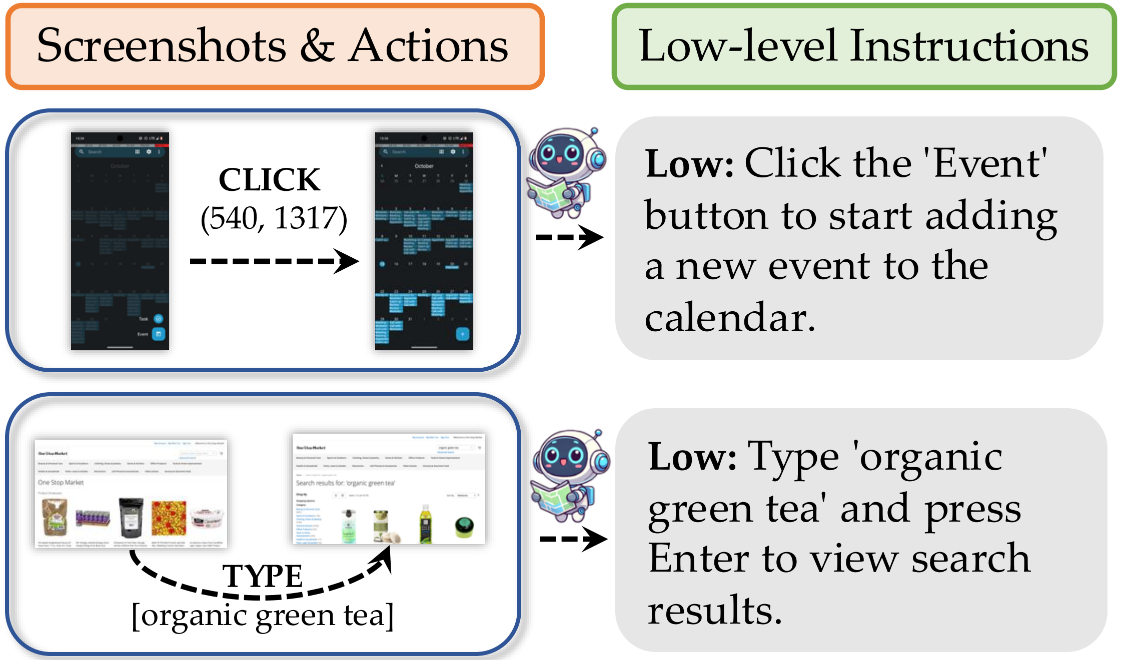
Retroactively interpreting changes in the GUI environment caused by actions.





Reverse Task Synthesis

Retroactively interpreting changes in the GUI environment caused by actions, this process generates executable low-level instructions



The data we synthesized:

1. Grounded

2. Actionable

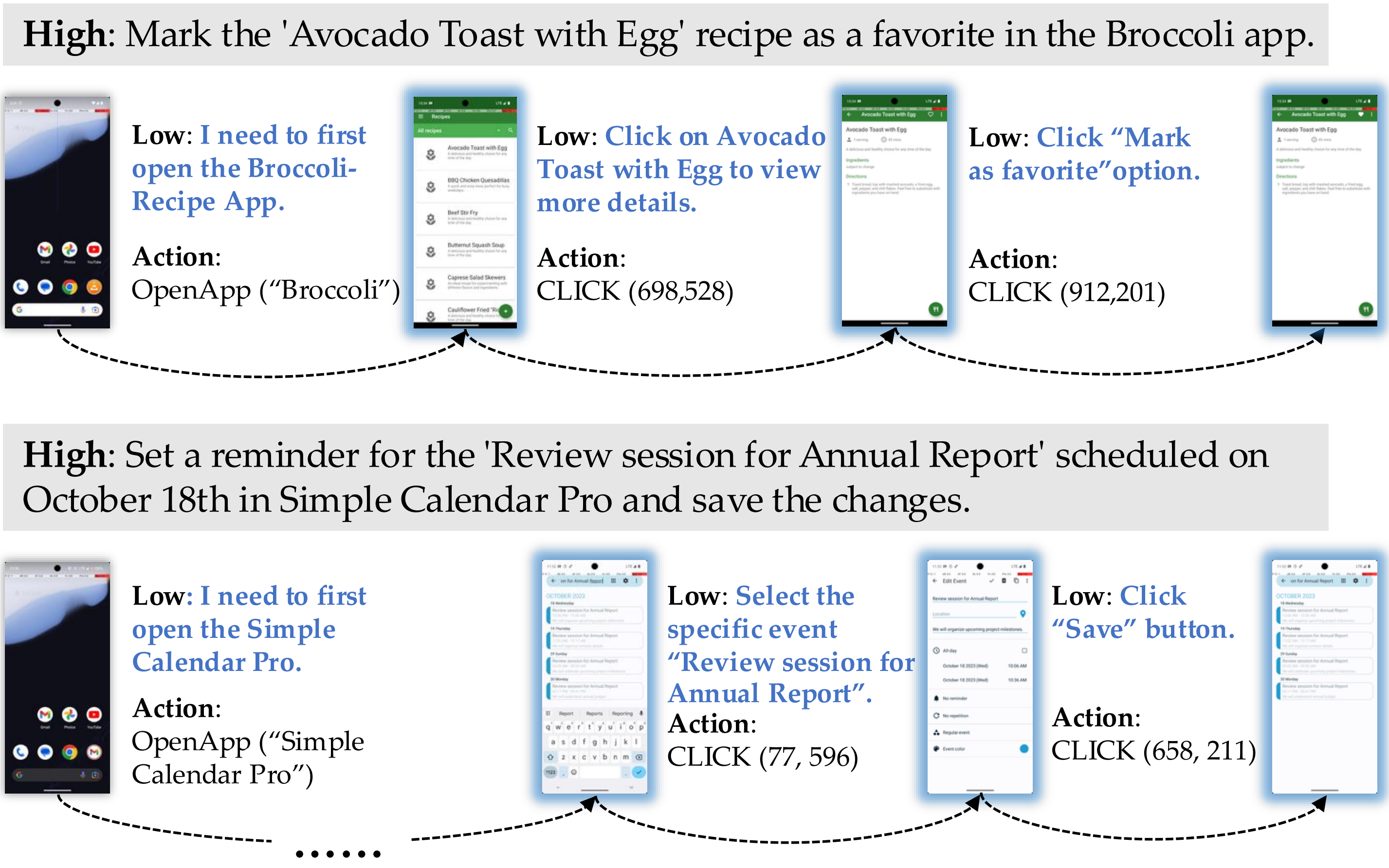
Reverse Task Synthesis

Retroactively interpreting changes in the GUI environment caused by actions, this process generates executable low-level instructions, which are then transformed into broader, goal-oriented high-level tasks

Screenshots & Actions	Low-level Instructions	High-level Instruction
	**Low:** Click the 'Event' button to start adding a new event to the calendar.	**High**: In Simple Calendar Pro, create a new event titled 'Team Meeting' scheduled for October 15, 2023, at 10:00 AM. Save the event after filling in the details.
	**Low:** Type 'organic green tea' and press Enter to view search results.	**High**: Search for 'organic green tea' and filter the results to show only products under the 'Health & Household' category, sorted by price from lowest to highest.

Reverse Task Synthesis

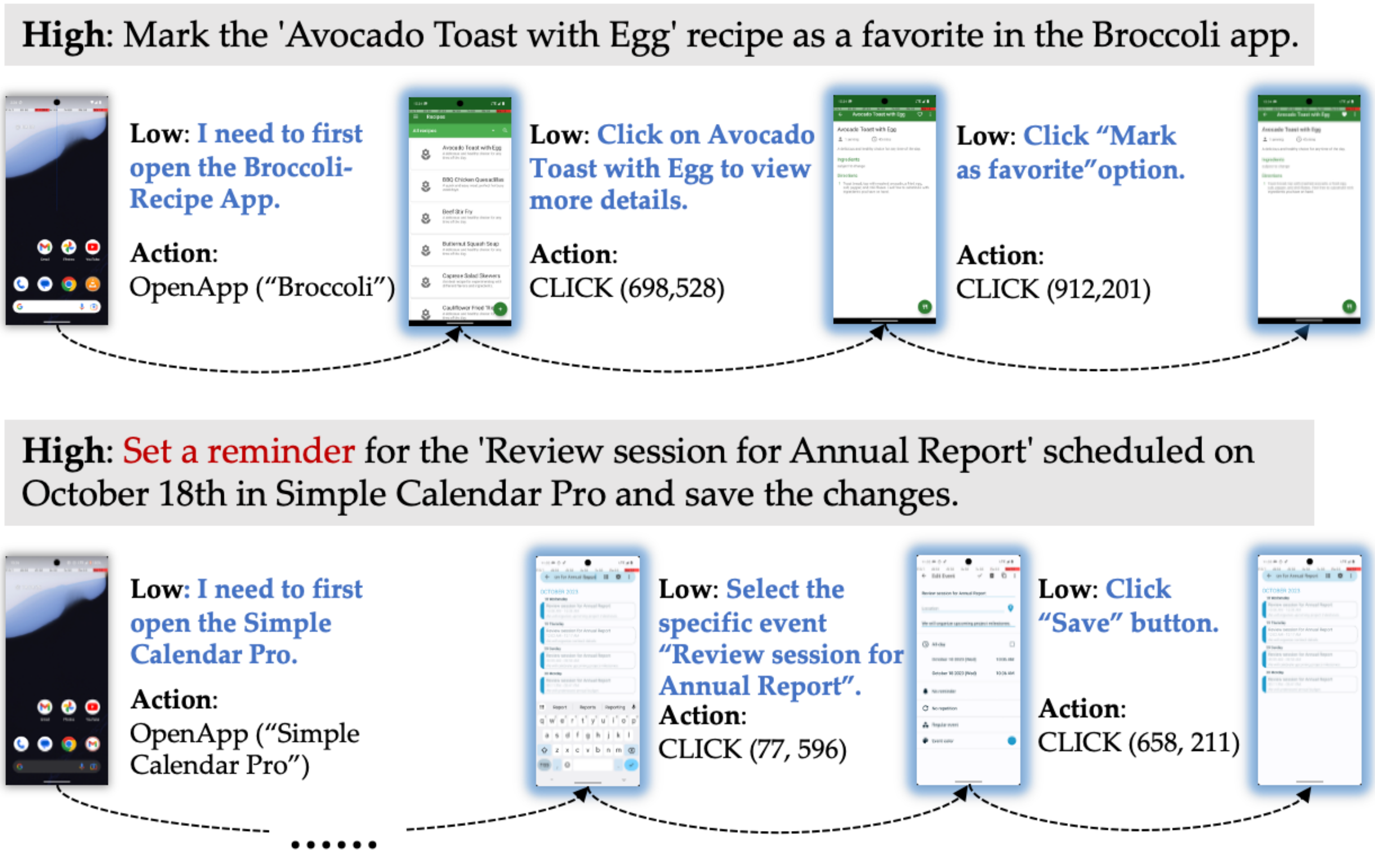
After reverse task synthesis generates task instructions, they are automatically executed in the GUI environment to build complete trajectories.

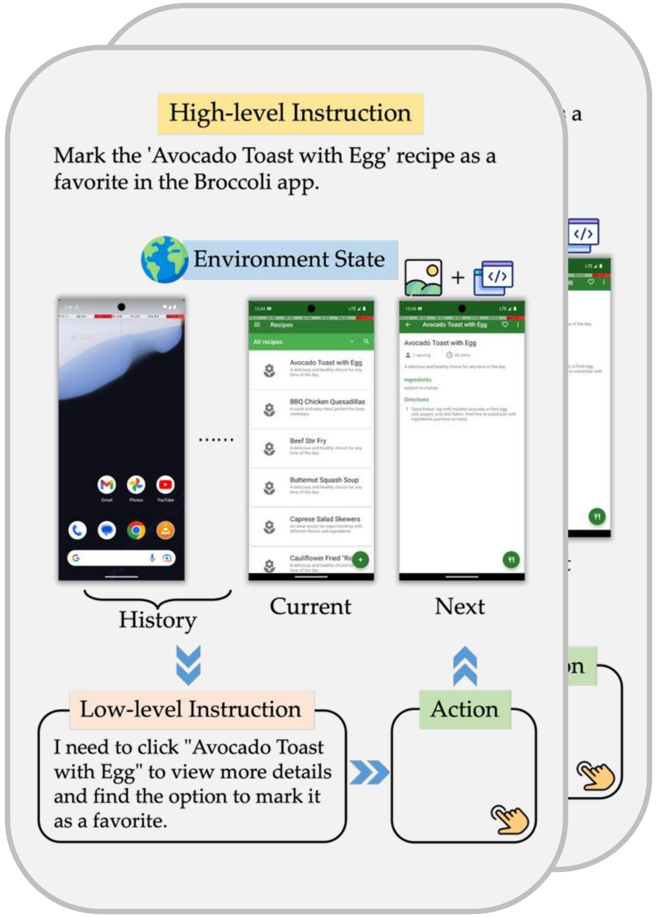


Reverse Task Synthesis

Trajectories collected! But is this all?

Let's consider data quality and synthesis efficiency.





Data Quality Control

Tasks are executed by machines, not all of them are successful.

Previous approach:

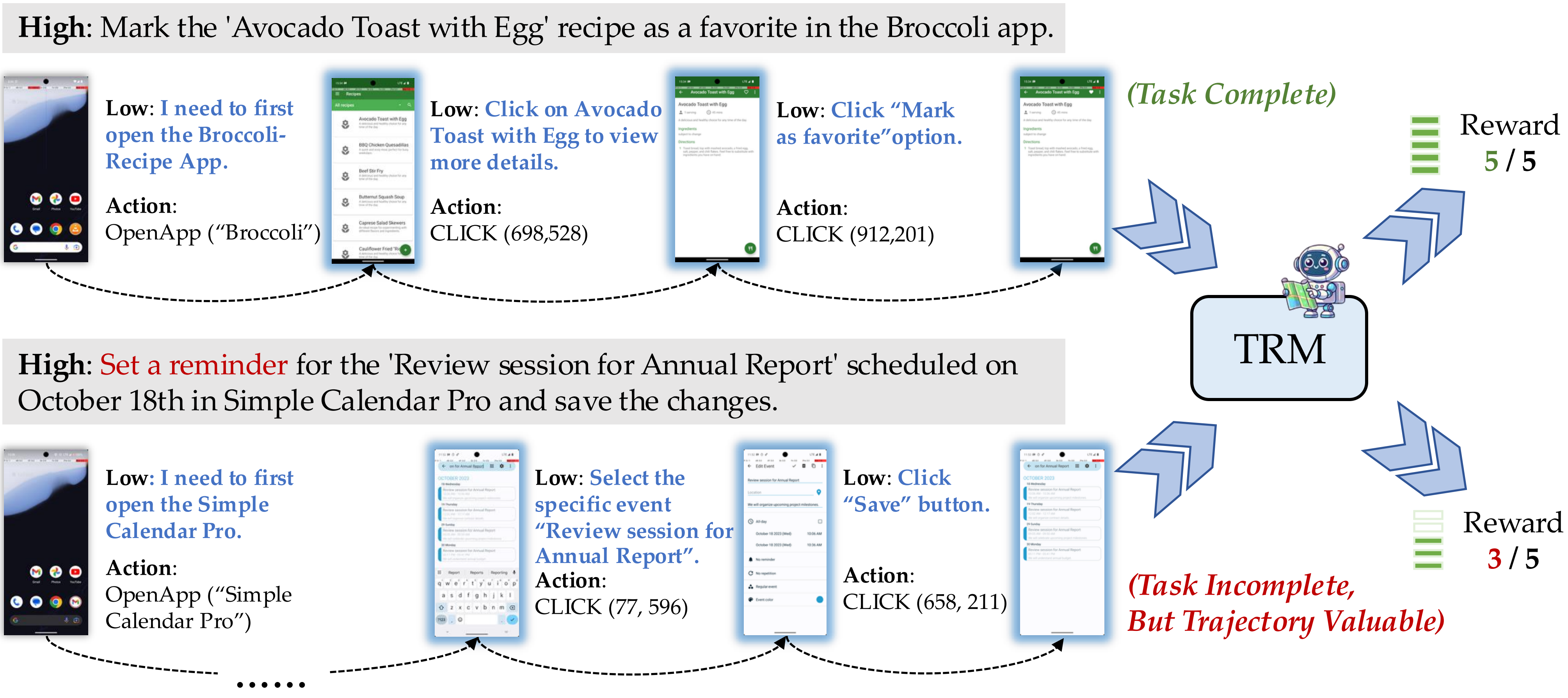
1. Training all data at once - what about the quality?

2. Discarding all incomplete Trajectories - what about the efficiency?

Thus, we introduce a Trajectory Reward Model to handle this.

Reward Modeling

We introduce a Trajectory Reward Model for weighted sampling in training.



Models

Data Synthesis

GPT-4o

Qwen-VL Qwen2-VL-72B-Instruct

Backbones

InternVL InternVL2-4B / 8B

Qwen-VL Qwen2-VL-7B-Instruct

Baselines

We adapt / build the following forward baselines

- **Zero-Shot.** Advanced prompting-based agents, such as M3A.

- **Task-Driven.** GUI Trajectories synthesized using pre-defined tasks. Given initial screenshots of the app/web page and task examples, use GPT-4 to generate high-level instructions and collect data.

- **Self-Instruct.** Builds on Task-Driven by adding self-instructed tasks.

Setting: Screenshot + A11ytree

[8] Self-Instruct: Aligning Language Models with Self-Generated Instructions, ACL 2023

Experiments: Mobile

Base Model	Strategies	AndroidWorld	AndroidControl-High		AndroidControl-Low	
			SR	Type	SR	Type
GPT-4o	Zero-Shot (M3A)	23.70	53.04	69.14	69.59	80.27
InternVL2-4B	Zero-Shot	0.00	16.62	39.96	33.69	60.65
	Task-Driven	4.02	27.37	47.08	66.48	90.37
	Task-Driven w. Self Instruct	7.14	24.95	44.27	66.70	90.79
	OS-Genesis	**15.18**	**33.39**	**56.20**	**73.38**	**91.32**
InternVL2-8B	Zero-Shot	2.23	17.89	38.22	47.69	66.67
	Task-Driven	4.46	23.79	43.94	64.43	89.83
	Task-Driven w. Self Instruct	5.36	23.43	44.43	64.69	89.85
	OS-Genesis	**16.96**	**35.77**	**64.57**	**71.37**	**91.27**
Qwen2-VL-7B	Zero-Shot	0.89	28.92	61.39	46.37	72.78
	Task-Driven	6.25	38.84	58.08	71.33	88.71
	Task-Driven w. Self Instruct	9.82	39.36	58.28	71.57	89.73
	OS-Genesis	**17.41**	**44.54**	**66.15**	**74.17**	**90.72**

Table 1: Performance on AndroidWorld and AndroidControl benchmarks.

Findings: OS-Genesis + Opensource VLM > Propriety Models + Complex Prompting

Experiments: Web

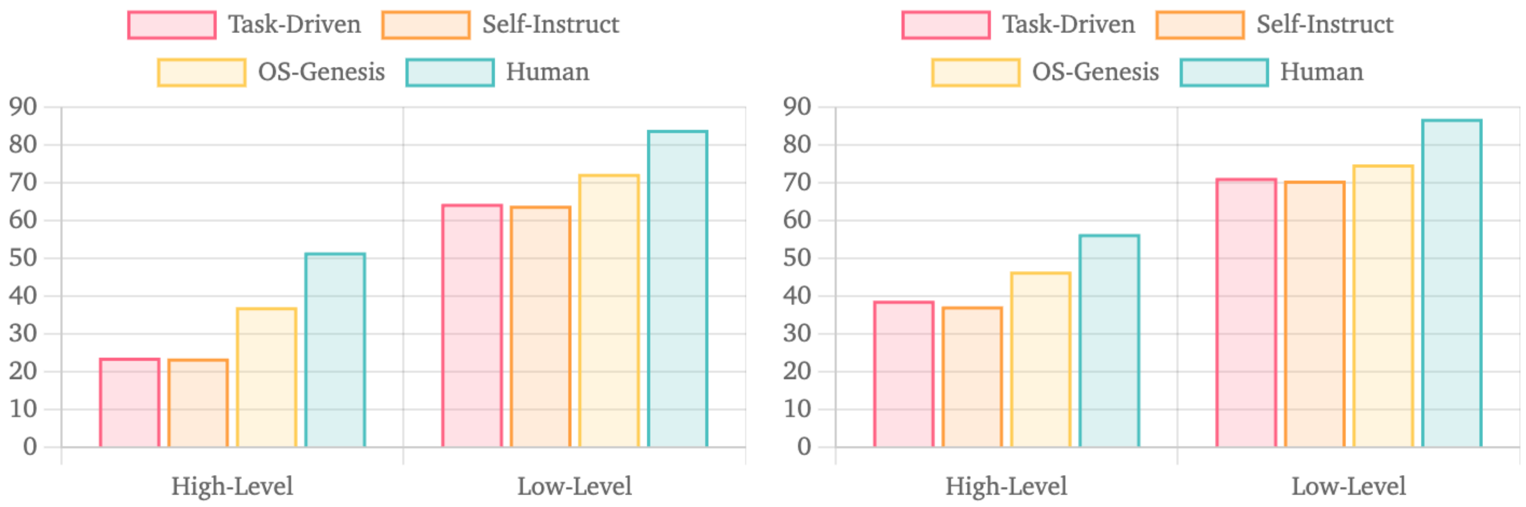
Base Model	Strategies	Shopping	CMS	Reddit	Gitlab	Maps	Overall
GPT-4o	Zero-Shot	14.28	21.05	6.25	14.29	20.00	16.25
InternVL2-4B	Zero-Shot	0.00	0.00	0.00	0.00	0.00	0.00
	Task-Driven	5.36	1.76	0.00	**9.52**	5.00	4.98
	Task-Driven w. Self Instruct	5.36	3.51	0.00	**9.52**	7.50	5.81
	OS-Genesis	**10.71**	**7.02**	**3.13**	7.94	**7.50**	**7.88**
InternVL2-8B	Zero-Shot	0.00	0.00	0.00	0.00	0.00	0.00
	Task-Driven	3.57	7.02	0.00	6.35	2.50	4.56
	Task-Driven w. Self Instruct	**8.93**	10.53	6.25	**7.94**	0.00	7.05
	OS-Genesis	7.14	**15.79**	**9.34**	6.35	**10.00**	**9.96**
Qwen2-VL-7B	Zero-Shot	**12.50**	7.02	6.25	6.35	5.00	7.47
	Task-Driven	8.93	7.02	6.25	6.35	5.00	7.05
	Task-Driven w. Self Instruct	8.93	1.76	3.13	4.84	**7.50**	5.39
	OS-Genesis	7.14	**8.77**	**15.63**	**15.87**	5.00	**10.79**

Table 2: Performance on WebArena benchmarks.

Analysis

How Far are we from Human Data?

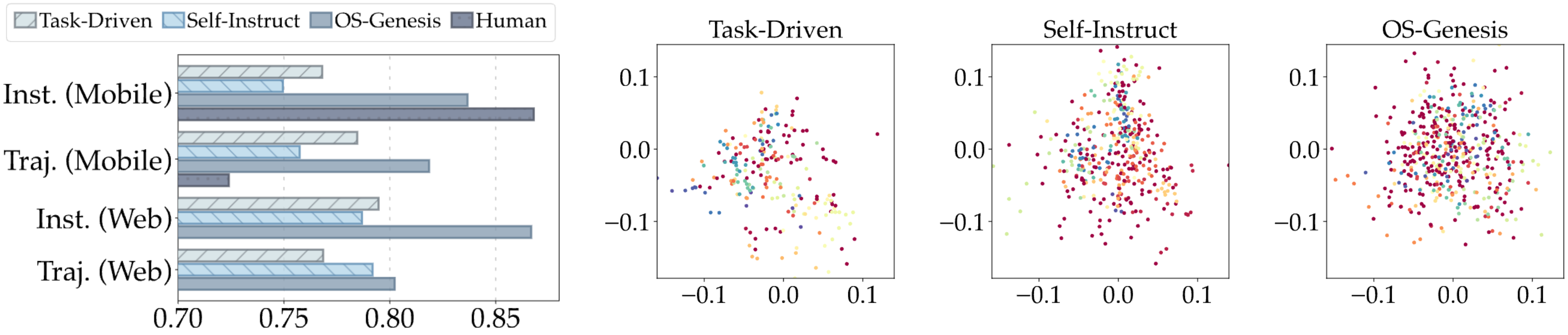
Then, OS-Genesis v.s. Human-annotated Trajectories.



Insight: OS-Genesis achieves ~80% of human data's effectiveness.

Analysis

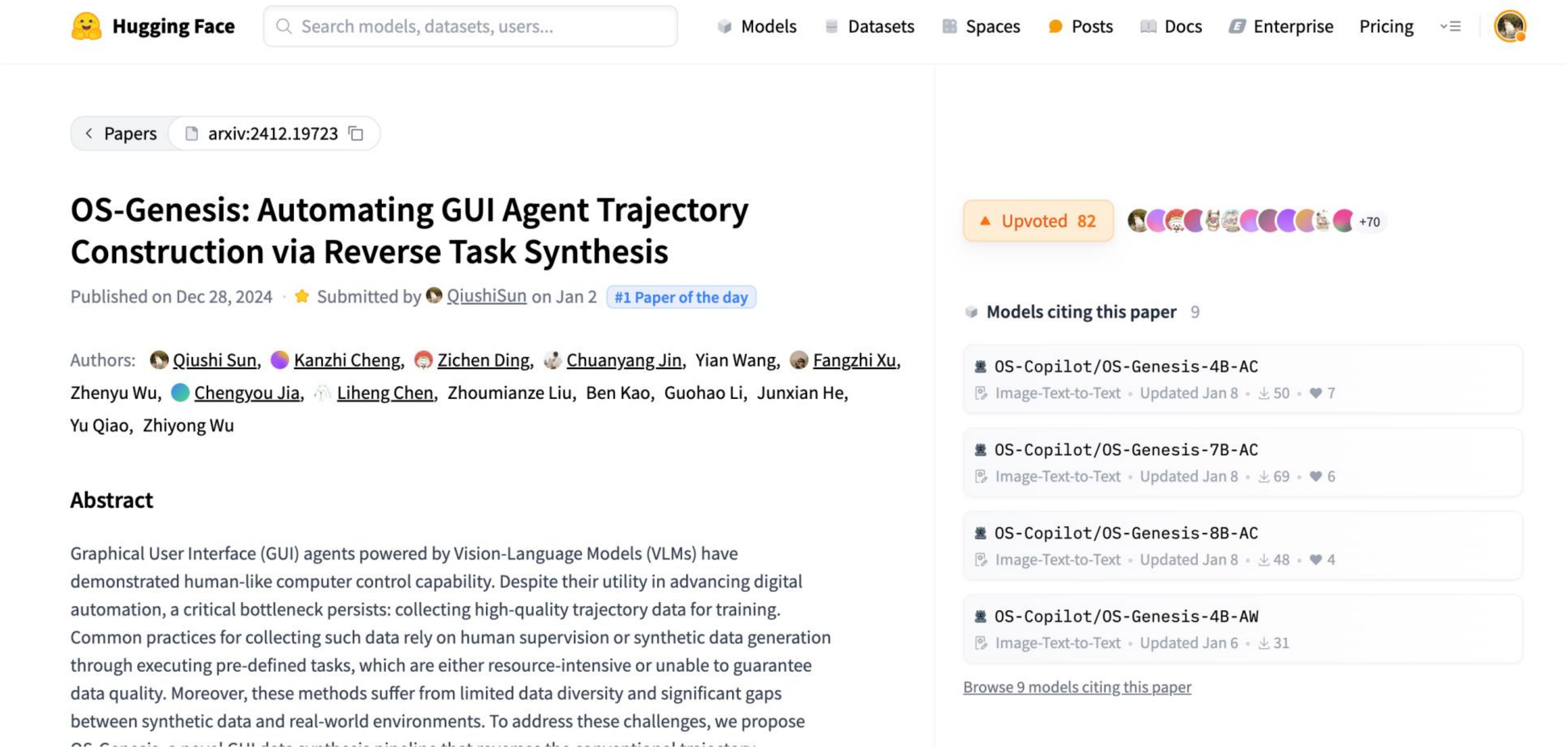
How about our data diversity?



Insight: Significantly better than Forward methods and approaches the human level.

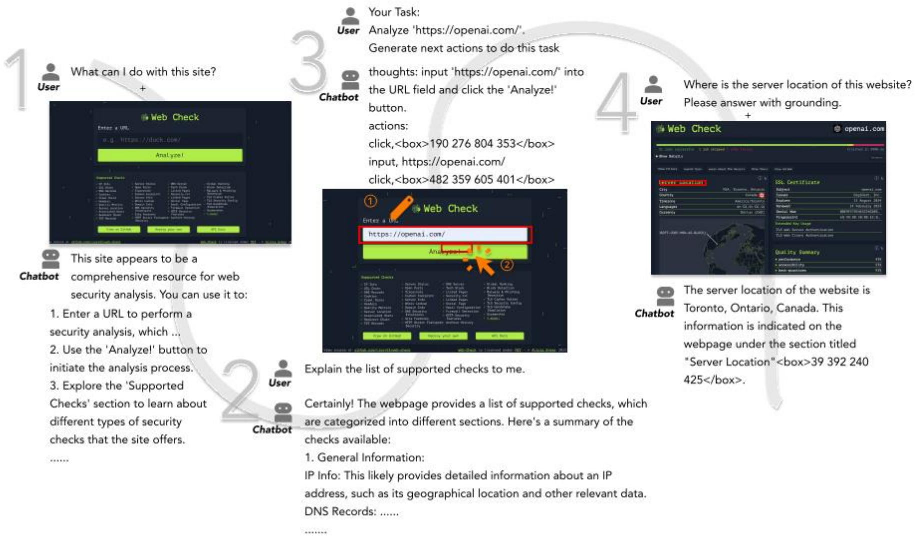
Checkpoints & Data Access

Available on Hugging Face

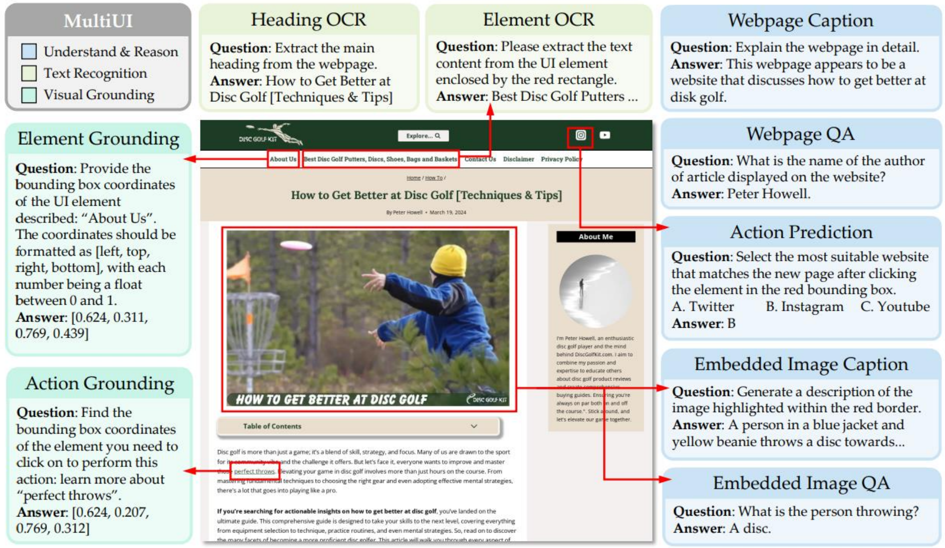


Next Step?

Beyond Planning and Action: What Else Do We Need?



GUI Trajectory Data



GUI Perception/Knowledge…

[9] *Harnessing Webpage UIs for Text-Rich Visual Understanding, ICLR 2025.*
[10] *Guicourse: From general vision language models to versatile gui agents, arxiv 2406.11317*

GUIMid

Beyond Planning and Action: What Else Do We Need?

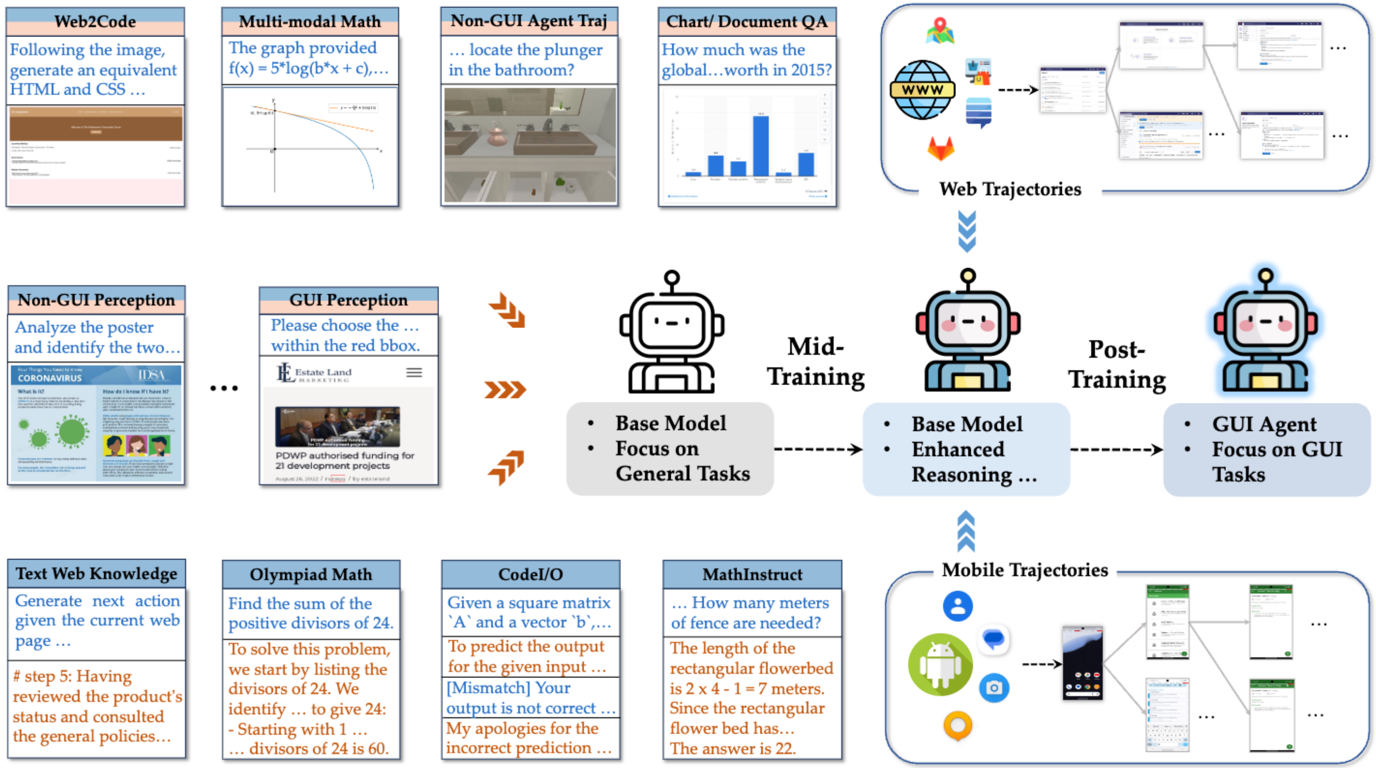
Domains	Ability	Datasets	Samples	Type
		Vision-and-Language Modality		
Chart/Document QA	Perception	InfographicVQA (Guo et al., 2024)	2,184	Instruction, Thought*, Answer
		Ureader QA (Guo et al., 2024)	53,794	Instruction, Thought, Answer
		MPDocVQA (Tito et al., 2023)	431	Instruction, Thought, Answer
		MathV360k (Liu et al., 2024b)	93,591	Instruction, Thought, Answer
Non-GUI Perception	Perception	Ureader OCR (Ye et al., 2023)	6,146	Instruction, Thought*, Answer
		DUE (Borchmann et al., 2021)	143,854	Instruction, Answer
GUI Perception	Perception	MultiUI (Liu et al., 2024a)	150,000	Instruction, Answer
Web Screenshot2Code	Perception	Web2Code (Yun et al., 2024)	150,000	Instruction, Answer
Multi-modal Math	Reasoning	Mavis (Zhang et al., 2024b)	150,000	Instruction, Thought, Answer
Multi-round Visual Conversation	Interaction	SVIT (Zhao et al., 2023)	150,000	Instruction, Thought, Answer
Non-GUI Agent Trajectories	Interaction	AlfWorld (Guo et al., 2024)	51,780	Instruction, Thought, Answer
		Language Modality		
MathInstruct	Reasoning	MathInstruct (Yue et al., 2023)	150,000	Instruction, Thought, Answer
Olympiad Math	Reasoning	NuminaMath (LI et al., 2024)	150,000	Instruction, Thought, Answer
CodeI/O	Reasoning	CodeI/O (Li et al., 2025)	150,000	Instruction, Thought, Answer
Web Knowledge Base	Knowledge	Synatra (Ou et al., 2024)	99,924	Instruction, Thought, Answer
		AgentTrek (Xu et al., 2024a)	50,076	Instruction, Thought, Answer

We have abundant non-GUI data available to enhance versatile abilities

Can we take advantage of these data-rich domains?

GUIMid

Breaking the Data Barrier – Building GUI Agents Through Task Generalization: arXiv 2504.10127



Mid-training: Training phrase between pre-training and post-training

GUIMid

Breaking the Data Barrier – Building GUI Agents Through Task Generalization: arXiv 2504.10127

Domains	Observation	WebArena PR	WebArena SR	AndroidWorld SR
GUI Post-Training Only	Image	26.3	6.2	9.0
Public Baselines				
GPT-4o-2024-11-20	Image	36.9	15.6	11.7
OS-Genesis-7B	Image + Accessibility Tree	–	–	17.4
AGUVIS-72B	Image	-	-	26.1
Claude3-Haiku	Accessibility Tree	26.8	12.7	-
Llama3-70b	Accessibility Tree	35.6	12.6	-
Gemini1.5-Flash	Accessibility Tree	32.4	11.1	-
Vision-and-Language Modality				
Chart/ Document QA	Image	24.6	6.2	15.3
Non-GUI Perception	Image	28.7	7.6	14.0
GUI Perception	Image	27.4	7.1	14.0
Web Screenshot2Code	Image	28.0	6.6	9.9
Non-GUI Agents	Image	30.8	8.5	13.5
Multi-modal Math ✓	Image	30.4	8.5	15.3
Multi-round Visual Conversation	Image	30.0	9.0	12.6
Language Modality				
MathInstruct ✓	Image	31.9	10.9	14.4
Olympiad Math ✓	Image	31.5	8.5	13.1
CodeI/O ✓	Image	29.2	9.0	14.9
Web Knowledge Base	Image	31.3	9.5	9.0
Domain Combination (Sampled data from ✓domains)				
GUIMid	Image	34.3	9.5	21.2

Mid-training: Training phrase between pre-training and post-training

Our Project

OS-Genesis

Automating GUI Agent Trajectory Construction via Reverse Task Synthesis

Introducing OS-Genesis, a ***manual-free*** data pipeline for synthesizing GUI agent trajectory. OS-Genesis is characterized by the following core features:

- **Interaction-driven**: Agents actively explore GUI environments through stepwise interactions to discover functionalities and generate data.
- **Reverse Task Synthesis**: OS-Genesis retroactively derives meaningful low/high-level task instructions from observed interactions and state changes, enabling the construction of diverse and executable trajectories without pre-defined tasks.
- **Trajectory Data**: We construct and release high-quality mobile and web trajectories to accelerate GUI agents research.
- **Performance**: OS-Genesis significantly outperforms other synthesis methods on benchmarks like AndroidWorld and WebArena.

arXiv | Code | Checkpoints | Data

https://qiushisun.github.io/OS-Genesis-Home/

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Thanks for listening

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