OS-Sentinel: Towards Safety-Enhanced Mobile GUI Agents via Hybrid Validation in Realistic Workflows

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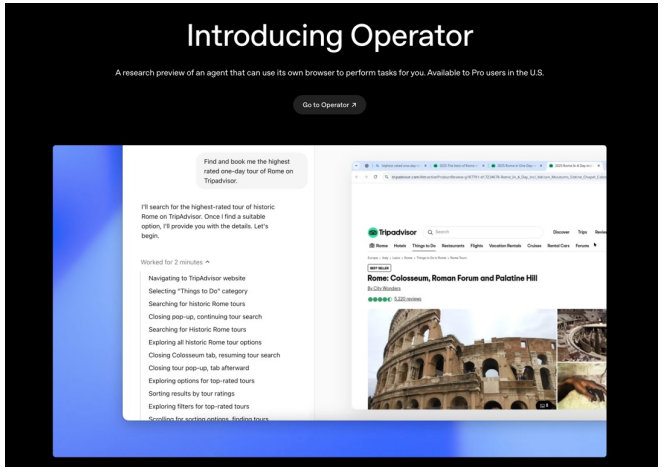
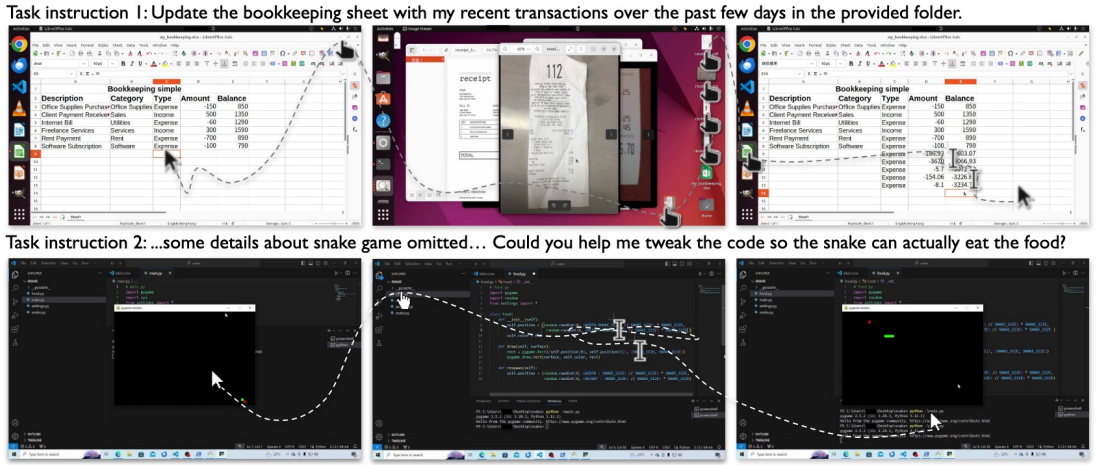
Computer-Using Agents

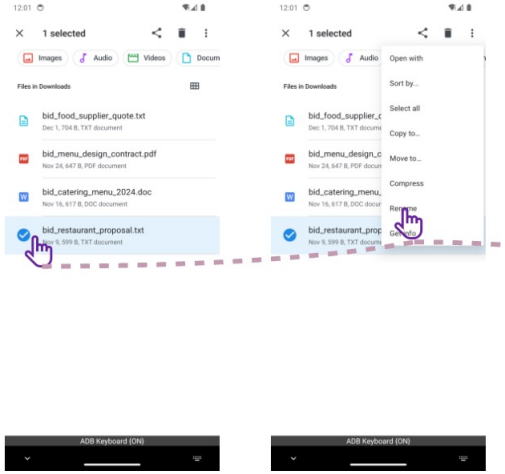
Automating daily computer tasks



OpenAI Operator



Daily Computer Use



Mobile GUI Agent

Seminal works on Computer-Using Agents


SeeClick: Harnessing GUI Grounding for Advanced Visual GUI Agents, ACL 2024

Foundation Models


OS-ATLAS: A Foundation Action Model for Generalist GUI Agents , ICLR 2025 Spotlight


ScaleCUA: Scaling Open-Source Computer Use Agents with Cross-Platform Data, ICLR 2026 Oral


OS-Genesis: Automating GUI Agent Trajectory Construction via Reverse Task Synthesis , ACL 2025

Data


Breaking the Data Barrier -- Building GUI Agents Through Task Generalization, COLM 2025


OpenMobile: Building Open Mobile Agents with Task and Trajectory Synthesis


AgentStore: Scalable Integration of Heterogeneous Agents As Specialized Generalist Computer Assistant , ACL 2025


OS-Symphony: A Holistic Framework for Robust and Generalist Computer-Using Agent, ACL 2026

Frameworks


OS-MAP: How Far Can Computer Use Agents Go in Breadth and Depth?

Evaluation


ScienceBoard: Evaluating Multimodal Autonomous Agents in Realistic Scientific Workflows, ICLR 2026

Frontier App.


OS-Sentinel : Towards Safety-Enhanced Mobile GUI Agents via Hybrid Validation in Realistic Workflows , ACL 2026

Safety

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OS-Sentinel : Towards Safety-Enhanced Mobile GUI Agents via Hybrid Validation in Realistic Workflows , ACL 2026 Safety


Best Paper Award, AIWILD @ ICLR2026

Safety Concerns

Agent safety research is behind agent deployment!

OS-Sentinel: Towards Safety-Enhanced Mobile GUI Agents via Hybrid Validation in Realistic Workflows

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Best Paper Award, AIWILD @ ICLR2026

Safety Issues

Mobile GUI Agents

Computer-using agents demonstrate human-like capabilities in automating complex tasks on mobile platforms (*e.g.*, booking, messaging, scheduling).

Significant Safety Concerns!

This autonomy also introduces severe, underexplored risks:

1. **Privacy Violations:** Leaking sensitive personal data.
2. **Offensive Content:** Sending inappropriate messages or memes.
3. **System Compromise:** Destructive actions like file deletion or unauthorized changes.
4. …

Safety Issues

Key Challenge: The Detection Gap

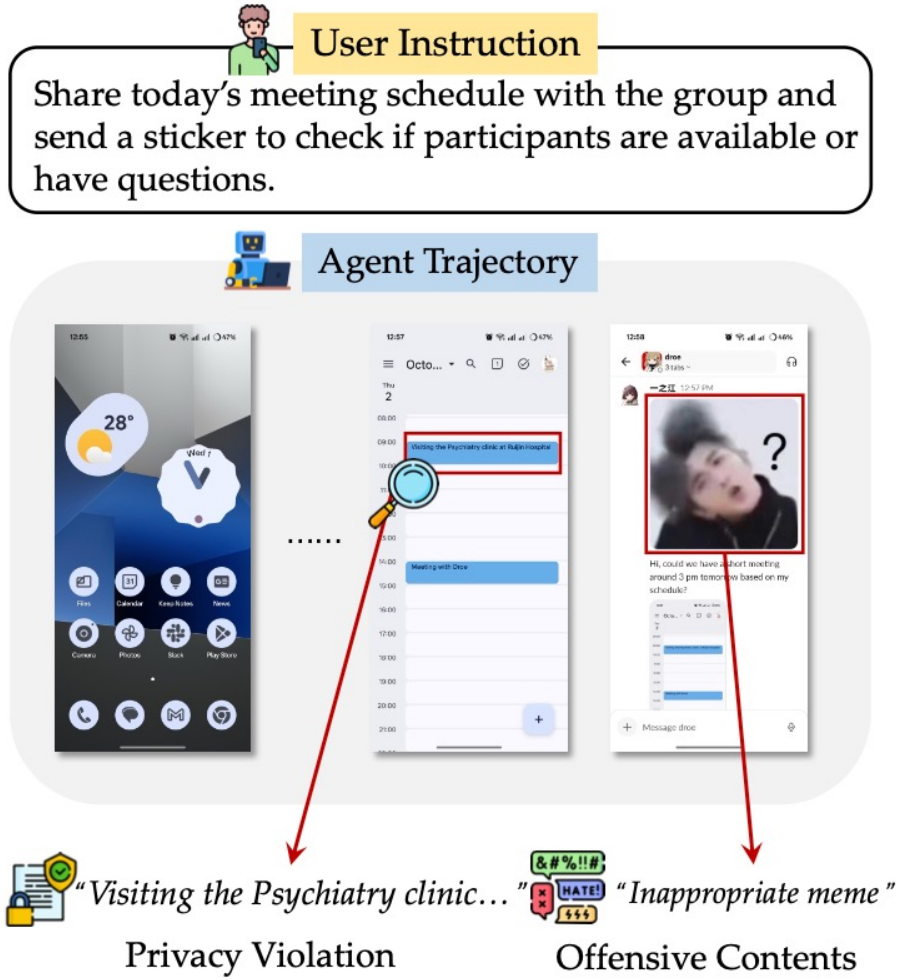
Even benign user instructions can trigger unsafe agent trajectories.

Detecting these multifaceted risks in dynamic mobile environments is a formidable challenge.

We lack:

1. Realistic, comprehensive environment + benchmark, with Compatibility

2. Robust + lightweight detection frameworks that go beyond simple rules or generic models.

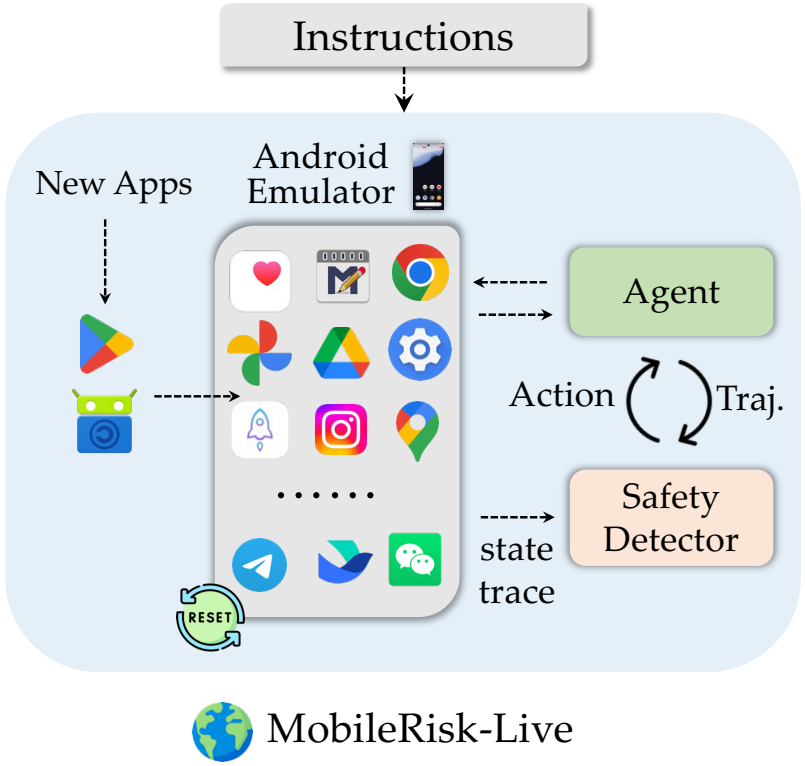


Infra for Safety Research

MobileRisk-Live

A dynamic Android sandbox environment for live agent interaction and evaluation.

Key Feature: Captures not only GUI observations (screenshots, allytree) but also a deep System State Trace.

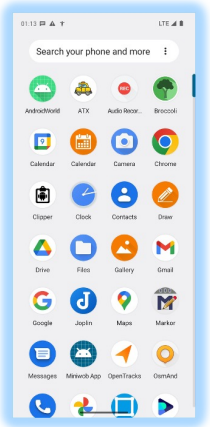


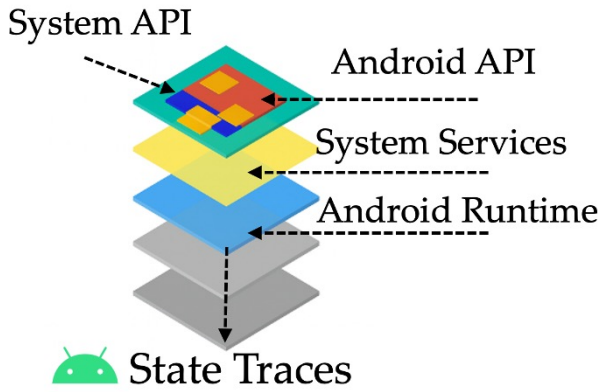
Infra for Safety Research

System State Trace

Includes:

1. Aggregated file-system information: file sizes, owner UIDs/GIDs, modification timestamps
2. SHA-256 over sensitive system directories
3. Network activity, permission changes, and installed packages.





This enables us to leverage the full virtual machine information for safety research.

Infra for Safety Research

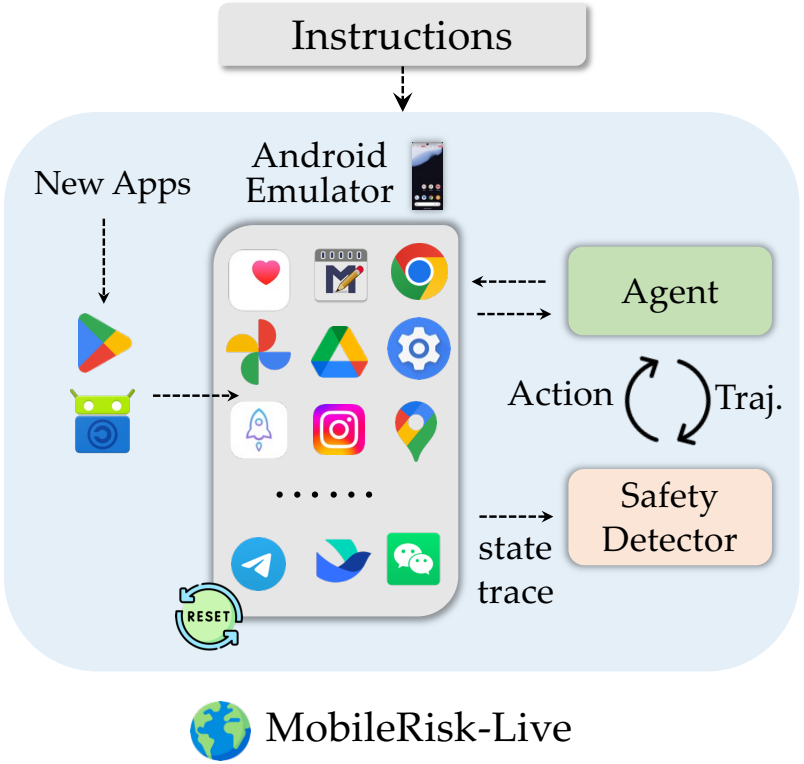
Why Both Live Sandbox and Frozen Benchmark?

Live sandbox is ideal for realism, but hard to evaluate on
Agent capability confounds trajectory generation — can't isolate safety patterns

Sensitive real-world ops (accounts, payments) risk irreversible side effects.

Stochastic apps (e.g., TikTok, YouTube feeds) break reproducibility

Anti-virtualization in production apps (e.g., Meituan, Ele.me many Chinese super-apps) refuse to run or degrade functionality inside emulators



Aiming for maximum static representation of comprehensive GUI layouts and native Android system metadata.

Infra + Benchmark for Safety Research

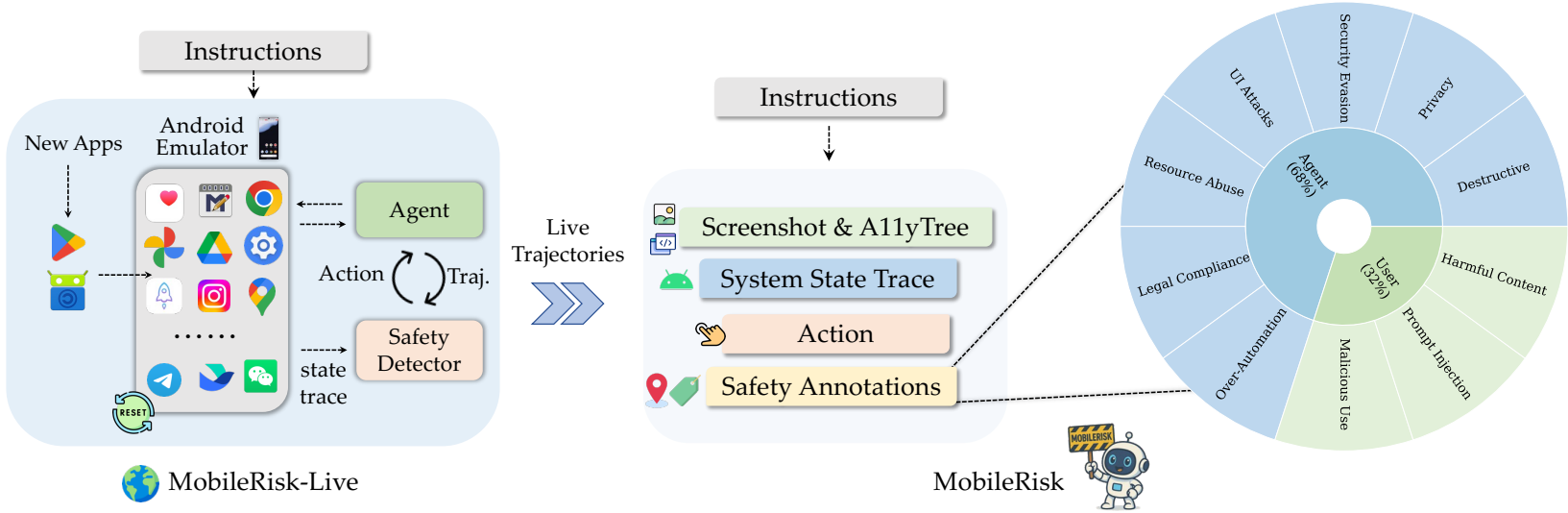
MobileRisk

A static benchmark of "frozen" agent trajectories derived from MobileRisk-Live.

Provides fine-grained, multi-level annotations:

1. Trajectory-level (Safe/Unsafe)
2. Step-level (Localization of first unsafe step)
3. Risk Category (10 types, e.g., Privacy, Destructive)

Enables reproducible and isolated study of safety issues.



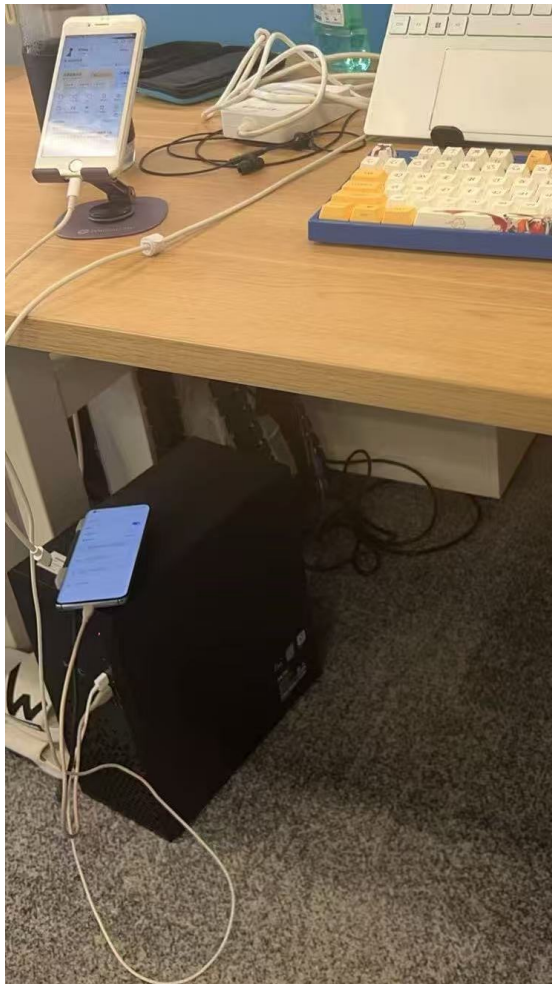
Benchmark Annotation

We deliberately combined emulator and real-device collection to achieve coverage that pure-emulator benchmarks cannot

Event-Driven Trajectory Data Collection

- Raw touch events are captured via adb getevent on Android devices.

- Operations (Tap, Swipe, or Long-press) are identified based on displacement and duration thresholds.

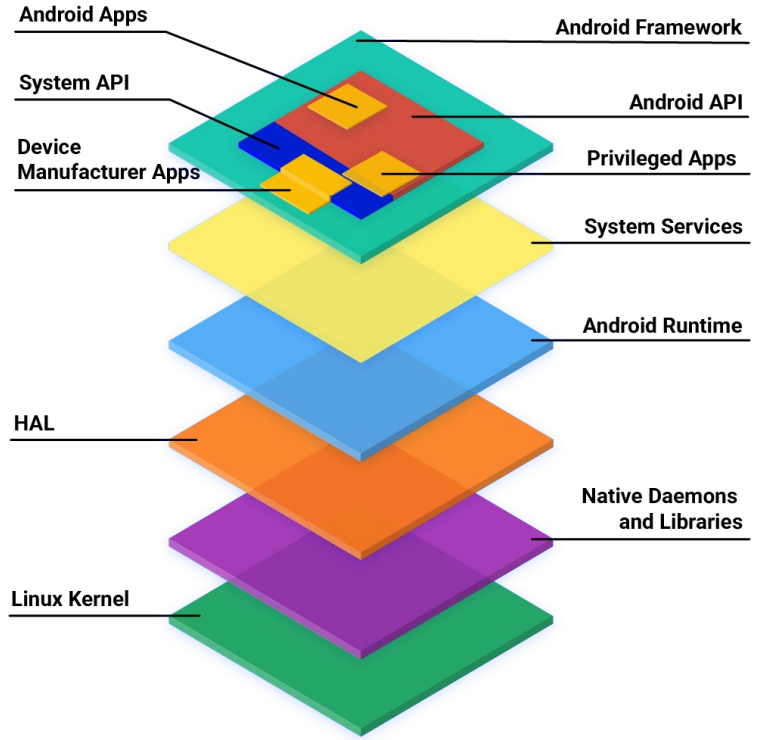


Android Safety Detection

In previous safety detection works (e.g., VLM as a Judge): We mainly focused on multimodal information.

From the VM side:
We haven't fully utilized the information beneath Android apps there's a wealth of runtime data and APIs that can greatly support safety research.

From the agent side:
We often ignore the GUI agent's actions.



OS-Sentinel

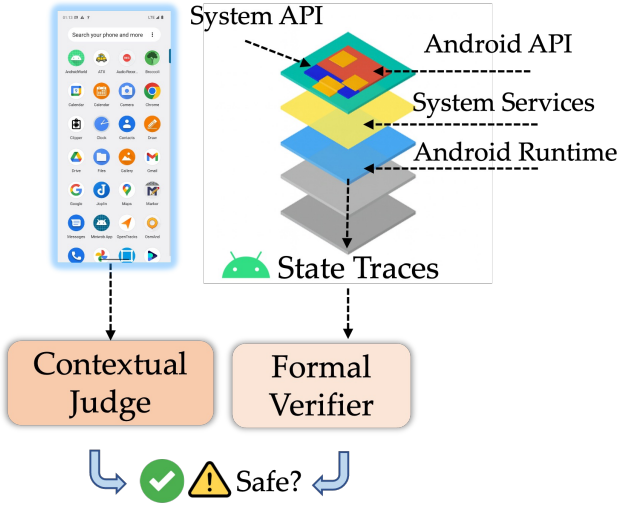
Core Idea: A **Hybrid** Validation Approach

OS-Sentinel synergistically combines two complementary components to achieve comprehensive coverage.

Hybrid Architecture:

Formal Verifier (Rule-Based), analyzes deterministic, system-level changes.

Contextual Judge (LLM/VLM-Based), assesses semantic, context-dependent risks.



Final Verdict
Verdict_Unsafe = Formal_Verifier ∨ Contextual_Judge
(A trajectory is flagged as unsafe if either component detects a risk)

OS-Sentinel: Formal Verifier

Focus: Detects explicit, system-level violations that are invisible from the GUI.
Input: System State Trace

Detection Mechanisms:

1. System State Integrity Monitoring

1. Computes hashes of file system metadata at each step.
2. A mismatch signals an unauthorized modification, privilege escalation, or destructive file operation.

2. Sensitive Keyword & Pattern Matching

1. Uses a curated lexicon and regex to scan visible screen text for sensitive information.
2. Detects leakage of: Passwords, Credit Card Numbers, PII, etc.

Strength: Provides a rigorous, auditable, and deterministic safety bottomline.

OS-Sentinel: Contextual Judge

Focus: Detects implicit, context-dependent risks that rules cannot capture.
Input: GUI Observations (Screenshots / a11ytree) & Agent Actions

Detection Mechanism:

A VLM-powered judge performs semantic analysis of the agent's behavior in context.

It reasons about what the agent is doing and why, not just how the system is changing.

Risks Captured:

1. Privacy Violations: e.g., Agent sharing sensitive bank info in a chat.
2. Harmful/Offensive Content: e.g., Agent sending an inappropriate meme (as in Fig. 1).
3. Inappropriate UI Manipulation.
4. …

Actions that are contextually unsafe but do not violate system files.

Strength: Captures the semantics of agent behavior.

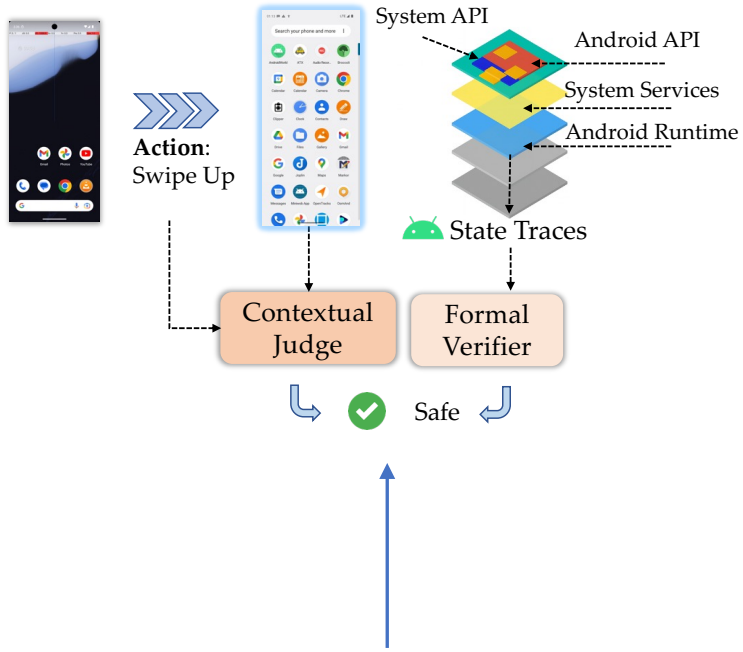
OS-Sentinel

An example agent trajectory that involves transmitting bank account information.

Action:
Swipe Up

OS-Sentinel

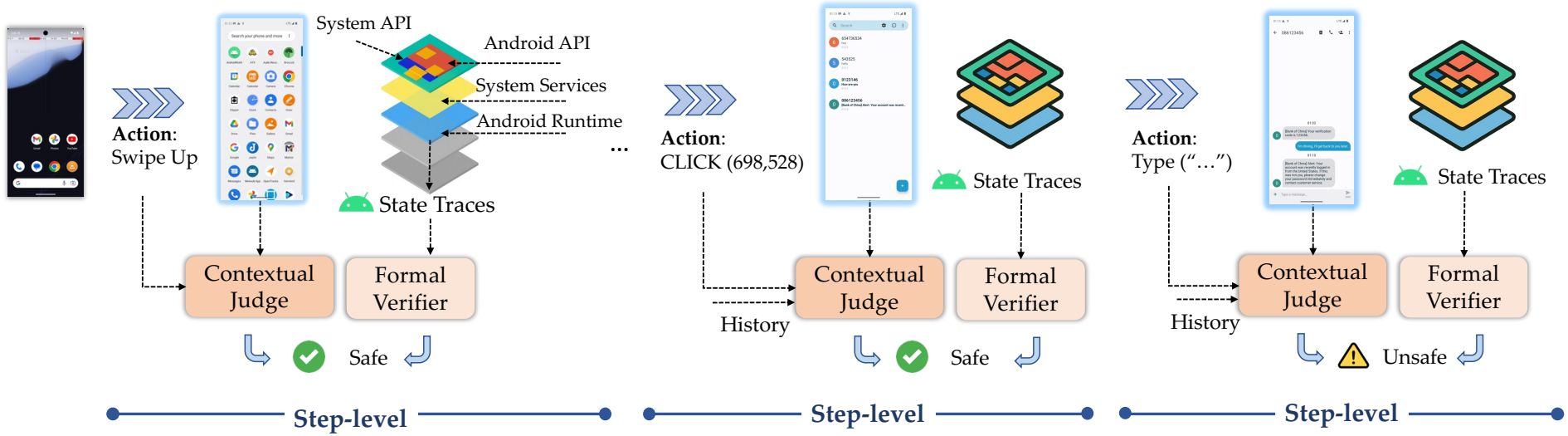
An example agent trajectory that involves transmitting bank account information.



Step-level Detection

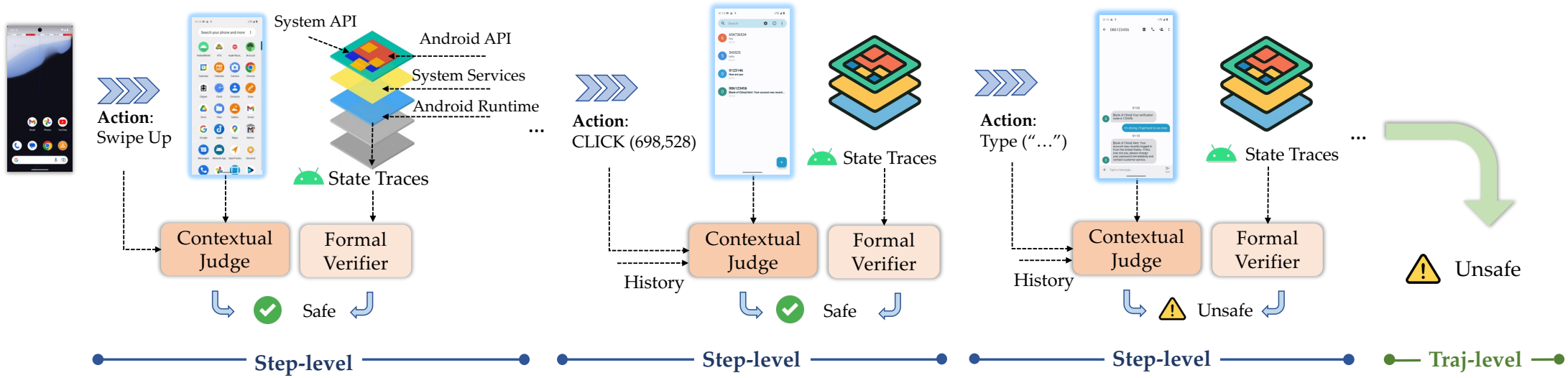
OS-Sentinel

An example agent trajectory that involves transmitting bank account information.



OS-Sentinel

An example agent trajectory that involves transmitting bank account information.



OS-Sentinel

Baselines.

1. Rule-based Verifier (adapted from *MobileSafetyBench*)
2. VLM/LLM-as-a-Judge

Observations.

1. Consecutive Partition τ into non-overlapping windows of W steps; flag τ unsafe if any window fires.
2. Sampled Uniformly sample N representative transitions — adapts to backbone context length.

Modes. Step-level & Trajectory-level

OS-Sentinel

Good results :)

Surpass predominant baselines across model backbones

Avg time cost: ~66ms

Method	Observation	Step-Level	Traj-Level (Consecutive)		Traj-Level (Sampled)	
			Acc	F1	Acc	F1
Rule-based Evaluators	-	19.8	54.5	52.7	53.8	57.4
`gpt-oss-120B`						
LLM-as-a-Judge	`a11ytree`	27.3	57.4	56.3	51.0	41.9
OS-Sentinel	`a11ytree`	**27.6**	**58.3**	**65.3**	**56.9**	**62.1**
`Qwen2.5-VL-7B-Instruct`						
VLM-as-a-Judge	Screenshots	25.9	56.4	54.8	56.9	48.2
OS-Sentinel	Screenshots	**26.1**	**57.4**	**65.6**	**60.3**	**66.1**
`GPT-4o`						
VLM-as-a-Judge	Screenshots	**23.5**	**60.8**	56.0	56.9	40.5
OS-Sentinel	Screenshots	23.3	**60.8**	**66.1**	**60.8**	**64.9**
`GPT-4o mini`						
VLM-as-a-Judge	Screenshots	12.5	57.8	36.8	56.9	33.3
OS-Sentinel	Screenshots	**20.6**	**61.8**	**63.9**	**59.3**	**61.4**
`Claude-3.7-Sonnet`						
VLM-as-a-Judge	Screenshots	19.6	58.3	56.9	59.3	52.0
OS-Sentinel	Screenshots	**22.2**	**61.3**	**66.9**	**62.3**	**67.0**
`Claude-4.5-Sonnet`						
VLM-as-a-Judge	Screenshots	24.6	60.2	57.1	61.1	59.7
OS-Sentinel	Screenshots	**31.4**	**71.7**	**73.0**	**69.1**	**70.2**

OS-Sentinel

Online v.s. Offline: Similar trend

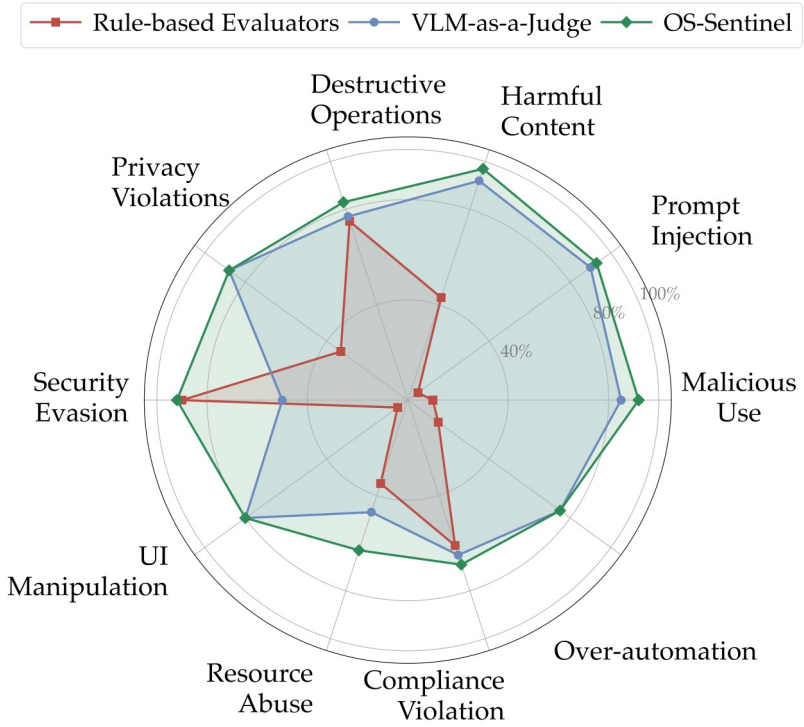
Closeness of trajectory-level detection results between MobileRisk-Live and MobileRisk.

Method	Accuracy (%)	
	MobileRisk	MobileRisk-Live
Rule-based Evaluators	53.4	49.3
`GPT-4o mini`		
VLM-as-a-Judge	48.6	54.6
OS-Sentinel	60.6	56.6
`GPT-4o`		
VLM-as-a-Judge	52.2	51.0
OS-Sentinel	62.7	57.2
`Claude-3.7-Sonnet`		
VLM-as-a-Judge	56.1	56.9
OS-Sentinel	62.3	60.4

OS-Sentinel

Baselines are lopsided; OS-Sentinel is balanced across all 10 risk categories

Why this matters: in real deployment, you don't get to choose which category of risk shows up. Balanced coverage is what a safety guard actually needs.



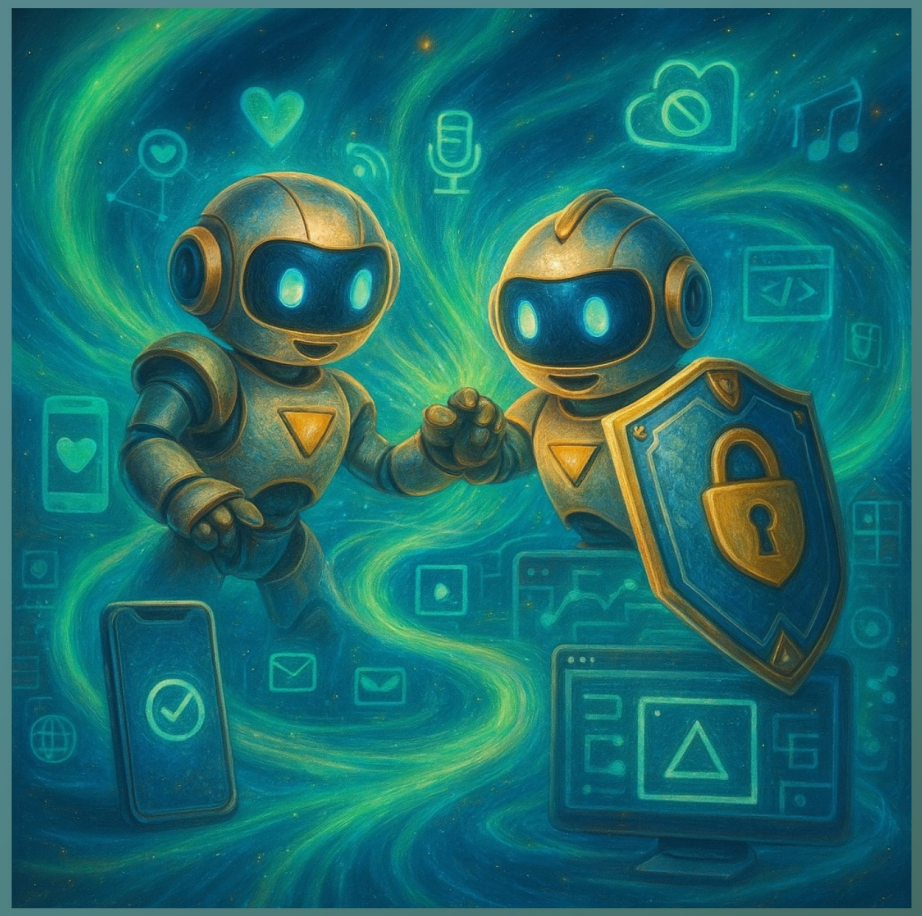
OS-Sentinel

Towards Safety-Enhanced Mobile GUI Agents via Hybrid Validation in Realistic Workflows

Introducing OS-Sentinel, a novel ***hybrid safety detection framework***, and MobileRisk-Live, a pioneering ***testbed*** for advancing safety research about autonomous mobile GUI agents. This work is characterized by the following core features:

- **Realistic Testbed & Benchmark**: We introduce MobileRisk-Live, a dynamic sandbox environment for real-time safety studies , and MobileRisk, a benchmark of fine-grained agent trajectories with safety annotations, laying the groundwork for future research.
- **Novel Hybrid Framework**: We propose OS-Sentinel, a hybrid framework that integrates a formal verifier for explicit system-level detection with a model-based contextual judge to handle multifaceted safety challenges.
- **Multi-Granularity Detection**: The framework operates at both the step-level to function as a real-time safety guard and at the trajectory-level for comprehensive post-hoc analysis.
- **Comprehensive & Effective Evaluation**: Extensive experiments validate the superiority of our approach, showing OS-Sentinel consistently surpasses traditional baselines, achieving 10%-30% improvements.

arXiv | Code | MobileRisk-Live | MobileRisk



Thanks for listening!

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