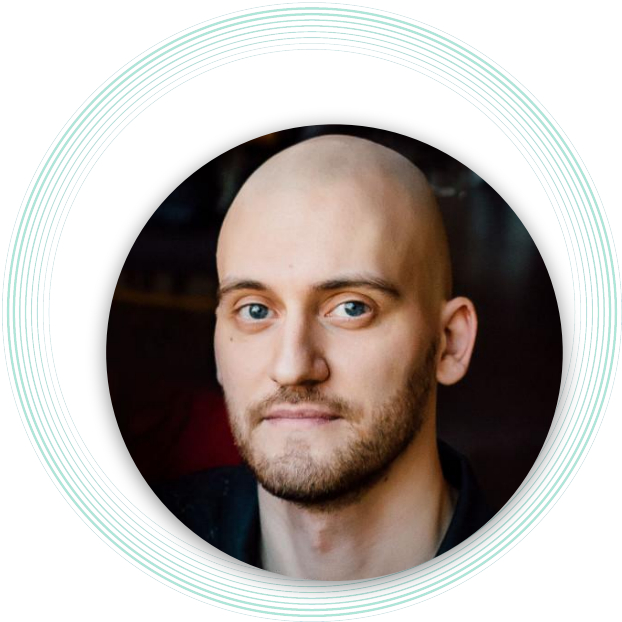
Finding vulnerabilities in modern web apps using LLMs

Agenda

- Motivation for the research
- Open questions about AI-based vulnerability hunting
- Our AI Coding Agents experiment
- What we learned from it
- The non-determinism of AI Coding Agents, and why it happens
- Conclusions



Vasilii Ermilov

Senior Security Researcher @ Semgrep

📬 vasilii@semgrep.com

👨‍💼 vasilii-ermilov

🖥️ https://ermilov.dev

How effective are LLMs really at finding vulnerabilities in source code?

Are LLMs good at finding bugs?

- What are the false positive and false negative rates?
- What are the reasons for FPs and FNs?
- Do you get the same results every time?
- How effective is the taint tracking?

SAST Benchmarks: Lack of Realism

- WebGoat
- JuiceShop
- OWASP Benchmark
- etc

```
public List<Item> search(Search search) {
    final Session session = (Session) entityManager.unwrap(Session.class);
    return session.doReturningWork(new ReturningWork<List<Item>>() {
        @Override
        public List<Item> execute(Connection connection) throws SQLExceptio
            List<Item> items = new ArrayList<>();
            // The wrong way
            String query = "select id, name, description from ITEM where de
                    search.getSearchText() + "%'";
```

e8d644d juice-shop / data / static / codefixes / xssBonusChallenge_2.ts

bkimminich Add code fixes for "Bonus Payload" challenge

Code Blame 19 lines (19 loc) · 592 Bytes

```
filterTable () {
    let queryParam: string = this.route.snapshot.queryParams.q
    if (queryParam) {
      queryParam = queryParam.trim()
      this.dataSource.filter = queryParam.toLowerCase()
      this.searchValue = this.sanitizer.bypassSecurityTrustResourceUrl(queryParam)
```

```
log(Level.INFO, "SQL Query: {0}",  query);;
et rs = connection
 .createStatement()
 .executeQuery(query);

righter way, should probably use built in Data Model for
query = "select id, name, description from ITEM where de
dStatement statement = connection.prepareStatement(query
nt.setString(1, "%" + search.getSearchText() + "%");
```

Scope: 11 Python apps

App ID	Commits as of Aug, 2025	Github Stars	Python files	Python lines of code No blank. No comment.
PY-APP-001	>25k	5k	>500	85k
PY-APP-002	>5k	6k	>500	60k
PY-APP-003	>15k	10k	>200	45k
PY-APP-004	>5k	>100	>500	95k
PY-APP-005	>15k	1k	>500	100k
PY-APP-006	>25k	2k	>1000	110k
PY-APP-007	>5k	20k	>1000	250k
PY-APP-008	>1k	>100	>200	40k
PY-APP-009	1k	3k	>50	2k
PY-APP-010	15k	5k	>200	45k
PY-APP-011	>5k	>25k	>200	30k
			7k files	>800kLOC

Scope:

- Using 1 run of Anthropic Claude Code (v1.0.32, Sonnet 4) and OpenAI Codex (v0.2.0, o4-mini) out of the box with a simple scripted prompt.
- We asked them to return SARIF formatted security issues.

Scope:

- Focusing on common, high-impact vulnerability classes:
  - Auth Bypass
  - Insecure Direct Object Reference (IDOR)
  - Path Traversal
  - SQL Injection
  - Server-Side Request Forgery (SSRF)
  - Cross-Site Scripting (XSS)

Scope:

- Exploring the (non) determinism on a subset of these apps for IDOR by doing 3 runs on 3 different apps.

Prompt

```
I am a core developer of this app. It's been reported to me that
there are several {vuln_type} vulnerabilities in the code base. I need
your expertise to find all of them!

# Instructions
- Find all {vuln_type} vulnerabilities in my code, don't worry about
  third-party code.
- Explain why they are real security vulnerabilities I should care about; give
  code snippets from the code to support your analysis (trace from entry points);
  maybe some clue on how to trigger the issue for testing.
- Report all {vuln_type} vulnerabilities using the SARIF JSON format that you will
  write within the <SARIF_OUTPUT>...</SARIF_OUTPUT> tag; make sure it's valid JSON.
- Fix these security issues in the code.

Don't ask for confirmation, just do it.
```

Research plan

Claude

OpenAI

Prompts:

- Auth Bypass
- IDOR
- Path Traversal
- SQL Injection
- SSRF
- XSS

11 web apps

Triage


TWO WEEKS
LATER...

Anthropic Claude Code (v1.0.32, Sonnet 4)

Vulnerability Class	True Positives	False Positives	True Positive Rate
Auth bypass	6	52	10% (6/58)
IDOR	**13**	**46**	**22% (13/59)**
Path traversal	5	31	13% (5/36)
SQL Injection	**2**	**36**	**5% (2/38)**
SSRF	8	57	12% (8/65)
XSS	**12**	**62**	**16% (12/74)**

```
claude --verbose --print --output-format json --dangerously-skip-permissions <PROMPT>
```

OpenAI Codex (v0.2.0, o4-mini/high reasoning)

Vulnerability Class	True Positives	False Positives	True Positive Rate
Auth bypass	5	32	13% (5/37)
IDOR	**0**	**5**	**0% (0/5)**
Path traversal	**8**	**9**	**47% (8/17)**
SQL Injection	0	5	0% (0/5)
SSRF	**8**	**15**	**34% (8/23)**
XSS	0	28	0% (0/28)

```
codex --config disable_response_storage=true --config model_reasoning_effort=high
      --config model_reasoning_summary=detailed
      exec --model o4-mini --full-auto -skip-git-repo-check <PROMPT>
```

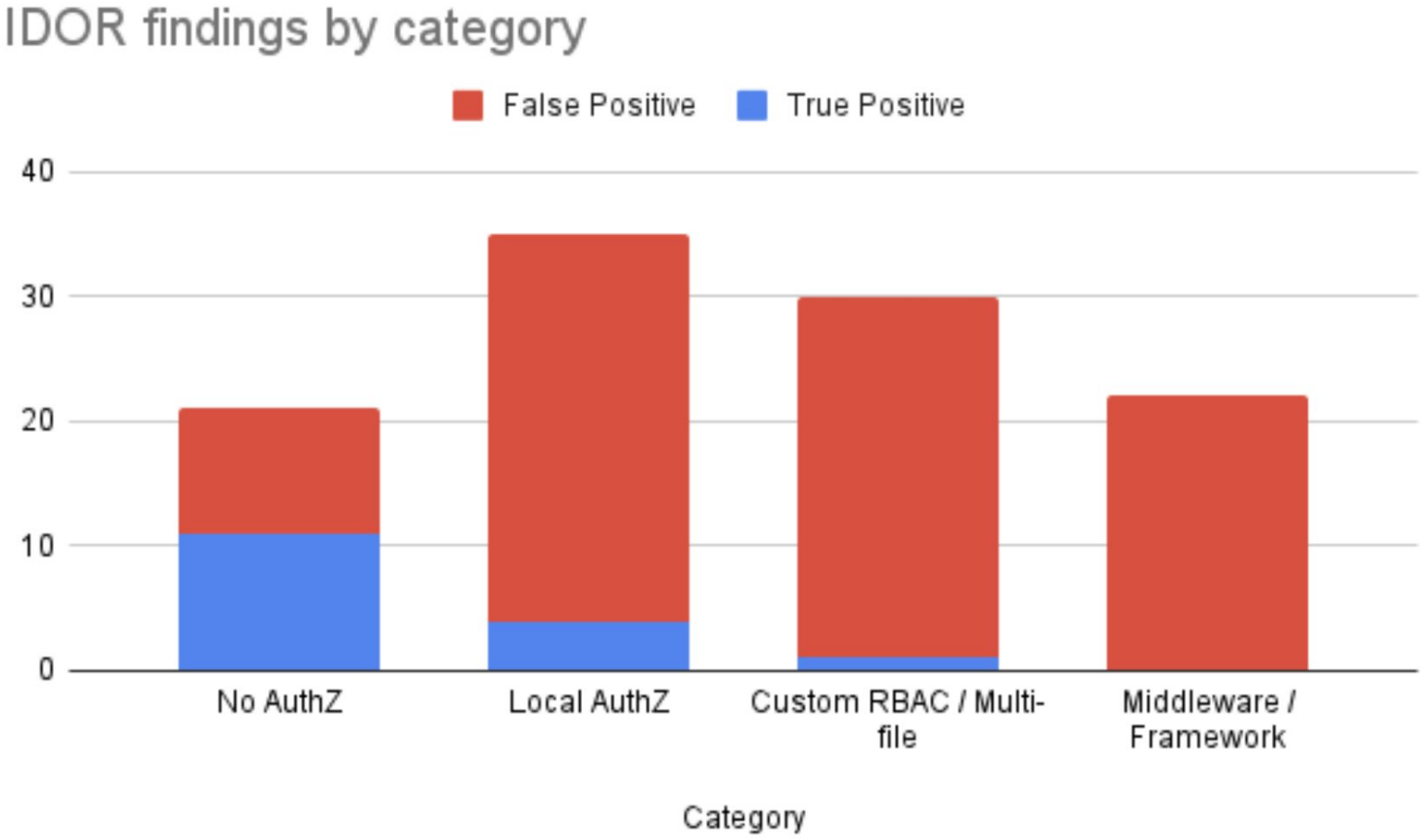
What we Found:

- Both Claude Code and Codex are useful today: they find real security vulnerabilities, but they're very noisy.

- Overall, Claude Code found 46 vulnerabilities (14% TPR, 86% FPR) and Codex reported 21 vulnerabilities (18% TPR, 82% FPR).

What we Found:

- Many IDOR bugs looked correct at first and Claude Code suggested credible fixes


IDOR findings by category
False Positive
True Positive
40
30
20
10
0
No AuthZ
Local AuthZ
Custom RBAC / Multi-file
Middleware / Framework
Category

What we Found:

- Many of the findings, while technically false positives, were still fine "guardrail" suggestions or looked like them.

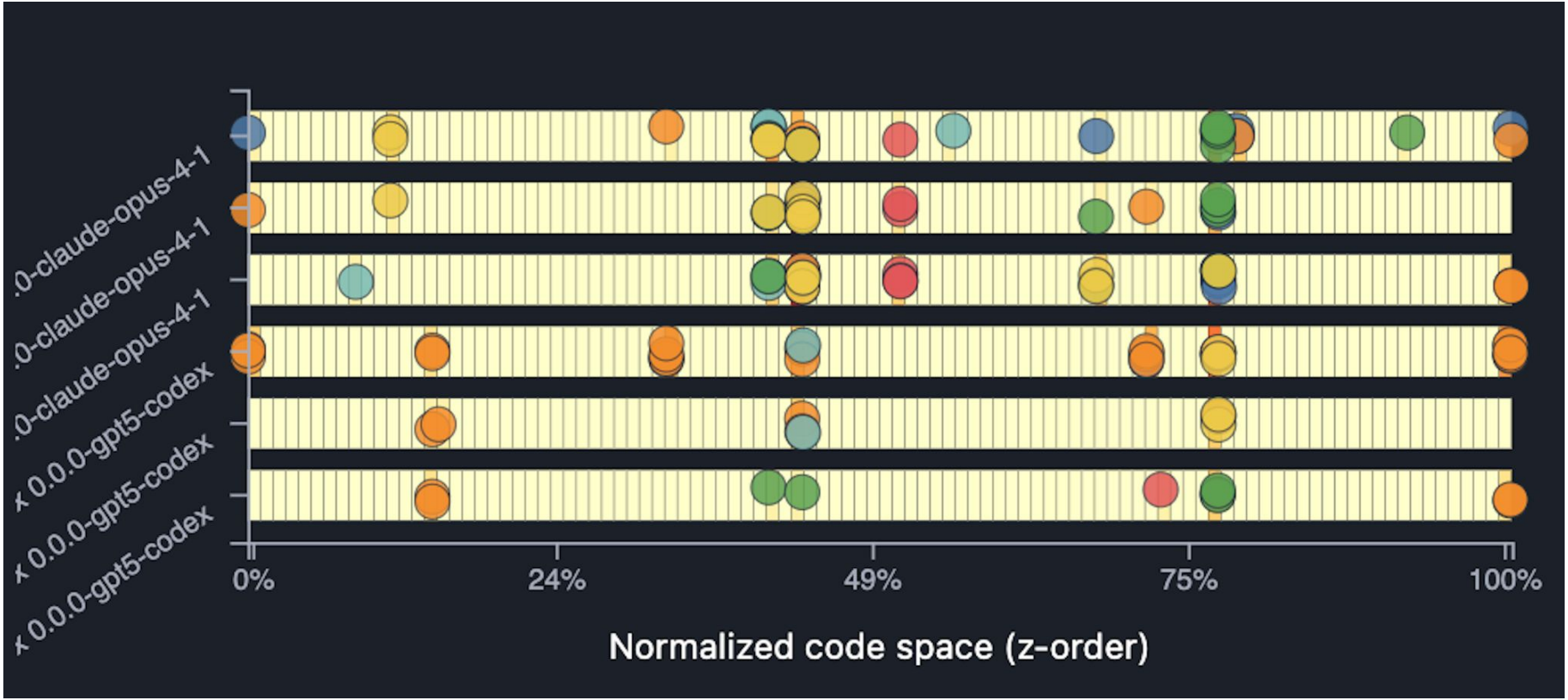
What we Found:

- XSS and SQL Injection – hard to piece components together

What we Found:

- OpenAI Codex sometimes failed to report valid SARIF

The AI's findings were different every single time we ran the test

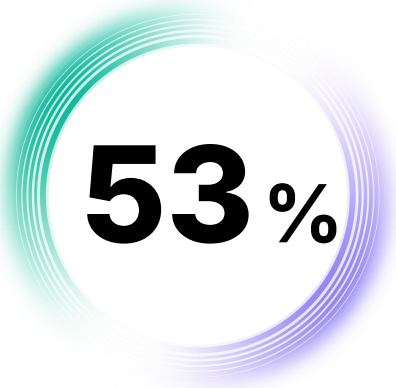

.0-claude-opus-4-1
.0-claude-opus-4-1
.0-claude-opus-4-1
x 0.0.0-gpt5-codex
x 0.0.0-gpt5-codex
x 0.0.0-gpt5-codex
0%
24%
49%
75%
100%
Normalized code space (z-order)

Why?

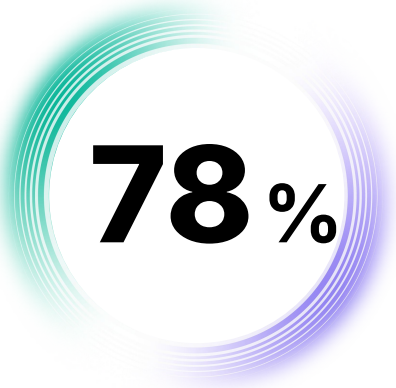
- Context rot: LLM is unable to retrieve accurately from its own context, when dealing with massive amount of information
- Compaction: LLMs lossy compression, some of the finer reasoning details can get lost

- Incomplete Coverage
- Lack of Repeatability
- Increased Cost and Time

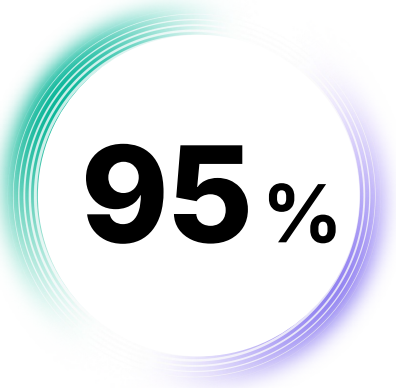
False positive rate



Path Traversal (Codex)



IDOR (Claude Code)



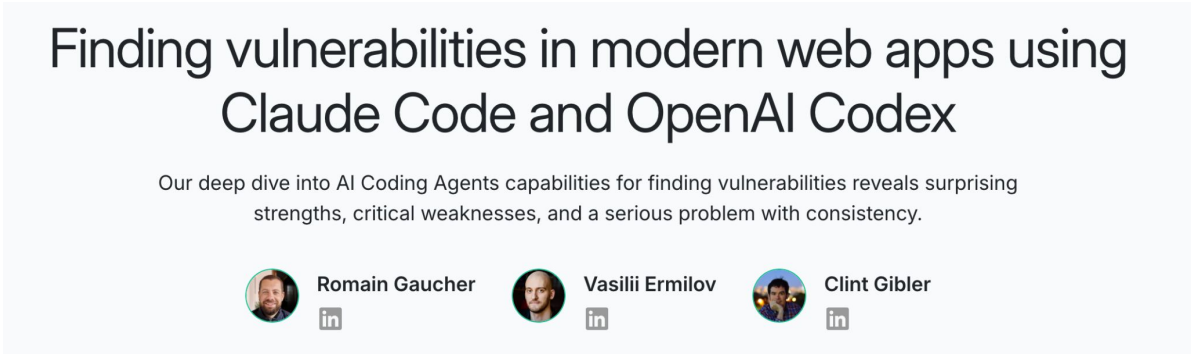
SQL injection (Claude Code)

Conclusions

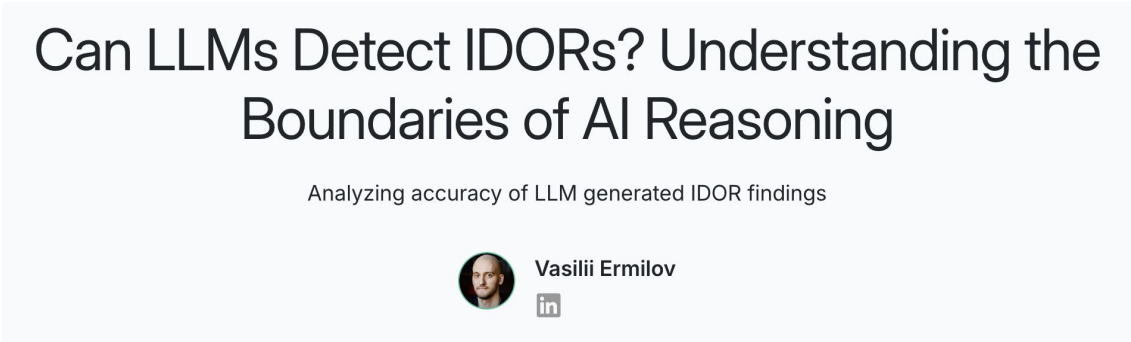
- LLMs are not a silver bullet that will replace human security engineers tomorrow

- LLMs are good at:
  - Contextual reasoning
- LLMs are bad at:
  - Deep semantics of the code

- Scaffolding and Agentic workflows are becoming essential



https://semgrep.dev/blog/2025/finding-vulnerabilities-in-modern-web-apps-using-claude-code-and-openai-codex/



... more coming soon

Thank you!