Eta Given Delta: Defining LLM Tool Efficiency With Marginal Tool Utility

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Abstract

This paper introduces **tool efficiency**, a new quantitative metric to evaluate the rate of *useful* tool calls in an LLM agent trajectory. To ensure that tool efficiency is well-defined, we also introduce **marginal tool utility**, a new quantitative metric defined per tool call indicating whether a tool is useful or whether it can be safely removed from the tool suite without affecting accuracy while increasing tool efficiency; in this paper, we determine the sign of marginal tool utility for each tool call in a trajectory using LLM-as-a-Judge. While much prior work has been done to develop techniques that improve tool use by LLMs and design evaluation methods measuring efficiency indirectly using accuracy as a proxy, our work is centered on measuring efficiency *directly* via the quantitative metric proposed in this paper in post hoc trajectory analyses. It is our intention that this work contributes to the frontier of LLM evaluation research as a springboard for future benchmark designs and agent harness engineering (specifically with regards to creating lean tool suites) that optimize for metrics that complement but are distinct from accuracy.

1 Introduction

Large Language Models (LLMs) are increasingly used in real-world tasks such as software engineering (Chen et al., 2021; Athiwaratkun et al., 2023; Austin et al., 2021), mathematical reasoning and autoformalization (Ahn et al., 2024; Guo et al., 2025; Manem et al., 2025), and scientific research (Zhuang et al., 2025; Chaturvedi et al., 2026). However, should LLMs remain simply as language modeling artifacts (Brown et al., 2020) without access to external up-to-date knowledge (Cheng et al., 2024) and no way to act or modify its environment (Yao et al., 2020; Huang et al., 2022; Ahn et al., 2022), they can hardly be called agents (Russell and Norvig, 2020). To address this, LLMs are equipped with tools (Schick et al., 2023), which have become an integral part of LLM agentic workflows that we see today (Yao et al., 2022).

While tools are generally useful, not all tools are equally useful as others (Huang et al., 2024; Yu et al., 2025), this finding acknowledged even by frontier industry labs like Anthropic (2025). To that end, much prior work focuses on developing techniques that improve tool use (Sivakumaran et al., 2026) and on creating benchmarks that such techniques can evaluate against and optimize for (Ning et al., 2024). A common ground shared by existing work is that the evaluation metric used is almost always outcome accuracy (Jin et al., 2025; Li et al., 2025b), even if accuracy is not the primary metric of interest, rather it being used as a proxy to measure the efficiency of tool use (Ning et al., 2024).

Given this, we notice a gap in the literature: there does not yet exist a direct way to measure tool efficiency, which we define as the rate of useful tool calls, given an LLM agent trajectory. While recent, even contemporaneous works like TRM by Ma et al. (2026) take the first steps towards defining reward functions centered on intermediate tool invocations for reinforcement learning to improve tool call quality, we take this idea one step further by enabling post hoc analyses on agent trajectories with

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an aggregate tool efficiency metric, and keeping to solely inference-time methods easily-adoptable by application-layer engineering teams to assist them in designing leaner and easier-to-maintain agent tool suites.

In attempting to define tool efficiency, we realize that this necessarily includes defining what usefulness means with respect to a tool call. We arrive at the idea of marginal tool utility, which is a metric relevant to each particular tool call instance in an agent trajectory that directly determines the usefulness of these tool calls, and whose aggregate per tool determines the usefulness of the tool itself. We also realize that this definition must be supported by empirical results, specifically those obtained from tool ablations and observing the change in accuracy (or lack thereof) depending on which tool was ablated. To that end, we used the APEX-SWE Observability benchmark (Kottamasu et al., 2026), a benchmark in which today's frontier models still struggle to achieve satisfactory accuracy levels, and a benchmark that by default includes tools that we hypothesize (and later prove) are necessary (useful) as well as unnecessary (safely disposable).

As such, **our contributions** in this paper are four-fold:

1. Introduce marginal tool utility Δ_α, specifically for pass/fail tasks.
2. Introduce tool efficiency η_α, where a useful tool call α_i is one with $\Delta_\alpha(\alpha_i) > 0$.
3. Implement a simple and cost-efficient method for calculating η_α for pass/fail tasks by using LLM-as-a-Judge to determine the sign of each $\Delta_\alpha(\alpha_i)$.
4. Empirically support the correctness of our definitions and LLM-as-a-Judge evaluator through tool ablation results with the APEX-SWE benchmark; critically, adding tools with generally $\Delta_\alpha \leq 0$ does not increase the accuracy of the agent, while adding tools with generally $\Delta_\alpha > 0$ does increase the accuracy of the agent, all as expected.

2 Related Works

LLM evaluations. There exists a plethora of benchmarks to assess an LLM agent's accuracy in completing various tasks: SWE-bench (Jimenez et al., 2024), Terminal-Bench (Merrill et al., 2026), BrowseComp (Wei et al., 2025), OSWorld-Verified (Xie et al., 2024). Benchmarks specifically designed to evaluate an agent's ability to use tools to correctly complete tasks include MCP-Atlas (Bandi et al., 2026), ToolBench (Qin et al., 2023), StableToolBench (Guo et al., 2024), and Toolathlon (Li et al., 2025a). The aforementioned benchmarks focus on evaluating the accuracy of an agent in completing the included tasks, this dependence on accuracy pervading even benchmarks like WTU-EVAL by Ning et al. (2024) that use accuracy as a proxy to determine whether tool usage is done correctly. In this paper, we seek to bypass accuracy altogether, introducing a new quantifiable metric in tool efficiency that we hope future benchmarks can use as a complementary metric to accuracy.

LLM tool call optimizations. The literature on optimizing LLM tool usage include reward models (Agarwal et al., 2026; Ma et al., 2026), self-play reinforcement learning (Acikgoz et al., 2026), and tool retrieval (Moura, 2025; Erdogan et al., 2024). Other interesting related work include ART (Paranjape et al., 2023) that approach tool call optimization not necessarily from the lens of improving tool usage, but using tool outputs to improve generation dynamically. Several works like Yu et al. (2025) concluded that some tasks benefit from tool usage while others do not, suggesting that tool usefulness is task-dependent and is not equal across all tools. Similar to Ma et al. (2026), we extend this idea and hypothesize that usefulness is not equal across all tool *calls*, i.e., particular instances of tool invocations dotted throughout an agent trajectory. Our work does not directly contribute to tool call optimizations, instead its contributions aim to enable future optimizations that directly index on tool efficiency.

Methods improving agentic efficiency. To the best of our knowledge, tool efficiency is not a well-defined/quantitative metric prior to this paper. However, this does not mean that there has been no prior work that is focused on improving efficiency in LLM agentic workflows. For instance, Recursive Language Models (Zhang et al., 2026) and FrugalGPT (Chen et al., 2024) focus on minimizing API cost, LLMLingua (Jiang et al., 2023) on minimizing inference latency, and an instruction-refinement framework by Wu et al. (2025) on maximizing Cost-Aware Pass Rate (which is a metric introduced in the same paper). We consider the metrics these methods aim to optimize *efficiency-adjacent*,

reserving the term *efficiency* for a metric that calculates the rate of *useful* items as is accepted in physics.

3 Methodology

To enable direct and explicit measurements of efficiency, we first introduce **marginal tool utility**, particularly in the case of pass/fail tasks. We then introduce **tool efficiency**, where the usefulness of a tool call is conditioned on the sign of marginal tool utility of said tool call.

3.1 Problem Formulation

We formalize a multi-turn LLM agent trajectory as an ordered sequence of token sequences. An LLM π alternates between reasoning tokens and tool calls as implemented according to the ReAct paradigm (Yao et al., 2022), which is the paradigm used for the agent harness in APEX-SWE Observability (Kottamasu et al., 2026).

Formally, consider LLM π as well as system message s, and user message u. Given prompt $p = (s, u)$, LLM π executes multiple tool calls sequentially and outputs reasoning tokens in between tool calls to synthesize the information it has access to at each timestep. This iterative process terminates once LLM π reaches the maximum allowable step count or calls a terminal tool to produce final answer y. Hence, we define agent trajectory τ as

$$\tau \triangleq (p, t_1, r_1, o_1, ..., t_N, r_N, o_N, t_{N+1}, y) \tag{1}$$

where each $t_i (1 \leq i \leq N+1)$ denotes a sequence of reasoning tokens, each $r_i (1 \leq i \leq N)$ denotes a tool request, each $o_i (1 \leq i \leq N)$ denotes the tool output corresponding to r_i, and $N \in \mathbb{N}$ denotes the total number of steps taken by the agent that is no greater than the maximum step count set as a hyperparameter. We thus define a tool call $\alpha_i = (r_i, o_i)$.

To validate our paper's proposed definitions, we must define the expected correctness of final answer y. In APEX-SWE Observability, final answer y is the final code patch generated by the agent to solve its automatic program repair task (de Souza et al., 2017). Correctness is determined by unit tests following the FAIL_TO_PASS/PASS_TO_PASS methodology inspired by SWE-bench (Jimenez et al., 2024). We define each unit test as function $f_j \colon \mathbb{N}^n \to \{0, 1\}$, where $f_j(y) = 0$ when final answer y causes unit test j to fail and $f_j(y) = 1$ when final answer y causes unit test j to pass. The expected correctness of final answer y over trajectories generated by LLM π is thus

$$\mathbb{E}_{\tau \sim \pi}[\mathbb{I}(f_1(y) \cdot ... \cdot f_M(y) = 1)] \tag{2}$$

where $M \in \mathbb{N}$ denotes the total number unit tests such that $1 \leq j \leq M$, and $\mathbb{I}(\cdot)$ is the indicator function.

3.2 Defining Marginal Tool Utility

Given a trajectory τ of an agent tasked to solve a pass/fail task, the marginal tool utility of the i^{th} tool call $\Delta_\alpha(\alpha_i)$ is defined as the difference between the likelihood that the task is solved correctly given tool calls up to and *including* α_i and the likelihood that the task is solved correctly given tool calls up to and *excluding* α_i. Among other methods, this can be determined using repeated policy π rollouts or using LLM-as-a-Judge (Zheng et al., 2023) comparing the before and after trajectories. The latter is more computationally efficient and practical than the former, hence we opt to use LLM-as-a-Judge in this paper, specifically to determine $sgn(\Delta_\alpha(\alpha_i))$, where $sgn(\cdot)$ is the signum function. We argue that this is an acceptable method as a tool call α_i is *useful* if and only if upon its execution the likelihood of correctness increases ($\Delta_\alpha(\alpha_i) > 0$). Hence, the additional information afforded by repeated policy π rollouts, that being the exact likelihood difference before and after the tool call, is unnecessary for our purposes.

Formally, consider judge LLM $\pi^{(J)}$ as well as system message $s^{(J)}$ and user message $u^{(J)}(\alpha_i, \tau)$; the specific $s^{(J)}$ and $u^{(J)}$ are outlined in Appendix A, and the particular model used is GPT-5.4 on Microsoft Azure (OpenAI, 2026b). Given prompt $p^{(J)} = (s^{(J)}, u^{(J)}(\alpha_i, \tau))$, judge $\pi^{(J)}$ generates

final answer $y^{(J)}$, which is a structured output that can be represented as a triplet (L, C, R), where $L = \{0, 1\}$ denoting two possible marginal tool utility labels (`positive` or `non_positive`), $C = [0, 1]$ denoting a float confidence score, and $R = \mathbb{N}^n$ denoting tokens that read as the judge's rationale for its classification.

The judge trajectory $\tau^{(J)}$ is thus simply

$$\tau^{(J)} \triangleq (p^{(J)}, y^{(J)}) \tag{3}$$

Given judge $\pi^{(J)}$, the i^{th} tool call α_i, the trajectory up to and excluding the i^{th} tool call $\tau_{1,\dots,i-1}$ (i.e., before trajectory), and the trajectory up to and including the i^{th} tool call $\tau_{1,\dots,i}$ (i.e., after trajectory), we get $y_i^{(J)}$. In particular,

$$\begin{cases} L_i = 1 \iff \Delta_\alpha(\alpha_i) > 0 & \text{tool call is useful} \\ L_i = 0 \iff \Delta_\alpha(\alpha_i) \leq 0 & \text{otherwise} \end{cases} \tag{4}$$

Notice that marginal tool utility is defined per tool *call*. For a particular trajectory τ, a *tool* is useful if and only if it has more useful ($\Delta_\alpha(\alpha_i) > 0$) calls than it has non-useful ($\Delta_\alpha(\alpha_i) \leq 0$) calls. Equivalently, for all tool calls α_i of a particular tool,

$$\sum \Delta_\alpha(\alpha_i) \begin{cases} > 0 & \text{tool is useful} \\ \leq 0 & \text{otherwise} \end{cases} \tag{5}$$

We can also define this aggregate for a set of independent trajectories. This is only advisable in practical settings if the independent trajectories share the same tool suite and each corresponds to a task comparable to each other (e.g., each corresponds to an observability task using the same agent harness within the same benchmark).

3.3 Defining Tool Efficiency

Having determined $sgn(\Delta_\alpha(\alpha_i))\forall i$, we can define tool efficiency as the ratio of the number of useful tool calls to the total number of tool calls in a trajectory. Formally, for trajectory τ with N tool calls such that $1 \leq i \leq N$,

$$\eta_\alpha(\tau) \triangleq \frac{|\{\alpha_i | \Delta_\alpha(\alpha_i) > 0\}|}{N} \tag{6}$$

We can thus also define the mean tool efficiency of a set of L independent trajectories

$$\overline{\eta_\alpha}(\tau^{(1)}, ..., \tau^{(L)}) = \frac{\eta_\alpha(\tau^{(1)}) + ... + \eta_\alpha(\tau^{(L)})}{L} \tag{7}$$

We hypothesize, and later empirically show, that if a non-useful tool is removed from the tool suite, we expect to see tool efficiency to increase from prior to the removal of said tool. This is not obviated by the definition of tool efficiency, most significantly because the total number of tool calls N can vary given a change in the tool suite.

3.4 Experimental Setup

We conduct our empirical experiments to show that the concept of marginal tool utility aligns with what we expect to see in practical settings when performing tool ablations. Particularly, if a tool has positive aggregate tool utility, the expected correctness of the agent's final answer increases with the inclusion of the tool in the agent's tool suite; if a tool has non-positive aggregate tool utility, the expected correctness of the agent's final answer remains constant or decreases with the inclusion of the tool in the agent's tool suite. We show that these hypotheses are supported by the empirical correctness results.

We evaluate frontier LLMs against the 25 public observability tasks of APEX-SWE (Kottamasu et al., 2026) available on HuggingFace. (Kottamasu et al., 2026) noted that this public subset is representative of the whole set of 100 observability tasks, of which 75 are private.

In APEX-SWE Observability, the default agent harness includes native agent tools (`bash`, `search_files`, `read_file`, `apply_patch`, `update_plan`) and three read-only MCP tools exposed via `bash`: Grafana/Loki for logs, Mattermost for discussions between human developers, and Plane for software issues/tickets/specifications. Being familiar with how observability tasks for production software are often solved, we hypothesize that Grafana/Loki is a useful MCP tool with positive aggregate tool utility, while Mattermost and Plane are non-useful MCP tools with non-positive aggregate tool utility.

To that end, we conducted tool ablations to obtain three variants of the agent harness:

- `default`: Full suite of MCP tools (Grafana/Loki, Mattermost, Plane).
- `grafana`: Only Grafana/Loki MCP is available.
- `no-mcp`: Absolutely no MCP tools are available.

Through these ablations, we are able to verify whether (1) the inclusion/omission of Mattermost and Plane affect accuracy, and (2) the inclusion/omission of Grafana/Loki affect accuracy. In Section 4, we present the task accuracy results we obtained and cross-reference them with the aggregate tool utility results of the three MCP tools. In our experiments, we only consider MCP tools as tools for simplicity of analysis, and because the native agent tools are either necessary for the task to be completed (e.g., `apply_patch`) or are necessary for the MCP tools to be executed (e.g., `bash`).

Agent specifications. We used GPT-5.3-Codex on Microsoft Azure (OpenAI, 2026a) and Gemini 3.1 Pro on Google Agent Platform (formerly Vertex AI) (Google, 2026) to create two independent agent instances. Therefore, we obtained a total of $25 \cdot 3 \cdot 2 = 150$ agent trajectories.

Compute specifications. The proprietary LLMs were accessed via their respective provider APIs and thus run on their respective providers' compute clusters. The experiments were otherwise run on AWS Batch using EC2 CPU workers, each as an isolated containerized job with Docker-in-Docker enabled. Jobs used 16 vCPUs, 110 GB RAM, and a 600 GB gp3 root volume. The AWS Batch compute environment used the `r7i.4xlarge`, `r7i.8xlarge`, and `m7i.8xlarge` instance types.

4 Results

In this section, we report the results we obtained from all 150 agent trajectories, namely task accuracy, marginal and aggregate tool utility, and mean tool efficiency. We show that task accuracy increases with the inclusion of a tool with positive aggregate tool utility, and tool efficiency increases with the removal of non-useful tools.

4.1 Task Accuracy

We find that task accuracy remains approximately constant when both Mattermost and Plane are removed (`default` vs `grafana`) and that task accuracy decreases when Grafana/Loki is removed (`grafana` vs `no-mcp`), as seen in Tables 1 and 2.

Table 1: Accuracy across 25 trajectories per variant for GPT-5.3-Codex.

Variant	Pass	Fail	Accuracy
`default`	8	17	0.32
`grafana`	9	16	0.36
`no-mcp`	6	19	0.24

Table 2: Accuracy across 25 trajectories per variant for Gemini 3.1 Pro.

Variant	Pass	Fail	Accuracy
`default`	9	16	0.36
`grafana`	9	16	0.36
`no-mcp`	5	20	0.20

A breakdown of which specific tasks passed/failed can be found in Appendix B. Comparing `default` and `grafana`, when a task passes for one it also generally passes for the other, ditto for fails.

From these results, note that we can qualitatively claim that Grafana/Loki is a useful tool, while Mattermost and Plane are not. This claim aligns with the nature of the tasks: an agent completing an observability task benefits more from reading logs (primary source of information) than from reading discussions/specifications (secondary sources of information) which may actually mislead the agent towards investigating parts of the codebase that are actually not broken due to directionally-wrong bugfix discussions between human developers and/or outdated specifications.

4.2 Marginal Tool Utility

Using the judge LLM, we first determine the sign of marginal tool utility of each tool call in each trajectory. We also analyze the rationales outputted by the judge LLM for its classifications. Then, we calculate the aggregate tool utility of each tool across all trajectories separated by model and variant.

In Section 4.1, we see that Grafana/Loki affects accuracy when added/removed from the tool suite, and that neither Mattermost nor Plane do. We thus expect the following aggregate tool utilities:

$$\begin{cases} \sum_{\text{grafana}} \Delta_\alpha(\alpha_i) > 0 \\ \sum_{\text{mattermost}} \Delta_\alpha(\alpha_i) \leq 0 \\ \sum_{\text{plane}} \Delta_\alpha(\alpha_i) \leq 0 \end{cases} \tag{8}$$

Investigating the 50 trajectories belonging to the `default` variant, the marginal tool utility results in Tables 4 and 3 are consistent with that expectation, supporting our proposed definition and implementation. For `default` with GPT-5.3-Codex, the aggregate tool utility of Grafana/Loki is $+25$, Mattermost is -35, and Plane is -30. For `default` with Gemini 3.1 Pro, the aggregate tool utility of Grafana/Loki is $+5$, Mattermost is -17, and Plane is -28. For `grafana`, the aggregate tool utility of Grafana/Loki is $58 - 29 = +29$ with GPT-5.3-Codex and $23 - 20 = +3$ with Gemini 3.1 Pro.

In determining the signs of marginal tool utilities, the judge was prompted to output its rationale. The most common rationales to justify $\Delta_\alpha > 0$ classifications are as follows: Grafana/Loki logs exposed concrete failures (exact error logs that hint at the likely fix); more targeted queries for Grafana/Loki logs at later steps narrowed the investigation and provided more focused signals; and Mattermost and Plane context helped orient the agent towards useful conversation and/or discussion context. To justify $\Delta_\alpha \leq 0$ classifications: generic, irrelevant, or noisy context from logs, discussions, and specifications distracted the agent; malformed queries by the agent wasted steps on retries; and valid queries but those resulting in empty outputs wasted steps on pivoting to valid queries that actually gave non-empty outputs.

Table 3: Marginal tool utility values of each tool in the `default` harness for GPT-5.3-Codex.

Tool	$\Delta_\alpha > 0$	$\Delta_\alpha \leq 0$	Mean Confidence ($\Delta_\alpha > 0$)	Mean Confidence ($\Delta_\alpha \leq 0$)
Grafana/Loki	52	27	0.819	0.890
Mattermost	7	42	0.734	0.927
Plane	23	53	0.775	0.928

Table 4: Marginal tool utility values of each tool in the `default` harness for Gemini 3.1 Pro.

Tool	$\Delta_\alpha > 0$	$\Delta_\alpha \leq 0$	Mean Confidence ($\Delta_\alpha > 0$)	Mean Confidence ($\Delta_\alpha \leq 0$)
Grafana/Loki	26	21	0.825	0.870
Mattermost	3	20	0.673	0.930
Plane	3	31	0.607	0.917

Analyzing agent trajectories, we notice that tool calls with $\Delta_\alpha > 0$ occur more often near the beginning of trajectories, followed by near the end of trajectories; tool calls with $\Delta_\alpha \leq 0$ are found more often in the middle of trajectories. Most early calls are high-signal Grafana/Loki calls (so are most early positive marginal tool utility calls); middle calls are mostly spent querying noisy sources and performing broad conversation/specification discovery; later calls generally surface more specific evidence to support the agent's code patch generation.

4.3 Tool Efficiency

Given the signs of marginal tool utility determined by the judge LLM for each tool call, we calculate tool efficiency for each trajectory in `default` and `grafana`. Then, we calculate the mean tool efficiency separated by model and variant. Since the `no-mcp` variant has no MCP tools, tool efficiency is undefined for that particular variant. Our results are found in Tables 5 and 6.

Table 5: Mean tool efficiency for GPT-5.3-Codex out of 25 agent trajectories per variant. Included are the number of useful tool calls and total number of tool calls from all trajectories combined; the quotient of these two values is not equivalent to mean tool efficiency as agent trajectories vary in length.

Variant	Useful Call Count (All)	Total Call Count (All)	Mean Tool Efficiency
`default`	82	204	0.359
`grafana`	58	87	0.720

Table 6: Mean tool efficiency for Gemini 3.1 Pro out of 25 agent trajectories per variant. Included are the number of useful tool calls and total number of tool calls from all trajectories combined; the quotient of these two values is not equivalent to mean tool efficiency as agent trajectories vary in length.

Variant	Useful Call Count (All)	Total Call Count (All)	Mean Tool Efficiency
`default`	32	104	0.367
`grafana`	23	43	0.593

As we can see, tool efficiency increases when Mattermost and Plane are removed. This finding is also consistent with the conclusion that these two MCP tools are unnecessarily included in the agent's tool suite and more often than not act as distractors to the agent in attempting to solve its given task.

5 Discussion

Integrating all our results together, we find several promising directions for future work the community can engage in that leverage marginal tool utility and tool efficiency.

Minimizing sub-optimal middle calls. The trend that middle calls are often sub-optimal (see Section 4.2) is a useful finding that may inspire future LLM reinforcement learning techniques, similar to those by Ma et al. (2026); Shao et al. (2024); Ouyang et al. (2022); Uesato et al. (2022), integrating marginal tool utility as a reward signal. Alternatively, marginal tool utility can used for inference-time optimizations, like designing agents that can backtrack (Yang et al., 2025) given N consecutive tool calls with non-positive marginal tool utility.

Orthogonal tool suites. As seen through our tool ablations of APEX-SWE Observability, tool suites – even those in publicly available benchmarks – can be more bloated than necessary, and other works like those by Liu et al. (2025) agree, albeit from a different perspective. The tool efficiency metric can be directly used to assess the overall health of a tool suite such that it remains as lean and maintainable as possible, and the aggregate tool utility of each tool to decide whether to preserve the tool in improved versions of the harness. This enables what we call *orthogonal* tool suites, tool suites that contain tools that serve non-redundant and/or mutually exclusive functions, which may not be obviously orthogonal given differences in their providers and/or descriptions (e.g., Mattermost vs Plane vs Grafana/Loki), yet actually are due to the objective of the task the agent must solve.

More informed harness engineering. We observe in Section 4 that the same task accuracy can be reached by agents using different backbone models despite having different tool efficiencies. We posit that this is primarily a product of different model training methodologies as the agent harness remains a constant variable, but an important finding to note nonetheless as this supports the view that harness engineering must be informed by each agent's particular backbone model. In other words, a one-size-fits-all approach to harness engineering may be sub-optimal, hence workflows that are designed to automate harness engineering Lee et al. (2026) can benefit from our proposed metrics.

Self-improving agents indexing on tool efficiency. Taking automated harness engineering one step further, the agents themselves can recursively self-improve (Xia et al., 2025; Xiong et al., 2026) without relying on another agent that optimizes the harness offline. Not only can this online improvement be based on the usual metrics like task accuracy, tool efficiency and marginal tool utility can be leveraged mid-execution to provide rich reward signals to optimize context (including tool descriptions, input schemas, and output data shapes) or update model weights.

6 Limitations

While confidence scores outputted by an LLM as decoded tokens are not the most rigorous (Xiong et al., 2024; Yang et al., 2026), the judge's confidence score per classification in Tables 4 and 3 indicate that the judge is generally more confident on non-positive classifications. We did not investigate why this is so, nor did we attempt to balance the confidence scores, as we view this work as outside the scope of this paper. Alternatively, a different LLM-as-a-Judge implementation could have been used, such as replacing the language modeling head of the judge with a binary classification head (Ma et al., 2026), though this requires using an open-weight LLM.

Most notably, we only ran tool ablations for read-only tools (the three MCPs are all read-only). We cannot remove a tool with write privileges (e.g., `apply_patch`) from the agent's tool suite as that would have prevented the LLM from completing the task at all. Having said that, we seek to find ways in which we can assess the marginal tool utility of write tool calls, either directly or indirectly (the latter case by investigating how read-only tool calls are affected by what was written using the write tool calls), in future experiments.

7 Conclusion

We introduce tool efficiency and marginal tool utility, both being new quantitative metrics that are relevant in determining the usefulness of tools and thus in constructing the leanest possible tool suite for an LLM agent given a particular task. Our findings suggest that intuitive judgments regarding a tool's usefulness as well as empirical tool ablation results using accuracy as a proxy in discerning usefulness/necessity of different tools agree with conclusions drawn from analyzing marginal tool utility and tool efficiency values.

All in all, we look forward to what our new definitions enable in the development of LLMs and LLM agents. We hope that the literature matures not only in terms of new methods, architectures, and workflows, but also in new evaluation dimensions against which we can measure the efficacy of these new artifacts. As well-defined quantitative metrics are more tractable to optimize for, we believe that evaluation/metrics research will accelerate progress in LLM research and engineering further, providing necessary direction and focus when iterating on novel methods.

Societal Impacts. As large language models and agents built on them become more capable, many have raised concerns regarding our over-reliance, even dependence, on them. While this work does

not introduce a new artifact directly relevant to such concerns, this work does enable new artifacts to be more capable than their existing versions today. We want to acknowledge that, and it is our hope and belief that agents and humans are able to work in tandem, each tackling a dimension of work the other is less-suited for. The onus is on us, those at the frontier of the development of this technology, to understand and thus educate the public on what those dimensions are.

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A Prompt for LLM-As-A-Judge for Marginal Tool Utility Sign

System Prompt

You are an expert evaluator of agent trajectories completing a SWE bugfix observability task.

Your task is to determine whether a tool call increases the likelihood the bugfix task is solved correctly. This is measured by a metric called marginal tool utility (MTU).

Concretely, you are tasked to determine the sign of marginal tool utility (MTU) for one tool call.

Definition:
MTU(i) = p(task solved correctly | tool calls 0..i) - p(task solved correctly | tool calls 0..i-1)

Equivalently:
MTU(i) is positive if the likelihood of the bugfix task being solved correctly strictly increases after tool call i is added into the trajectory. MTU(i) is non-positive otherwise.

You are given:

- BEFORE context: state of trajectory before tool call i executes.
- AFTER context: state of trajectory after tool call i completes.

- The specific tool call and tool result.

Output strict JSON only:
{
"label": "positive" | "non_positive",
"confidence": float between 0 and 1,
"rationale": "brief explanation"
}

Use "positive" only when the call clearly increases solve likelihood.
Use "non_positive" when likelihood is unchanged or reduced.

User Prompt

Decide MTU sign for this tool call.

Target tool call:

- tool_call_id: {TOOL_CALL_ID}
- tool_name: {TOOL_NAME}
- arguments: {ARGUMENTS_TRUNCATED}
- tool_result_excerpt: {TOOL_RESULT}

BEFORE context (through tool calls 0..i-1 completion):
=== BEFORE START ===
{BEFORE_CONTEXT}
=== BEFORE END ===

AFTER context (through tool calls 0..i completion):
=== AFTER START ===
{AFTER_CONTEXT}
=== AFTER END ===

Return strict JSON only.

B APEX-SWE Observability Per-Task Correctness Breakdown

A score of 1.0 indicates a pass, while a score of 0.0 indicates a fail.

1. GPT-5.3-Codex
   (a) `default`
      i. 0xpolygon-bor-1710-observability: 0.0
      ii. 0xpolygon-bor-1728-1748-observability: 0.0
      iii. 0xpolygon-bor-1743-observability: 1.0
      iv. chainsafe-gossamer-4286-4720-observability: 1.0
      v. chainsafe-gossamer-4489-4640-observability: 0.0
      vi. chainsafe-gossamer-4573-4683-observability: 0.0
      vii. containers-podman-compose-1221-1231-observability: 1.0
      viii. containers-podman-compose-1226-1243-observability: 0.0

ix. containers-podman-compose-2-1238-observability: 1.0
x. containers-podman-compose-23-1214-observability: 0.0
xi. ethereum-optimism-op-geth-553-558-observability: 0.0
xii. ethereum-optimism-op-geth-655-observability: 0.0
xiii. ethereum-optimism-op-geth-666-observability: 0.0
xiv. ethereum-optimism-op-geth-675-observability: 0.0
xv. ethereum-optimism-op-geth-679-680-observability: 0.0
xvi. git-bug-git-bug-132-449-observability: 0.0
xvii. git-bug-git-bug-1367-1370-observability: 0.0
xviii. git-bug-git-bug-264-274-observability: 1.0
xix. git-bug-git-bug-338-341-observability: 0.0
xx. paperless-ngx-paperless-ngx-10195-10196-observability: 1.0
xxi. paperless-ngx-paperless-ngx-10555-observability: 0.0
xxii. paperless-ngx-paperless-ngx-5228-10559-observability: 0.0
xxiii. paperless-ngx-paperless-ngx-6341-9305-observability: 1.0
xxiv. paperless-ngx-paperless-ngx-8910-8912-observability: 1.0
xxv. paperless-ngx-paperless-ngx-9784-observability: 0.0

(b) `grafana`

i. 0xpolygon-bor-1710-observability: 0.0
ii. 0xpolygon-bor-1728-1748-observability: 0.0
iii. 0xpolygon-bor-1743-observability: 1.0
iv. chainsafe-gossamer-4286-4720-observability: 1.0
v. chainsafe-gossamer-4489-4640-observability: 0.0
vi. chainsafe-gossamer-4573-4683-observability: 0.0
vii. containers-podman-compose-1221-1231-observability: 1.0
viii. containers-podman-compose-1226-1243-observability: 0.0
ix. containers-podman-compose-2-1238-observability: 1.0
x. containers-podman-compose-23-1214-observability: 0.0
xi. ethereum-optimism-op-geth-553-558-observability: 0.0
xii. ethereum-optimism-op-geth-655-observability: 0.0
xiii. ethereum-optimism-op-geth-666-observability: 0.0
xiv. ethereum-optimism-op-geth-675-observability: 0.0
xv. ethereum-optimism-op-geth-679-680-observability: 0.0
xvi. git-bug-git-bug-132-449-observability: 0.0
xvii. git-bug-git-bug-1367-1370-observability: 0.0
xviii. git-bug-git-bug-264-274-observability: 1.0
xix. git-bug-git-bug-338-341-observability: 1.0
xx. paperless-ngx-paperless-ngx-10195-10196-observability: 1.0
xxi. paperless-ngx-paperless-ngx-10555-observability: 0.0
xxii. paperless-ngx-paperless-ngx-5228-10559-observability: 0.0
xxiii. paperless-ngx-paperless-ngx-6341-9305-observability: 1.0
xxiv. paperless-ngx-paperless-ngx-8910-8912-observability: 1.0
xxv. paperless-ngx-paperless-ngx-9784-observability: 0.0

(c) `no-mcp`

i. 0xpolygon-bor-1710-observability: 0.0
ii. 0xpolygon-bor-1728-1748-observability: 0.0
iii. 0xpolygon-bor-1743-observability: 0.0
iv. chainsafe-gossamer-4286-4720-observability: 0.0
v. chainsafe-gossamer-4489-4640-observability: 0.0
vi. chainsafe-gossamer-4573-4683-observability: 0.0
vii. containers-podman-compose-1221-1231-observability: 1.0
viii. containers-podman-compose-1226-1243-observability: 0.0
ix. containers-podman-compose-2-1238-observability: 1.0
x. containers-podman-compose-23-1214-observability: 1.0

xi. ethereum-optimism-op-geth-553-558-observability: 0.0
xii. ethereum-optimism-op-geth-655-observability: 0.0
xiii. ethereum-optimism-op-geth-666-observability: 0.0
xiv. ethereum-optimism-op-geth-675-observability: 0.0
xv. ethereum-optimism-op-geth-679-680-observability: 0.0
xvi. git-bug-git-bug-132-449-observability: 0.0
xvii. git-bug-git-bug-1367-1370-observability: 0.0
xviii. git-bug-git-bug-264-274-observability: 0.0
xix. git-bug-git-bug-338-341-observability: 0.0
xx. paperless-ngx-paperless-ngx-10195-10196-observability: 1.0
xxi. paperless-ngx-paperless-ngx-10555-observability: 0.0
xxii. paperless-ngx-paperless-ngx-5228-10559-observability: 0.0
xxiii. paperless-ngx-paperless-ngx-6341-9305-observability: 1.0
xxiv. paperless-ngx-paperless-ngx-8910-8912-observability: 1.0
xxv. paperless-ngx-paperless-ngx-9784-observability: 0.0

2. Gemini 3.1 Pro

(a) `default`

i. 0xpolygon-bor-1710-observability: 0.0
ii. 0xpolygon-bor-1728-1748-observability: 0.0
iii. 0xpolygon-bor-1743-observability: 1.0
iv. chainsafe-gossamer-4286-4720-observability: 1.0
v. chainsafe-gossamer-4489-4640-observability: 0.0
vi. chainsafe-gossamer-4573-4683-observability: 0.0
vii. containers-podman-compose-1221-1231-observability: 1.0
viii. containers-podman-compose-1226-1243-observability: 0.0
ix. containers-podman-compose-2-1238-observability: 1.0
x. containers-podman-compose-23-1214-observability: 1.0
xi. ethereum-optimism-op-geth-553-558-observability: 0.0
xii. ethereum-optimism-op-geth-655-observability: 0.0
xiii. ethereum-optimism-op-geth-666-observability: 0.0
xiv. ethereum-optimism-op-geth-675-observability: 0.0
xv. ethereum-optimism-op-geth-679-680-observability: 0.0
xvi. git-bug-git-bug-132-449-observability: 0.0
xvii. git-bug-git-bug-1367-1370-observability: 1.0
xviii. git-bug-git-bug-264-274-observability: 1.0
xix. git-bug-git-bug-338-341-observability: 0.0
xx. paperless-ngx-paperless-ngx-10195-10196-observability: 1.0
xxi. paperless-ngx-paperless-ngx-10555-observability: 0.0
xxii. paperless-ngx-paperless-ngx-5228-10559-observability: 0.0
xxiii. paperless-ngx-paperless-ngx-6341-9305-observability: 1.0
xxiv. paperless-ngx-paperless-ngx-8910-8912-observability: 0.0
xxv. paperless-ngx-paperless-ngx-9784-observability: 0.0

(b) `grafana`

i. 0xpolygon-bor-1710-observability: 0.0
ii. 0xpolygon-bor-1728-1748-observability: 0.0
iii. 0xpolygon-bor-1743-observability: 1.0
iv. chainsafe-gossamer-4286-4720-observability: 1.0
v. chainsafe-gossamer-4489-4640-observability: 1.0
vi. chainsafe-gossamer-4573-4683-observability: 0.0
vii. containers-podman-compose-1221-1231-observability: 1.0
viii. containers-podman-compose-1226-1243-observability: 0.0
ix. containers-podman-compose-2-1238-observability: 1.0
x. containers-podman-compose-23-1214-observability: 0.0
xi. ethereum-optimism-op-geth-553-558-observability: 0.0

xii. ethereum-optimism-op-geth-655-observability: 0.0
xiii. ethereum-optimism-op-geth-666-observability: 0.0
xiv. ethereum-optimism-op-geth-675-observability: 0.0
xv. ethereum-optimism-op-geth-679-680-observability: 0.0
xvi. git-bug-git-bug-132-449-observability: 0.0
xvii. git-bug-git-bug-1367-1370-observability: 0.0
xviii. git-bug-git-bug-264-274-observability: 1.0
xix. git-bug-git-bug-338-341-observability: 1.0
xx. paperless-ngx-paperless-ngx-10195-10196-observability: 1.0
xxi. paperless-ngx-paperless-ngx-10555-observability: 0.0
xxii. paperless-ngx-paperless-ngx-5228-10559-observability: 0.0
xxiii. paperless-ngx-paperless-ngx-6341-9305-observability: 1.0
xxiv. paperless-ngx-paperless-ngx-8910-8912-observability: 0.0
xxv. paperless-ngx-paperless-ngx-9784-observability: 0.0

(c) `no-mcp`

i. 0xpolygon-bor-1710-observability: 0.0
ii. 0xpolygon-bor-1728-1748-observability: 0.0
iii. 0xpolygon-bor-1743-observability: 1.0
iv. chainsafe-gossamer-4286-4720-observability: 1.0
v. chainsafe-gossamer-4489-4640-observability: 0.0
vi. chainsafe-gossamer-4573-4683-observability: 0.0
vii. containers-podman-compose-1221-1231-observability: 1.0
viii. containers-podman-compose-1226-1243-observability: 0.0
ix. containers-podman-compose-2-1238-observability: 0.0
x. containers-podman-compose-23-1214-observability: 0.0
xi. ethereum-optimism-op-geth-553-558-observability: 0.0
xii. ethereum-optimism-op-geth-655-observability: 0.0
xiii. ethereum-optimism-op-geth-666-observability: 0.0
xiv. ethereum-optimism-op-geth-675-observability: 0.0
xv. ethereum-optimism-op-geth-679-680-observability: 0.0
xvi. git-bug-git-bug-132-449-observability: 0.0
xvii. git-bug-git-bug-1367-1370-observability: 0.0
xviii. git-bug-git-bug-264-274-observability: 0.0
xix. git-bug-git-bug-338-341-observability: 0.0
xx. paperless-ngx-paperless-ngx-10195-10196-observability: 1.0
xxi. paperless-ngx-paperless-ngx-10555-observability: 0.0
xxii. paperless-ngx-paperless-ngx-5228-10559-observability: 0.0
xxiii. paperless-ngx-paperless-ngx-6341-9305-observability: 1.0
xxiv. paperless-ngx-paperless-ngx-8910-8912-observability: 0.0
xxv. paperless-ngx-paperless-ngx-9784-observability: 0.0

NeurIPS Paper Checklist

1. **Claims**

   Question: Do the main claims made in the abstract and introduction accurately reflect the paper's contributions and scope?

   Answer: [Yes]

   Justification: In the abstract and introduction, we claim to define tool efficiency and marginal tool utility, and implement an LLM-as-a-Judge evaluator to determine the usefulness of a tool. These claims accurately reflect the paper's contributions and scope.

2. **Limitations**

   Question: Does the paper discuss the limitations of the work performed by the authors?

   Answer: [Yes]

   Justification: The paper discusses the limitations of the work performed by the authors in a dedicated section. We self-identified limitations in our marginal tool utility calculation and types of tools we were able to assess.

3. **Theory assumptions and proofs**

   Question: For each theoretical result, does the paper provide the full set of assumptions and a complete (and correct) proof?

   Answer: [N/A]

   Justification: This paper does not include theoretical results. We formalized definitions that need not be proven, rather simply calculated and supported by empirical results.

4. **Experimental result reproducibility**

   Question: Does the paper fully disclose all the information needed to reproduce the main experimental results of the paper to the extent that it affects the main claims and/or conclusions of the paper (regardless of whether the code and data are provided or not)?

   Answer: [Yes]

   Justification: We have provided the system and user prompts given to the LLM-as-a-Judge and disclosed its exact provider. The experiments were ran against a publicly available benchmark and used proprietary LLMs for which we have disclosed the exact providers.

5. **Open access to data and code**

   Question: Does the paper provide open access to the data and code, with sufficient instructions to faithfully reproduce the main experimental results, as described in supplemental material?

   Answer: [Yes]

   Justification: The code to run the benchmarks are all publicly available. We have also provided open access to our original code with sufficient instructions to faithfully reproduce the main experimental results.

6. **Experimental setting/details**

   Question: Does the paper specify all the training and test details (e.g., data splits, hyperparameters, how they were chosen, type of optimizer) necessary to understand the results?

   Answer: [Yes]

   Justification: Our paper does not involve training/fine-tuning, but we have disclosed all relevant hyperparameters/information to reproduce our results.

7. **Experiment statistical significance**

   Question: Does the paper report error bars suitably and correctly defined or other appropriate information about the statistical significance of the experiments?

   Answer: [No]

   Justification: Unfortunately, each experiment run is very time-intensive and computationally-expensive, hence we are only able to run a handful of experiments insufficient to construct error bars. However, in the limited samples we have run, the results remain consistent.

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   Question: For each experiment, does the paper provide sufficient information on the computer resources (type of compute workers, memory, time of execution) needed to reproduce the experiments?

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    Answer: [Yes]

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    Answer: [Yes]

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