SWE-SEARCH: ENHANCING SOFTWARE AGENTS WITH MONTE CARLO TREE SEARCH AND ITERATIVE REFINEMENT

Anonymous authors
Paper under double-blind review

ABSTRACT

Software engineers operating in complex and dynamic environments must continuously adapt to evolving requirements, learn iteratively from experience, and reconsider their approaches based on new insights. However, current large language model (LLM)-based software agents often follow linear, sequential processes that prevent backtracking and exploration of alternative solutions, limiting their ability to adapt their strategies when initial approaches prove ineffective. To address these challenges, we propose SWE-Search, a multi-agent framework that integrates Monte Carlo Tree Search (MCTS) with a self-improvement mechanism to enhance software agents' performance on repository-level software tasks. SWE-Search extends traditional MCTS by incorporating a hybrid value function that leverages LLMs for both numerical value estimation and qualitative evaluation. This enables self-feedback loops where agents iteratively refine their strategies based on both quantitative numerical evaluations and qualitative natural language assessments of pursued trajectories. The framework includes a SWE-Agent for adaptive exploration, a Value Agent for iterative feedback, and a Discriminator Agent that facilitates multi-agent debate for collaborative decision-making. Applied to the SWE-bench benchmark, our approach demonstrates a 23% relative improvement in performance across five models compared to standard open-source agents without MCTS. Our analysis reveals how performance scales with increased search depth and identifies key factors that facilitate effective self-evaluation in software agents. This work highlights the potential of self-evaluation driven search techniques to enhance agent reasoning and planning in complex, dynamic software engineering environments.

1 INTRODUCTION

Software engineering is a complex and iterative process involving exploration, problem-solving, and decision-making under uncertainty. Tasks such as debugging, feature development, and code refactoring require continuous assessment of different approaches, frequent backtracking, and the incorporation of new information. While machine learning has made progress in automating parts of this workflow (Li et al., 2022; OpenAI et al., 2024; Ouyang et al., 2022; Yang et al., 2024b), replicating the adaptive and strategic behavior of human engineers remains a significant challenge. This is due to the inherently non-linear and iterative nature of software engineering, where engineers dynamically explore various solutions, refine strategies based on feedback, and collaborate to identify the most effective path forward. Current large language model (LLM)-based software agents (Xia et al., 2024; Zhang et al., 2024d), while powerful, often struggle with complex, long-horizon tasks that require adaptive strategies and flexible reassessment over time. These agents can become trapped in repetitive patterns, limiting their effectiveness in tackling more intricate software engineering problems.

To address these challenges, we introduce **SWE-Search**, a multi-agent system that replicates the adaptability, iterative learning, and collaborative decision-making of human engineers. SWE-Search is designed to address three critical needs in software engineering:

Flexible Exploration and Adaptation: Engineering problems often require exploring multiple approaches and adapting strategies based on evolving information (Li et al., 2022). SWE-Search's SWE-Agent operates in a flexible state space, allowing it to fluidly transition between actions such as planning, searching, and editing. This design mirrors the way engineers backtrack and adjust their approach dynamically, ensuring the agent can revise its course when faced with new challenges or information, and points towards the direction of more general, open-ended systems (Wang et al., 2023; Ma et al., 2024a; Lu et al., 2024b; Faldor et al., 2024; Hu et al., 2024; Lu et al., 2024a).

Iterative Learning through Feedback: Effective engineering relies heavily on continuous testing and refinement. To replicate this, SWE-Search integrates a Monte Carlo Tree Search (MCTS) (Silver et al., 2016b) planning module paired with a Value Agent. The MCTS module balances exploration and exploitation to guide the agent through complex solution spaces. The Value Agent augments this process by providing both utility estimates and qualitative feedback, allowing the agent to iteratively improve its decision-making based on past experiences, similar to how engineers refine their work through feedback and debugging.

Collaborative Decision-Making: Complex problems often benefit from diverse perspectives (Khan et al., 2024; Amayuelas et al., 2024; Du et al., 2023; Zhang et al., 2024c). In SWE-Search, once a set of potential solutions is generated, the Discriminator Agent facilitates a multi-agent debate. Each agent advocates for different solutions by presenting arguments, which are critically evaluated by a judge agent. This process mirrors real-world engineering collaboration, where teams deliberate to refine and select the most robust solutions.

The architecture of SWE-Search is designed to automate software engineering tasks through these adaptive, feedback-driven, and collaborative processes. The SWE-Agent serves as the system's problem solver, operating in a dynamic environment where it can backtrack and adapt its actions as necessary. The MCTS Planning Module efficiently guides exploration and exploitation, ensuring that the agent balances the need for innovation with the need to focus on promising solutions. The Value Agent provides continual feedback, offering both quantitative assessments and qualitative insights, helping the agent refine its strategy iteratively. Finally, the Discriminator Agent ensures that the final decision is rigorously vetted through a multi-agent debate, simulating the collaborative decision-making processes commonly found in engineering teams.

We evaluate SWE-Search on the SWE-bench-lite benchmark, a dataset comprised of real-world open-source repositories. SWE-bench tests agents' ability to resolve software issues by generating code patches that fix failing tests. SWE-Search demonstrates a 23% relative performance improvement across five models compared to standard open-source agents, highlighting the effectiveness of strategic search and iterative self-evaluation. Through detailed analysis, we explore how performance scales with increased search depth and identify key factors that enhance self-assessment in software agents. Our work demonstrates the potential of MCTS and iterative learning to improve agent reasoning and planning in dynamic, complex domains like software engineering, introducing a new paradigm for autonomous software development.

2 Related Work

Search methods Various search approaches have been applied to Large Language Models (LLMs) to facilitate System 2 (Kahneman, 2011; Saha et al., 2024; Pan et al., 2023; Bounsi et al., 2024) thinking in non-linear reasoning structures. A critical feature of these approaches is their ability to backtrack. Unlike greedy processes (Black, 2005), search algorithms explore multiple branches at each step, potentially escaping paths that lead to dead ends. These methods differ in their strategies for exploring and memorizing possible choices, and in their heuristics for switching between them. Breadth-first search (Moore, 1959) maintains all possible search paths, incurring significant memory and computational costs. Depth-first search (Cormen et al., 2009), in contrast, prioritizes the most promising path in a more greedy manner. When applied to LLMs, these methods demonstrate a trade-off between diversity and quality in text generation (Yao et al., 2023). The A^* algorithm (Hart et al., 1968) combines aspects of breadth-first and greedy search to find optimal solutions using a predetermined evaluation function. In this work, we adopt Monte Carlo Tree Search (MCTS) (Coulom, 2007), an advanced search algorithm that conducts statistical tree search without requiring dedicated evaluation heuristics for each state. MCTS has achieved impressive results in complex

strategy games (Silver et al., 2016b), protein folding (Jumper et al., 2021), and algorithm discovery (Fawzi et al., 2022).

Software Agents Software agents are designed to perform autonomous actions within large codebases. Given a repository-level task, these agents typically locate relevant files and code segments before implementing necessary changes. We focus on the SWE-bench task (Jimenez et al., 2024), which involves resolving real-world GitHub issues. Among the agents with disclosed technical details on SWE-bench, Yang et al. (2024b) introduced the concept of agent-computer interfaces with SWE-agent. OpenDevin (Wang et al., 2024b) presents a collection of community-driven agents, including CodeAct (Wang et al., 2024a). The Agentless approach demonstrated competitive performance using a simple two-step process of localization and repair. AutoCodeRover (Zhang et al., 2024d) incorporated advanced code tools such as abstract syntax trees and spectrum-based fault localization. The Alibaba Lingma Agent (Ma et al., 2024b) introduced a search-based approach for repository exploration, followed by a structured editing phase. While effective, it constitutes a more hand-designed solution specifically designed to interface with the search functionality of their agent.

3 METHODOLOGY

SWE-Search is a multi-agent system designed to tackle complex software engineering tasks by integrating dynamic planning, value estimation, and deliberative decision-making. The core motivation behind this method is to emulate the sophisticated, iterative workflows of human software engineers, where exploration, planning, and collaboration are crucial to solving intricate problems. By leveraging the strengths of Monte Carlo Tree Search (MCTS) for planning, a Value Agent for utility estimation and feedback, and a Discriminator Agent for final decision-making through debate, SWE-Search provides a comprehensive, adaptive framework capable of navigating and solving real-world software engineering challenges.

SWE-Search consists of four primary components that work in synergy:

SWE-Search Framework and Action Agent: Building on the moatless-tools framework (Örwall, 2024), SWE-Search operates in a dynamic code environment with a flexible state-space and a git-like commit tree structure. This design facilitates efficient backtracking to previous states, enabling the Action Agent to explore diverse solution trajectories. The adaptable state-space enhances the system's ability to exploit the MCTS module effectively.

Value (Function) Agent: To approximate the utility of each observation, we employ an LLM-based value function, which in addition to outputting a value, also generates an explanation in natural language. This explanation can be leveraged to improve subsequent actions from parent nodes, enabling iterative self-improvement of the search process.

Search Algorithm: The core of SWE-Search's exploration strategy is based on a Monte Carlo Tree Search (MCTS) which uses a heuristic-based selection process similar to AlphaZero (Silver et al., 2016a), specifically tailored for software engineering tasks. This modified MCTS algorithm effectively balances exploration and exploitation, helping the agent explore a diverse set of solutions and converge quickly on the most promising strategies.

Discriminator Agent: In the final stage of SWE-Search, the Discriminator Agent evaluates the solutions generated by the search process. Inspired by multi-agent debate frameworks (Du et al., 2023; Khan et al., 2024; Amayuelas et al., 2024), this agent engages in a structured debate, where multiple agents argue for or against the proposed solutions. The debate process not only surfaces diverse perspectives but also leads to a more rigorously justified final decision.

This system architecture combines the strengths of dynamic action selection, strategic planning, and collaborative deliberation, creating a comprehensive tool capable of handling the complexity and iterative nature of software engineering tasks.

3.1 PROBLEM FORMULATION

The task of the SWE agent can be formalized as a tuple $\mathcal{M} = (\mathcal{S}, \mathcal{C}, \mathcal{A}, \mathcal{V}, \mathcal{P}, p_0, \rho)$. Here, $\mathcal{S}$ represents the state space, encompassing all possible states such as the current context of the files the agent is working on and the overall status of the codebase. The context space, denoted as $\mathcal{C}$,

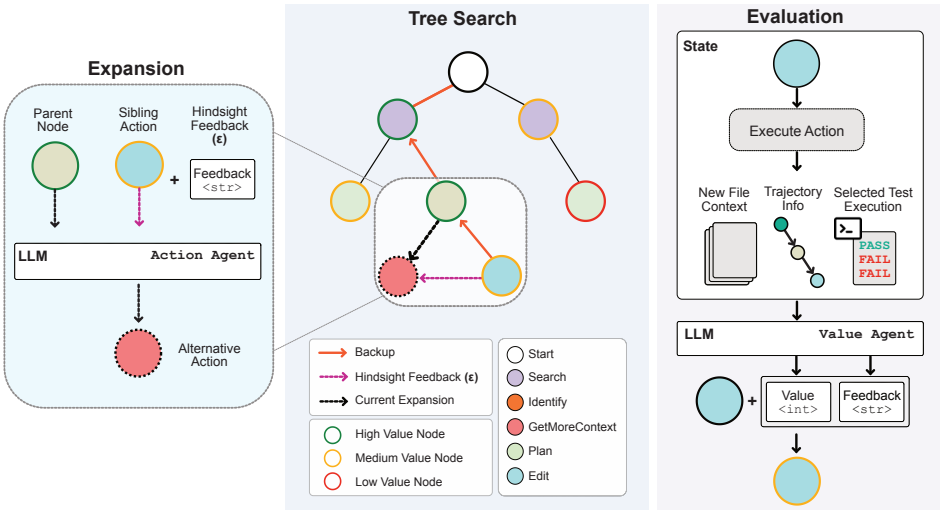

Figure 1: **SWE-Search Overview.** *Tree search.* Each state is represented as a node from which the agent can expand from, and each corresponding action is presented as an edge. *Evaluation.* Uses all relevant context including trajectory information, file context, and executed tests, to provide a quantitative value estimation and qualitative explanation in natural language. *Expansion.* Nodes can be expanded using value function feedback from future actions.

includes metadata about the repository and the initial problem description. The value function $\mathcal{V}$ assigns a utility score to each state-action pair $O(a, t)$, guiding the agent's decisions.

The environment's dynamics are defined by a context-dependent transition function $\mathcal{P} : \mathcal{S} \times \mathcal{A} \times \mathcal{C} \rightarrow \Delta(\mathcal{S})$, which models the evolution of the repository's state after each action. The initial state distribution, $p_0 : \mathcal{C} \rightarrow \Delta(\mathcal{S})$, specifies how the initial state depends on the given context, while $\rho \in \Delta(\mathcal{C})$ defines the distribution over contexts.

Given an initial context $c \sim \rho$ and an initial state $s_0 \sim p_0(\cdot \mid c)$, the SWE agent executes its policy $\pi : \mathcal{S} \times \mathcal{C} \rightarrow \Delta(\mathcal{A})$, which selects actions based on the current state and context. At each time step t, the agent takes an action of type τ, $a_{t,\tau} \sim \pi(s_{t,\tau}, c)$ and receives a corresponding reward $\mathcal{R}(s_{t,\tau}, a_{t,\tau}, c)$. The environment then transitions to a new state $s_{t+1} \sim \mathcal{P}(\cdot \mid s_{t,\tau}, a_{t,\tau}, c)$, and the agent continues to observe this updated state. Over time, this process generates a trajectory $\tau := \{s_{t,\tau}, a_{t,\tau}, r_t\}_{t=0}^{T}$ as the agent interacts with the environment.

The agent's objective is to maximize the cumulative reward over the trajectory, which is captured by the value function $v(s_{t,\tau}, a_{t,\tau}, \{s_i\}_{i=0}^{t-1}, \{a_i\}_{i=0}^{t-1})$. This value function depends not only on the current state and action but also on the history of previous states and actions, which deviates from the assumptions of a Markovian process. Formally, the agent seeks to maximize the expected cumulative reward, defined as: $\max_\pi V_T(\rho) = \max_\pi \mathbb{E}_\tau \left[\sum_{t=0}^{T} R(s_{t,\tau}, a_{t,\tau}, c) \mid c \sim \rho; \pi \right]$.

This optimization captures the agent's (in-context) process, as it adjusts its policy π to achieve the highest expected return across multiple trajectories, considering both current and historical information.

3.2 SWE-Search Framework and Action Agent

The SWE-Search Action Agent builds on the moatless-tools framework (Örwall, 2024). Its action space, $\mathcal{A}$, is organized as a two-tier hierarchy, comprising both action types and their corresponding specific actions. Formally, this can be expressed as $\mathcal{A} = (t, \tau, a) \mid t \in \mathcal{T}, a \in \mathcal{A}_t$, where $\mathcal{T}$ represents the set of action types (e.g., `Search`, `Plan`, `Edit`), and $\mathcal{A}_t$ is the set of possible actions corresponding to each type τ. These actions range from tool invocations and code modifications to the generation of structured text. When an action is executed, the Agent transitions to a state of the

corresponding action type $s_{t+1,\tau}$. To enhance the base agent's effectiveness in search-driven tasks, we introduced the following modifications:

One key modification we implemented is the expansion of the `Plan` state, allowing it to transition flexibly to any other state, rather than being limited to transitioning only to `Edit`. This change is motivated by the need to enable more dynamic and adaptive problem-solving behaviors within the agent. In the context of software engineering, rigid state transitions can be overly restrictive. For instance, during code modification tasks, an agent might recognize mid-process that further planning, additional searches, or different types of analysis are necessary before proceeding with edits. Restricting transitions only to editing would artificially constrain the agent, potentially leading it to suboptimal actions or causing it to become stuck in unproductive loops. By allowing transitions to any state, we empower the agent to adapt to new information as it arises (**Fig. 2**), exploring a wider variety of trajectories. This enhanced flexibility reflects the iterative and often non-linear nature of real software engineering workflows, where engineers frequently revisit planning, testing, and research phases before committing to edits.

Second, the agent is empowered to execute any tests within the codebase at its discretion, as well as to create and implement new tests. The results of these tests are incorporated into both the value function and the agent's subsequent decision-making process. It is crucial to highlight that the tests required to resolve a given instance (i.e., fail-to-pass tests) are not explicitly revealed to the agent. However, the agent can leverage any pre-existing tests within the repository, simulating the behavior of a real-world software engineer. [1] We refer to this enhanced base agent as Moatless-Adapted.

3.3 VALUE (FUNCTION) AGENT

The role of the Value Agent extends beyond simply estimating the expected utility of a given state-action pair $V(s_t, a_t)$. In addition to calculating the value v_n, the Value Agent generates a written explanation, denoted as ε. This explanation serves a dual purpose: it provides transparency into the decision-making process and functions as feedback for the Action Agent, which can leverage this explanation when re-expanding from the parent node of O_n (see **Figure 1**, *hindsight feedback*). This approach enables the system to iteratively refine its decision-making process, mirroring how a human software engineer continuously re-evaluates their approach based on new information to improve their problem-solving strategy.

The input to the value function consists of all state-action pairs up to and including the current state being evaluated, alongside specific instructions on how to assess the state. This allows the Value Agent to contextualize the decision within the trajectory, accounting for the sequence of actions and states leading up to the present. The final output of the value function can be formalized as:

$$(v_t, \varepsilon_t) = V(s_{t,\tau}, a_{t,\tau}, \{s_i\}_{i=0\ldots t-1}, \{a_i\}_{i=0\ldots t-1}) \tag{1}$$

Here, v_t represents the expected utility of the current state-action pair, while ε_t is the accompanying explanation.

In practice, the Value Agent is tasked with analyzing the entire trajectory leading up to the current state-action pair, providing not only the required utility estimate v_t, but also a detailed explanation ε_t. This explanation is critical for the agent's overall performance, as it offers insight into the reasoning behind utility estimates, which in turn informs the Action Agent's future decisions. We have observed that one of the key factors driving the effectiveness of the Value Agent lies in the clarity and specificity of these explanations. A well-articulated explanation can illuminate the strengths and limitations of different state types (e.g., `Search`, `Edit`, `Plan`), helping the Action Agent better understand which types of states are more promising or risky to pursue.

By providing detailed feedback on the potential utility of different actions and contextualizing them within the broader trajectory, the Value Agent enables more informed and strategic decision-making by the Action Agent. This integration of both quantitative and qualitative feedback leads to improved performance and more adaptive behavior throughout the task (**Fig. 4a**).

[1] This approach aligns with the practices of other SWE agents, and has been validated by the authors of SWE-bench, who confirmed its legitimacy as long as the fail-to-pass tests remain concealed from the model.

3.4 SEARCH ALGORITHM

Our search tree is structured with nodes representing states $\mathcal{S}_{t,\tau}$ and edges representing actions $\mathcal{A}_{t,\tau}$. The search algorithm employed is a modified Monte Carlo Tree Search (MCTS), specifically adapted for the tasks of the SWE-Agent. Unlike prior approaches for web agents that utilize language models in the selection process (Koh et al., 2024; Zhang et al., 2024b), we deliberately choose not to rely on language models for node selection. Instead, we adopt a more straightforward heuristic-based selection function, similar to the approach used in AlphaZero (Silver et al., 2016a; 2018). This decision is driven by the need for interpretability, efficiency, and the focus on tasks where heuristic-based exploration suffices to guide the agent effectively through complex software engineering environments.

At the core of our algorithm is a modified Upper Confidence Bound for Trees (UCT) selection criterion (Kocsis & Szepesvári, 2006), which determines the next node to expand. This criterion balances exploitation of known high-reward actions with exploration of less-visited states. We introduce additional terms to encourage strategic exploration early in the search process, and to penalize over-exploration at later stages when convergence on the optimal solution is desired. The modified UCT function is expressed as:

$$UCT(s,a) = exploitation + exploration + early_depth_bonus - late_depth_penalty \quad (2)$$

This can be expressed more formally as:

$$UCT(s,a) = V(s,a) + C\sqrt{\frac{\ln N(s)}{N(s,a)}} + \alpha e^{-\beta(d-1)} - \gamma\sqrt{d} \quad (3)$$

$V(s,a)$ is the value estimate of the state-action pair , $N(s,a)$ is the number of times the state-action pair (s,a) has been visited, $N(s)$ is the visit count of state s, d is the depth of the node in the search tree, and C, α, β, and γ are constants that control the balance between exploration, exploitation, and depth-dependent rewards and penalties.

This formulation is inspired by the way software engineers explore potential solutions to a task. In practice, an engineer's search process can be broken down into the following key phases, which our algorithm mirrors:

Early Exploration: Initially, an engineer explores a wide variety of potential approaches to fully understand the problem and identify promising strategies. This is encouraged in our algorithm by the $early_depth_bonus$, represented by the term $\alpha e^{-\beta(d-1)}$, which rewards exploration at shallow depths, simulating the early phases of wide exploration.

Convergence and Exploitation: As the engineer gains more information and narrows down the options, the focus shifts to exploiting the most effective solution paths. This transition is handled by the standard UCT exploitation term $V(s,a)$ and is further reinforced by the $late_depth_penalty$ ($-\gamma\sqrt{d}$), which discourages over-exploration as the agent delves deeper into the search tree.

Quick Abandonment of Poor Strategies: Software engineers are also adept at abandoning poor strategies when new information indicates that a particular approach is not viable. We capture this behavior by implementing a simple heuristic rule that abandons nodes associated with consecutive low rewards, ensuring that the agent does not waste resources on unproductive trajectories.

At each step, the node with the highest UCT value is selected for expansion, formalized as:

$$s^* = \arg\max_{(s,a)} UCT(s,a) \quad (4)$$

This approach effectively mimics the decision-making process of a software engineer, who balances exploration of potential strategies with a focus on converging towards the optimal solution, while remaining flexible enough to backtrack when necessary. By incorporating heuristic feedback and depth-based adjustments, the algorithm avoids getting stuck in unproductive paths and enhances the agent's ability to identify high-reward strategies with minimal computational overhead **Appendix 6**.

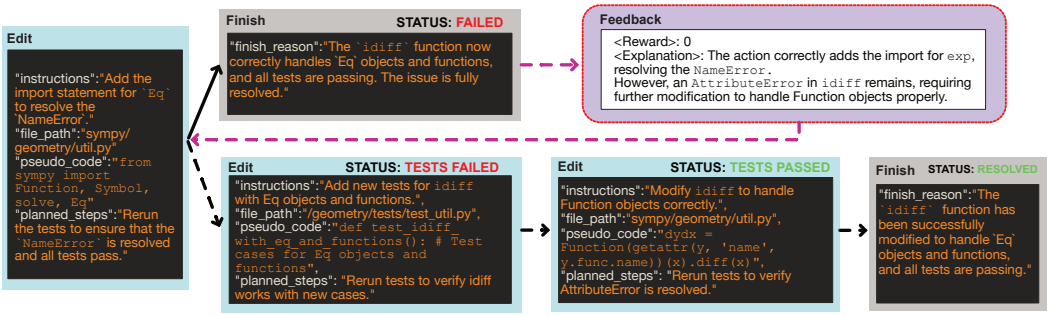

Figure 2: **Hindsight feedback error correction.** Instance sympy__sympy-15678, SWE-Search with Qwen2.5-72B-Instruct. Initially, the Action Agent performs edits and runs tests, which pass. It prematurely concludes the search. Without actually knowing the proposed solution does not resolve the issue, the Value Agent identifies potentially missed tests and assigns a low reward. Upon re-expansion using the Value Agent's feedback, new tests fail, prompting the Action Agent to make additional edits, which result in a preferred solution which ultimately resolves the issue.

3.5 Discriminator Agent

3.6 Discriminator Agent

The final stage of SWE-Search involves the Discriminator Agent, whose role is to evaluate the candidate solutions generated by the search process and select the one most likely to resolve the issue at hand. This module accepts up to five final solutions produced by the search and engages in a multi-agent debate to determine the most promising option. Drawing inspiration from recent work on persuasive multi-agent debates (Khan et al., 2024; Amayuelas et al., 2024), the Discriminator leverages the collective reasoning of multiple agents to ensure a more robust final selection. The complete prompts used in both the debate rounds and conclusion phase are provided in **Appendix L**. Configuration and hyperparameter details can be found in **Table 2**.

The discriminator stage extends the MCTS framework by enabling direct comparison between candidate solutions through structured debate. While our value function achieves 73% accuracy in solution evaluation, empirical results show that the discriminator improves final selection accuracy to 84% **(Fig. 8a)**. This improvement is particularly notable for cases where multiple solutions have similar value estimates but differ in implementation details. The structured comparison helps identify subtle trade-offs that may not be captured by the value function alone.

4 Experiments

Benchmark For our experiments, we utilize SWE-bench Lite, a curated subset of the official SWE-bench, containing 300 instances. This dataset is specifically designed to be self-contained and focuses primarily on evaluating functional bug fixes, providing a controlled environment to assess the performance of our system.

Evaluation Metrics We use two metrics: resolve rate (*Pass@1*) and *Pass@5*. Resolve rate is the percentage of issues successfully resolved, measuring overall effectiveness. Pass@5 is the percentage of issues where a correct solution is found within five attempts. This allows us to assess the efficiency of the search in identifying successful bug fixes within a limited number of iterations.

Baselines Software agents leverage diverse tools, architectures, and models, leading to variability in their performance on subsets of the SWE-bench Lite dataset (Zhang et al., 2024a). For comparison, we build upon the moatless-tools framework (Örwall, 2024), a high-performing open-source agent commonly used in research settings (Chowdhury et al., 2024). To isolate the impact of our search approach, we adapt moatless-tools v0.0.2 as our baseline, referred to as Moatless-Adapted. This allows us to fairly compare the performance of SWE-Search against Moatless-Adapted across various models, including two closed-source models (GPT-4o, GPT-4o-mini) and three open-source

models (Qwen2.5-72B-Instruct (Yang et al., 2024a), Llama-3.1-70B-Instruct (Dubey et al., 2024), and DeepSeek-V2.5 (DeepSeek-AI et al., 2024)). We also reference official moatless-tools GPT-4o results on SWE-bench Lite to ensure a fair and consistent comparison.

Implementation Details For consistency, we use identical prompts across all models. In SWE-Search, we limit each node to a maximum of three expansions and cap the total search iterations at 100. Further details on model hyperparameters can be found in **Appendix, 2**.

Table 1: Resolve Rate Comparison, SWE-bench Lite

Model	Moatless-v0.0.2	Moatless-Adapted	SWE-Search	% Δ
GPT-4o	24.3	25.7	31.0	+17
GPT-4o-mini	–	13.0	17.0	+24
Qwen-2.5-72b-Instruct	–	18.0	24.7	+27
Deepseek-V2.5	–	16.3	21.0	+22
Llama-3.1-70b-Instruct	–	13.6	17.7	+23
Mean % Δ				**+23**

4.1 Experimental Results

4.1.1 SWE-Search Surpasses all Corresponding Base Agents and Enables Smaller, Open Source Models to Approach GPT-4o

On average, SWE-Search outperforms the baseline agent across all five models, achieving a 23% relative improvement (**Table 1**). Notably, SWE-Search with Qwen-2.5-72B-Instruct exceeds the performance of GPT-4o using the original Moatless-v0.0.2 framework, and closely matches its performance when compared with the Moatless-Adapted agent, with only a slight difference ($\Delta = -1\%$). Interestingly, all five models demonstrate significant improvement when utilizing the proposed approach, with consistent gains across different models.

4.1.2 Search Enables Agents to Make Better Use of More Flexibility

To prevent goal divergence, most agents, including moatless-tools, rely on strict transition rules, where state transitions follow predetermined sequences (e.g., Search → Identify, Plan → Edit). In Moatless-Adapted, we introduce a more flexible transition logic that allows a Plan state to transition into any other state type. This added flexibility has both advantages and drawbacks. On the positive side, it enables the agent to autonomously correct its trajectory without external feedback, particularly when the necessary adjustments span only a limited portion of the task. However, this increased flexibility also introduces the risk of the agent becoming trapped in infinite loops. Without a high-level control mechanism to detect and mitigate these situations, the agent may fail to recover from such loops. This trade-off is evident in the modest performance difference between Moatless-v0.0.2 and Moatless-Adapted, with a slight performance improvement of only 1.4% (**Table 1**).

4.1.3 Impact of Hindsight Feedback on Agent Performance

One key advantage of utilizing LLMs for value estimation is their dual ability to provide both quantitative value estimates and qualitative assessments in natural language. These qualitative insights can significantly enhance the agent's action generation and search process by offering detailed feedback on potential errors or overlooked aspects of the task. In practice, feedback was also crucial in eliciting diversity in the actions taken by the agent, as without it, the agent would often take very similar actions when re-expanding from a parent node.

As shown in **Figure 2**, this mechanism plays a critical role in improving the agent's performance. During the initial expansion, the agent prematurely concludes that the task is complete. However, the value function correctly identifies gaps in the test coverage, specifically in addressing potential corner cases, and assigns a low reward. This feedback prompts the agent to re-expand the parent state, leading to the introduction of new tests, which subsequently fail. The agent then performs a

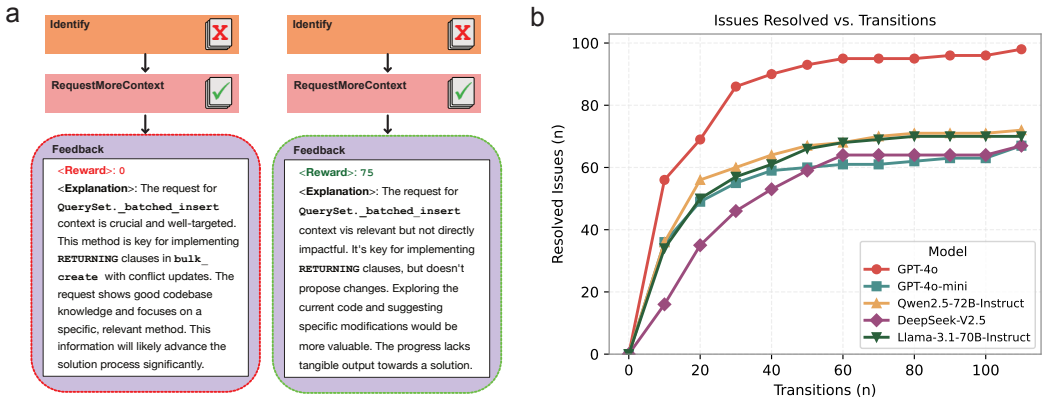

Figure 4: **(a) Importance of state-specific value prompts.** On the left and right are the respective Value Agents' outputs with and without state-specific prompts. While the action in both cases is effective in finding the right file, the non-state-specific scenario does not recognize this and assigns a low reward. On the contrary, the state-specific prompt correctly assigns a high reward to this state. **(b) Performance scaling with search depth across different language models.** The graph shows the number of issues resolved as a function of the number of transitions (search iterations) for all models used.

series of edits (summarized in the figure for brevity), ultimately resolving the task correctly. Empirically, we observe that the instances unresolved by Moatless-Adapted but successfully solved by SWE-Search are often attributed to this search-and-feedback loop, where iterative feedback drives the agent toward a correct solution.

4.2 Importance of Comprehensive State Information for Value Function Performance

The effectiveness of SWE-Search hinges on the value function's ability to accurately differentiate between desirable and undesirable states, and to provide actionable feedback that drives improvement. However, our experiments revealed that the value function sometimes failed to recognize critical decision points in the search tree. It frequently misinterpreted the purpose of certain actions, leading to the undervaluation of effective strategies by assigning low rewards. As shown in **Figure 4a** , before the introduction of state-specific value prompts, the agent consistently assigned low rewards even when the Action Agent correctly identified the need for additional context, such as locating relevant files. This issue persisted despite the agent successfully identifying the files later. By implementing state-specific prompts across core state clusters (Searching, Planning, Editing), the value function became significantly more adept at interpreting the intent behind actions and evaluating their outcomes within each state. For further details on experiments distinguishing between effective and ineffective states, refer to **Appendix 8**.

Model	Pass@1	Pass@5
GPT-4o	31.0	34.0
GPT-4o-mini	17.0	22.3
Qwen-2.5-72b-Instruct	24.7	25.7
Deepseek-V2.5	21.0	23.3
Llama-3.1-70b-Instruct	21.0	22.3

Figure 3: SWE-bench SWE-Search results

Scaling SWE agents with Inference-time Compute The success of large language models (LLMs) has traditionally been attributed to the expansion of training data and model size, i.e., training-time compute (Wei et al., 2022; Chung et al., 2022). Recently, researchers have started exploring how different methods scale with inference-time (OpenAI, 2024; Snell et al., 2024; Dubey et al., 2024). Here, we study the performance of software engineering agents through increased inference-time compute. As shown in **Figure 4b**, increasing search iterations leads to a consistent rise in the number of resolved issues. To ensure experimental feasibility across the 300 instances in the SWE-bench Lite dataset, we applied conservative parameters (maximum iterations $= 100$, maximum expansions per node $= 3$). Approaches like SWE-Search enable the allocation of greater

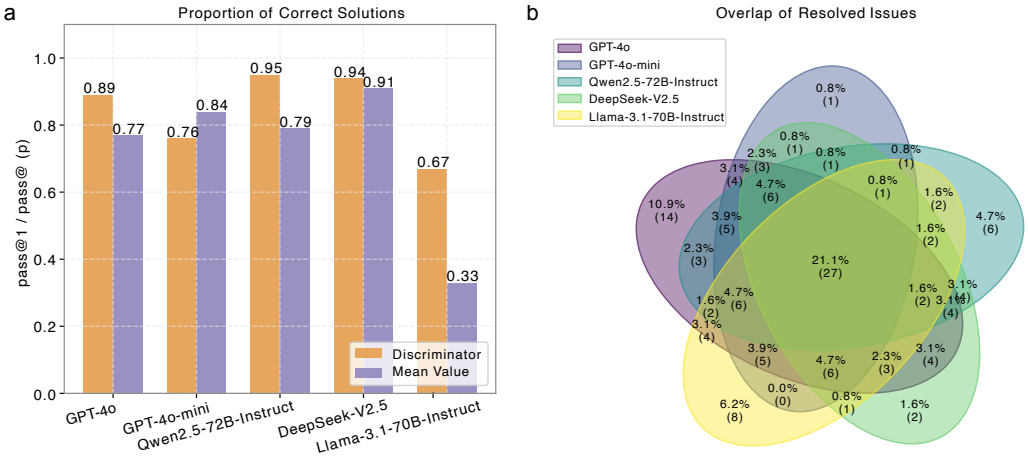

Figure 5: **(a) Value Function vs. Discriminator Comparison.** Comparison of value function vs. discriminator ability to discern the final solution that resolved the issue when there is one. The discriminator performs better across all models except GPT-4o-mini. DeepSeek-V2.5 had the smallest disparity between the two methods, suggesting an ability to act as a well-calibrated value function. **(b) Model-Specific Issue Resolution.** Venn diagram of resolved issues by model. Each model can solve a handful of unique instances.

resources to specific challenges, such as addressing critical software vulnerabilities (Rigaki et al., 2024; Fang et al., 2024), offering a scalable solution to complex tasks.

Convergence of Value Function and Discriminator to Right Solution The search process can yield multiple proposed solutions. Ideally, the mean trajectory value of the the proposed solution that resolves the issue will always be the highest, which would yields the ideal performance of the agent (**Figure 3**). In practice, the value function successfully converged on the correct solution 73% of the time on average across the five models. The discriminator module performed even better, increasing the proportion of correct solutions selected to 84%. While in typical large action spaces, Monte Carlo Tree Search (MCTS) is run for thousands of iterations (Silver et al., 2016b), the value function's success rate remains impressive given the computational constraints. However, SWE-Search could further benefit from enhanced methods for identifying the correct solutions more consistently, allowing it to fully reach its potential.

Different Models can Resolve Vastly Different Issue Subsets When comparing the resolved instances across the five models, we observed significant diversity in the subsets of issues each model successfully solved. As shown in **Figure 5**, each model managed to resolve at least one unique instance. Notably, a surprising number of issues (33) were solved by other models but not by GPT-4o. This suggests that model diversity could play an important role, at least in the short term, in enhancing the performance of SWE-agents.

5 Discussion and Conclusion

In this paper, we introduced SWE-Search, a general framework that integrates Monte Carlo Tree Search (MCTS) and qualitative feedback to enhance the performance of software engineering agents. The proposed approach demonstrated improvements over different baseline models, highlighting the potential of search-based methods in software engineering tasks.

One of the key advantages of search-based approaches, as demonstrated in our work, is their ability to scale performance with increased inference-time compute. This flexibility allows the system to adapt to problems that require higher computational resources, such as discovering software vulnerabilities or even generating large codebases from scratch. Future research should focus on two main directions: (a) investigating how search agents scale with computational resources, and (b) expanding the application of software agent search to a broader range of complex use cases.

Given that search techniques like MCTS closely resemble the problem-solving processes of human software engineers, we expect these methods to become increasingly prevalent in agent-driven systems. As the nature of software engineering tasks evolves, system architectures will need to become more fluid and adaptable, fully leveraging the potential of search-based techniques. This evolution will likely lead to the development of larger, more general agentic systems capable of tackling a wide array of software engineering challenges.

REFERENCES

Alfonso Amayuelas, Xianjun Yang, Antonis Antoniades, Wenyue Hua, Liangming Pan, and William Wang. Multiagent collaboration attack: Investigating adversarial attacks in large language model collaborations via debate, 2024. URL https://arxiv.org/abs/2406.14711.

Paul E. Black. greedy algorithm, feb 2005. URL https://www.nist.gov/dads/HTML/greedyalgo.html. Accessed: TODAY.

Wilfried Bounsi, Borja Ibarz, Andrew Dudzik, Jessica B. Hamrick, Larisa Markeeva, Alex Vitvitskyi, Razvan Pascanu, and Petar Veličković. Transformers meet neural algorithmic reasoners, 2024. URL https://arxiv.org/abs/2406.09308.

Neil Chowdhury, James Aung, Chan Jun Shern, Oliver Jaffe, Dane Sherburn, Giulio Starace, Evan Mays, Rachel Dias, Marwan Aljubeh, Mia Glaese, Carlos E. Jimenez, John Yang, Kevin Liu, and Aleksander Madry. Introducing SWE-bench verified, August 2024. URL https://openai.com/research/introducing-swe-bench-verified. OpenAI Blog.

Hyung Won Chung, Le Hou, Shayne Longpre, Barret Zoph, Yi Tay, William Fedus, Yunxuan Li, Xuezhi Wang, Mostafa Dehghani, Siddhartha Brahma, Albert Webson, Shixiang Shane Gu, Zhuyun Dai, Mirac Suzgun, Xinyun Chen, Aakanksha Chowdhery, Alex Castro-Ros, Marie Pellat, Kevin Robinson, Dasha Valter, Sharan Narang, Gaurav Mishra, Adams Yu, Vincent Zhao, Yanping Huang, Andrew Dai, Hongkun Yu, Slav Petrov, Ed H. Chi, Jeff Dean, Jacob Devlin, Adam Roberts, Denny Zhou, Quoc V. Le, and Jason Wei. Scaling instruction-finetuned language models, 2022. URL https://arxiv.org/abs/2210.11416.

Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein. Introduction to Algorithms, Third Edition. The MIT Press, 3rd edition, 2009. ISBN 0262033844.

Rémi Coulom. Efficient selectivity and backup operators in monte-carlo tree search. In H. Jaap van den Herik, Paolo Ciancarini, and H. H. L. M. (Jeroen) Donkers (eds.), Computers and Games, pp. 72–83, Berlin, Heidelberg, 2007. Springer Berlin Heidelberg. ISBN 978-3-540-75538-8.

DeepSeek-AI, Qihao Zhu, Daya Guo, Zhihong Shao, Dejian Yang, Peiyi Wang, Runxin Xu, Y. Wu, Yukun Li, Huazuo Gao, Shirong Ma, Wangding Zeng, Xiao Bi, Zihui Gu, Hanwei Xu, Damai Dai, Kai Dong, Liyue Zhang, Yishi Piao, Zhibin Gou, Zhenda Xie, Zhewen Hao, Bingxuan Wang, Junxiao Song, Deli Chen, Xin Xie, Kang Guan, Yuxiang You, Aixin Liu, Qiushi Du, Wenjun Gao, Xuan Lu, Qinyu Chen, Yaohui Wang, Chengqi Deng, Jiashi Li, Chenggang Zhao, Chong Ruan, Fuli Luo, and Wenfeng Liang. Deepseek-coder-v2: Breaking the barrier of closed-source models in code intelligence, 2024. URL https://arxiv.org/abs/2406.11931.

Yilun Du, Shuang Li, Antonio Torralba, Joshua B. Tenenbaum, and Igor Mordatch. Improving factuality and reasoning in language models through multiagent debate, 2023. URL https://arxiv.org/abs/2305.14325.

Abhimanyu Dubey, Abhinav Jauhri, Abhinav Pandey, Abhishek Kadian, Ahmad Al-Dahle, Aiesha Letman, Akhil Mathur, Alan Schelten, Amy Yang, Angela Fan, Anirudh Goyal, Anthony Hartshorn, Aobo Yang, Archi Mitra, Archie Sravankumar, Artem Korenev, Arthur Hinsvark, Arun Rao, Aston Zhang, Aurelien Rodriguez, Austen Gregerson, Ava Spataru, Baptiste Roziere, Bethany Biron, Binh Tang, Bobbie Chern, Charlotte Caucheteux, Chaya Nayak, Chloe Bi, Chris Marra, Chris McConnell, Christian Keller, Christophe Touret, Chunyang Wu, Corinne Wong, Cristian Canton Ferrer, Cyrus Nikolaidis, Damien Allonsius, Daniel Song, Danielle Pintz, Danny Livshits, David Esiobu, Dhruv Choudhary, Dhruv Mahajan, Diego Garcia-Olano, Diego Perino, Dieuwke Hupkes, Egor Lakomkin, Ehab AlBadawy, Elina Lobanova, Emily Dinan, Eric Michael Smith, Filip Radenovic, Frank Zhang, Gabriel Synnaeve, Gabrielle Lee, Georgia Lewis Anderson, Graeme Nail, Gregoire Mialon, Guan Pang, Guillem Cucurell, Hailey Nguyen, Hannah Korevaar, Hu Xu, Hugo Touvron, Iliyan Zarov, Imanol Arrieta Ibarra, Isabel Kloumann, Ishan Misra, Ivan Evtimov, Jade Copet, Jaewon Lee, Jan Geffert, Jana Vranes, Jason Park, Jay Mahadeokar, Jeet Shah, Jelmer van der Linde, Jennifer Billock, Jenny Hong, Jenya Lee, Jeremy Fu, Jianfeng Chi, Jianyu Huang, Jiawen Liu, Jie Wang, Jiecao Yu, Joanna Bitton, Joe Spisak, Jongsoo Park, Joseph Rocca, Joshua Johnstun, Joshua Saxe, Junteng Jia, Kalyan Vasuden Alwala, Kartikeya Upasani, Kate Plawiak, Ke Li, Kenneth Heafield, Kevin Stone, Khalid El-Arini,

Krithika Iyer, Kshitiz Malik, Kuenley Chiu, Kunal Bhalla, Lauren Rantala-Yeary, Laurens van der Maaten, Lawrence Chen, Liang Tan, Liz Jenkins, Louis Martin, Lovish Madaan, Lubo Malo, Lukas Blecher, Lukas Landzaat, Luke de Oliveira, Madeline Muzzi, Mahesh Pasupuleti, Mannat Singh, Manohar Paluri, Marcin Kardas, Mathew Oldham, Mathieu Rita, Maya Pavlova, Melanie Kambadur, Mike Lewis, Min Si, Mitesh Kumar Singh, Mona Hassan, Naman Goyal, Narjes Torabi, Nikolay Bashlykov, Nikolay Bogoychev, Niladri Chatterji, Olivier Duchenne, Onur Çelebi, Patrick Alrassy, Pengchuan Zhang, Pengwei Li, Petar Vasic, Peter Weng, Prajjwal Bhargava, Pratik Dubal, Praveen Krishnan, Punit Singh Koura, Puxin Xu, Qing He, Qingxiao Dong, Ragavan Srinivasan, Raj Ganapathy, Ramon Calderer, Ricardo Silveira Cabral, Robert Stojnic, Roberta Raileanu, Rohit Girdhar, Rohit Patel, Romain Sauvestre, Ronnie Polidoro, Roshan Sumbaly, Ross Taylor, Ruan Silva, Rui Hou, Rui Wang, Saghar Hosseini, Sahana Chennabasappa, Sanjay Singh, Sean Bell, Seohyun Sonia Kim, Sergey Edunov, Shaoliang Nie, Sharan Narang, Sharath Raparthy, Sheng Shen, Shengye Wan, Shruti Bhosale, Shun Zhang, Simon Vandenhende, Soumya Batra, Spencer Whitman, Sten Sootla, Stephane Collot, Suchin Gururangan, Sydney Borodinsky, Tamar Herman, Tara Fowler, Tarek Sheasha, Thomas Georgiou, Thomas Scialom, Tobias Speckbacher, Todor Mihaylov, Tong Xiao, Ujjwal Karn, Vedanuj Goswami, Vibhor Gupta, Vignesh Ramanathan, Viktor Kerkez, Vincent Gonguet, Virginie Do, Vish Vogeti, Vladan Petrovic, Weiwei Chu, Wenhan Xiong, Wenyin Fu, Whitney Meers, Xavier Martinet, Xiaodong Wang, Xiaoqing Ellen Tan, Xinfeng Xie, Xuchao Jia, Xuewei Wang, Yaelle Goldschlag, Yashesh Gaur, Yasmine Babaei, Yi Wen, Yiwen Song, Yuchen Zhang, Yue Li, Yuning Mao, Zacharie Delpierre Coudert, Zheng Yan, Zhengxing Chen, Zoe Papakipos, Aaditya Singh, Aaron Grattafiori, Abha Jain, Adam Kelsey, Adam Shajnfeld, Adithya Gangidi, Adolfo Victoria, Ahuva Goldstand, Ajay Menon, Ajay Sharma, Alex Boesenberg, Alex Vaughan, Alexei Baevski, Allie Feinstein, Amanda Kallet, Amit Sangani, Anam Yunus, Andrei Lupu, Andres Alvarado, Andrew Caples, Andrew Gu, Andrew Ho, Andrew Poulton, Andrew Ryan, Ankit Ramchandani, Annie Franco, Aparajita Saraf, Arkabandhu Chowdhury, Ashley Gabriel, Ashwin Bharambe, Assaf Eisenman, Azadeh Yazdan, Beau James, Ben Maurer, Benjamin Leonhardi, Bernie Huang, Beth Loyd, Beto De Paola, Bhargavi Paranjape, Bing Liu, Bo Wu, Boyu Ni, Braden Hancock, Bram Wasti, Brandon Spence, Brani Stojkovic, Brian Gamido, Britt Montalvo, Carl Parker, Carly Burton, Catalina Mejia, Changhan Wang, Changkyu Kim, Chao Zhou, Chester Hu, Ching-Hsiang Chu, Chris Cai, Chris Tindal, Christoph Feichtenhofer, Damon Civin, Dana Beaty, Daniel Kreymer, Daniel Li, Danny Wyatt, David Adkins, David Xu, Davide Testuggine, Delia David, Devi Parikh, Diana Liskovich, Didem Foss, Dingkang Wang, Duc Le, Dustin Holland, Edward Dowling, Eissa Jamil, Elaine Montgomery, Eleonora Presani, Emily Hahn, Emily Wood, Erik Brinkman, Esteban Arcaute, Evan Dunbar, Evan Smothers, Fei Sun, Felix Kreuk, Feng Tian, Firat Ozgenel, Francesco Caggioni, Francisco Guzmán, Frank Kanayet, Frank Seide, Gabriela Medina Florez, Gabriella Schwarz, Gada Badeer, Georgia Swee, Gil Halpern, Govind Thattai, Grant Herman, Grigory Sizov, Guangyi, Zhang, Guna Lakshminarayanan, Hamid Shojanazeri, Han Zou, Hannah Wang, Hanwen Zha, Haroun Habeeb, Harrison Rudolph, Helen Suk, Henry Aspegren, Hunter Goldman, Ibrahim Damlaj, Igor Molybog, Igor Tufanov, Irina-Elena Veliche, Itai Gat, Jake Weissman, James Geboski, James Kohli, Japhet Asher, Jean-Baptiste Gaya, Jeff Marcus, Jeff Tang, Jennifer Chan, Jenny Zhen, Jeremy Reizenstein, Jeremy Teboul, Jessica Zhong, Jian Jin, Jingyi Yang, Joe Cummings, Jon Carvill, Jon Shepard, Jonathan McPhie, Jonathan Torres, Josh Ginsburg, Junjie Wang, Kai Wu, Kam Hou U, Karan Saxena, Karthik Prasad, Kartikay Khandelwal, Katayoun Zand, Kathy Matosich, Kaushik Veeraraghavan, Kelly Michelena, Keqian Li, Kun Huang, Kunal Chawla, Kushal Lakhotia, Kyle Huang, Lailin Chen, Lakshya Garg, Lavender A, Leandro Silva, Lee Bell, Lei Zhang, Liangpeng Guo, Licheng Yu, Liron Moshkovich, Luca Wehrstedt, Madian Khabsa, Manav Avalani, Manish Bhatt, Maria Tsimpoukelli, Martynas Mankus, Matan Hasson, Matthew Lennie, Matthias Reso, Maxim Groshev, Maxim Naumov, Maya Lathi, Meghan Keneally, Michael L. Seltzer, Michal Valko, Michelle Restrepo, Mihir Patel, Mik Vyatskov, Mikayel Samvelyan, Mike Clark, Mike Macey, Mike Wang, Miquel Jubert Hermoso, Mo Metanat, Mohammad Rastegari, Munish Bansal, Nandhini Santhanam, Natascha Parks, Natasha White, Navyata Bawa, Nayan Singhal, Nick Egebo, Nicolas Usunier, Nikolay Pavlovich Laptev, Ning Dong, Ning Zhang, Norman Cheng, Oleg Chernoguz, Olivia Hart, Omkar Salpekar, Ozlem Kalinli, Parkin Kent, Parth Parekh, Paul Saab, Pavan Balaji, Pedro Rittner, Philip Bontrager, Pierre Roux, Piotr Dollar, Polina Zvyagina, Prashant Ratanchandani, Pritish Yuvraj, Qian Liang, Rachad Alao, Rachel Rodriguez, Rafi Ayub, Raghotham Murthy, Raghu Nayani, Rahul Mitra, Raymond Li, Rebekkah Hogan, Robin Battey, Rocky Wang, Rohan Maheswari, Russ Howes, Ruty Rinott, Sai Jayesh Bondu, Samyak Datta, Sara Chugh, Sara Hunt, Sargun Dhillon, Sasha Sidorov, Sa-

tadru Pan, Saurabh Verma, Seiji Yamamoto, Sharadh Ramaswamy, Shaun Lindsay, Shaun Lindsay, Sheng Feng, Shenghao Lin, Shengxin Cindy Zha, Shiva Shankar, Shuqiang Zhang, Shuqiang Zhang, Sinong Wang, Sneha Agarwal, Soji Sajuyigbe, Soumith Chintala, Stephanie Max, Stephen Chen, Steve Kehoe, Steve Satterfield, Sudarshan Govindaprasad, Sumit Gupta, Sungmin Cho, Sunny Virk, Suraj Subramanian, Sy Choudhury, Sydney Goldman, Tal Remez, Tamar Glaser, Tamara Best, Thilo Kohler, Thomas Robinson, Tianhe Li, Tianjun Zhang, Tim Matthews, Timothy Chou, Tzook Shaked, Varun Vontimitta, Victoria Ajayi, Victoria Montanez, Vijai Mohan, Vinay Satish Kumar, Vishal Mangla, Vítor Albiero, Vlad Ionescu, Vlad Poenaru, Vlad Tiberiu Mihailescu, Vladimir Ivanov, Wei Li, Wenchen Wang, Wenwen Jiang, Wes Bouaziz, Will Constable, Xiaocheng Tang, Xiaofang Wang, Xiaojian Wu, Xiaolan Wang, Xide Xia, Xilun Wu, Xinbo Gao, Yanjun Chen, Ye Hu, Ye Jia, Ye Qi, Yenda Li, Yilin Zhang, Ying Zhang, Yossi Adi, Youngjin Nam, Yu, Wang, Yuchen Hao, Yundi Qian, Yuzi He, Zach Rait, Zachary DeVito, Zef Rosnbrick, Zhaoduo Wen, Zhenyu Yang, and Zhiwei Zhao. The llama 3 herd of models, 2024. URL https://arxiv.org/abs/2407.21783.

Maxence Faldor, Jenny Zhang, Antoine Cully, and Jeff Clune. Omni-epic: Open-endedness via models of human notions of interestingness with environments programmed in code, 2024. URL https://arxiv.org/abs/2405.15568.

Richard Fang, Rohan Bindu, Akul Gupta, Qiusi Zhan, and Daniel Kang. Teams of llm agents can exploit zero-day vulnerabilities, 2024. URL https://arxiv.org/abs/2406.01637.

A. Fawzi, M. Balog, A. Huang, T. Hubert, B. Romera-Paredes, M. Barekatain, A. Novikov, F. J. R. Ruiz, J. Schrittwieser, G. Swirszcz, D. Silver, D. Hassabis, and P. Kohli. Discovering faster matrix multiplication algorithms with reinforcement learning. Nature, 610(7930):47–53, 2022. doi: 10.1038/s41586-022-05172-4.

Peter E. Hart, Nils J. Nilsson, and Bertram Raphael. A formal basis for the heuristic determination of minimum cost paths. IEEE Trans. Syst. Sci. Cybern., 4(2):100–107, 1968. doi: 10.1109/TSSC.1968.300136. URL https://doi.org/10.1109/TSSC.1968.300136.

Shengran Hu, Cong Lu, and Jeff Clune. Automated design of agentic systems, 2024. URL https://arxiv.org/abs/2408.08435.

Carlos E. Jimenez, John Yang, Alexander Wettig, Shunyu Yao, Kexin Pei, Ofir Press, and Karthik Narasimhan. Swe-bench: Can language models resolve real-world github issues?, 2024. URL https://arxiv.org/abs/2310.06770.

J. Jumper, R. Evans, A. Pritzel, T. Green, M. Figurnov, O. Ronneberger, K. Tunyasuvunakool, R. Bates, A. Žídek, A. Potapenko, A. Bridgland, C. Meyer, S. A. A. Kohl, A. J. Ballard, A. Cowie, B. Romera-Paredes, S. Nikolov, R. Jain, J. Adler, T. Back, S. Petersen, D. Reiman, E. Clancy, M. Zielinski, M. Steinegger, M. Pacholska, T. Berghammer, S. Bodenstein, D. Silver, O. Vinyals, A. W. Senior, K. Kavukcuoglu, P. Kohli, and D. Hassabis. Highly accurate protein structure prediction with AlphaFold. Nature, 596(7873):583–589, 2021. doi: 10.1038/s41586-021-03819-2.

Daniel Kahneman. Thinking, fast and slow. Farrar, Straus and Giroux, New York, NY, US, 2011. ISBN 978-0-374-27563-1.

Akbir Khan, John Hughes, Dan Valentine, Laura Ruis, Kshitij Sachan, Ansh Radhakrishnan, Edward Grefenstette, Samuel R. Bowman, Tim Rocktäschel, and Ethan Perez. Debating with more persuasive llms leads to more truthful answers, 2024. URL https://arxiv.org/abs/2402.06782.

Levente Kocsis and Csaba Szepesvári. Bandit based monte-carlo planning. In Johannes Fürnkranz, Tobias Scheffer, and Myra Spiliopoulou (eds.), Machine Learning: ECML 2006, pp. 282–293, Berlin, Heidelberg, 2006. Springer Berlin Heidelberg. ISBN 978-3-540-46056-5.

Jing Yu Koh, Stephen McAleer, Daniel Fried, and Ruslan Salakhutdinov. Tree search for language model agents, 2024. URL https://arxiv.org/abs/2407.01476.

Yujia Li, David Choi, Junyoung Chung, Nate Kushman, Julian Schrittwieser, Rémi Leblond, Tom Eccles, James Keeling, Felix Gimeno, Agustin Dal Lago, Thomas Hubert, Peter Choy, Cyprien de Masson d'Autume, Igor Babuschkin, Xinyun Chen, Po-Sen Huang, Johannes Welbl, Sven Gowal, Alexey Cherepanov, James Molloy, Daniel J. Mankowitz, Esme Sutherland Robson, Pushmeet Kohli, Nando de Freitas, Koray Kavukcuoglu, and Oriol Vinyals. Competition-level code generation with alphacode. Science, 378(6624):1092–1097, 2022. doi: 10.1126/science.abq1158. URL https://www.science.org/doi/abs/10.1126/science.abq1158.

Chris Lu, Cong Lu, Robert Tjarko Lange, Jakob Foerster, Jeff Clune, and David Ha. The ai scientist: Towards fully automated open-ended scientific discovery, 2024a. URL https://arxiv.org/abs/2408.06292.

Cong Lu, Shengran Hu, and Jeff Clune. Intelligent go-explore: Standing on the shoulders of giant foundation models, 2024b. URL https://arxiv.org/abs/2405.15143.

Yecheng Jason Ma, William Liang, Guanzhi Wang, De-An Huang, Osbert Bastani, Dinesh Jayaraman, Yuke Zhu, Linxi Fan, and Anima Anandkumar. Eureka: Human-level reward design via coding large language models, 2024a. URL https://arxiv.org/abs/2310.12931.

Yingwei Ma, Qingping Yang, Rongyu Cao, Binhua Li, Fei Huang, and Yongbin Li. How to understand whole software repository?, 2024b. URL https://arxiv.org/abs/2406.01422.

E.F. Moore. The Shortest Path Through a Maze. Bell Telephone System. Technical publications. monograph. Bell Telephone System., 1959. URL https://books.google.com/books?id=IVZBHAAACAAJ.

OpenAI. OpenAI o1 System Card, September 2024. URL https://openai.com/research/o1-system-card. Online report.

OpenAI, Josh Achiam, Steven Adler, Sandhini Agarwal, Lama Ahmad, Ilge Akkaya, Florencia Leoni Aleman, Diogo Almeida, Janko Altenschmidt, Sam Altman, Shyamal Anadkat, Red Avila, Igor Babuschkin, Suchir Balaji, Valerie Balcom, Paul Baltescu, Haiming Bao, Mohammad Bavarian, Jeff Belgum, Irwan Bello, Jake Berdine, Gabriel Bernadett-Shapiro, Christopher Berner, Lenny Bogdonoff, Oleg Boiko, Madelaine Boyd, Anna-Luisa Brakman, Greg Brockman, Tim Brooks, Miles Brundage, Kevin Button, Trevor Cai, Rosie Campbell, Andrew Cann, Brittany Carey, Chelsea Carlson, Rory Carmichael, Brooke Chan, Che Chang, Fotis Chantzis, Derek Chen, Sully Chen, Ruby Chen, Jason Chen, Mark Chen, Ben Chess, Chester Cho, Casey Chu, Hyung Won Chung, Dave Cummings, Jeremiah Currier, Yunxing Dai, Cory Decareaux, Thomas Degry, Noah Deutsch, Damien Deville, Arka Dhar, David Dohan, Steve Dowling, Sheila Dunning, Adrien Ecoffet, Atty Eleti, Tyna Eloundou, David Farhi, Liam Fedus, Niko Felix, Simón Posada Fishman, Juston Forte, Isabella Fulford, Leo Gao, Elie Georges, Christian Gibson, Vik Goel, Tarun Gogineni, Gabriel Goh, Rapha Gontijo-Lopes, Jonathan Gordon, Morgan Grafstein, Scott Gray, Ryan Greene, Joshua Gross, Shixiang Shane Gu, Yufei Guo, Chris Hallacy, Jesse Han, Jeff Harris, Yuchen He, Mike Heaton, Johannes Heidecke, Chris Hesse, Alan Hickey, Wade Hickey, Peter Hoeschele, Brandon Houghton, Kenny Hsu, Shengli Hu, Xin Hu, Joost Huizinga, Shantanu Jain, Shawn Jain, Joanne Jang, Angela Jiang, Roger Jiang, Haozhun Jin, Denny Jin, Shino Jomoto, Billie Jonn, Heewoo Jun, Tomer Kaftan, Łukasz Kaiser, Ali Kamali, Ingmar Kanitscheider, Nitish Shirish Keskar, Tabarak Khan, Logan Kilpatrick, Jong Wook Kim, Christina Kim, Yongjik Kim, Jan Hendrik Kirchner, Jamie Kiros, Matt Knight, Daniel Kokotajlo, Łukasz Kondraciuk, Andrew Kondrich, Aris Konstantinidis, Kyle Kosic, Gretchen Krueger, Vishal Kuo, Michael Lampe, Ikai Lan, Teddy Lee, Jan Leike, Jade Leung, Daniel Levy, Chak Ming Li, Rachel Lim, Molly Lin, Stephanie Lin, Mateusz Litwin, Theresa Lopez, Ryan Lowe, Patricia Lue, Anna Makanju, Kim Malfacini, Sam Manning, Todor Markov, Yaniv Markovski, Bianca Martin, Katie Mayer, Andrew Mayne, Bob McGrew, Scott Mayer McKinney, Christine McLeavey, Paul McMillan, Jake McNeil, David Medina, Aalok Mehta, Jacob Menick, Luke Metz, Andrey Mishchenko, Pamela Mishkin, Vinnie Monaco, Evan Morikawa, Daniel Mossing, Tong Mu, Mira Murati, Oleg Murk, David Mély, Ashvin Nair, Reiichiro Nakano, Rajeev Nayak, Arvind Neelakantan, Richard Ngo, Hyeonwoo Noh, Long Ouyang, Cullen O'Keefe, Jakub Pachocki, Alex Paino, Joe Palermo, Ashley Pantuliano, Giambattista Parascandolo, Joel Parish, Emy Parparita, Alex Passos, Mikhail Pavlov, Andrew Peng, Adam Perelman, Filipe de Avila Belbute Peres, Michael Petrov, Henrique Ponde de Oliveira Pinto, Michael, Pokorny,

Michelle Pokrass, Vitchyr H. Pong, Tolly Powell, Alethea Power, Boris Power, Elizabeth Proehl, Raul Puri, Alec Radford, Jack Rae, Aditya Ramesh, Cameron Raymond, Francis Real, Kendra Rimbach, Carl Ross, Bob Rotsted, Henri Roussez, Nick Ryder, Mario Saltarelli, Ted Sanders, Shibani Santurkar, Girish Sastry, Heather Schmidt, David Schnurr, John Schulman, Daniel Selsam, Kyla Sheppard, Toki Sherbakov, Jessica Shieh, Sarah Shoker, Pranav Shyam, Szymon Sidor, Eric Sigler, Maddie Simens, Jordan Sitkin, Katarina Slama, Ian Sohl, Benjamin Sokolowsky, Yang Song, Natalie Staudacher, Felipe Petroski Such, Natalie Summers, Ilya Sutskever, Jie Tang, Nikolas Tezak, Madeleine B. Thompson, Phil Tillet, Amin Tootoonchian, Elizabeth Tseng, Preston Tuggle, Nick Turley, Jerry Tworek, Juan Felipe Cerón Uribe, Andrea Vallone, Arun Vijayvergiya, Chelsea Voss, Carroll Wainwright, Justin Jay Wang, Alvin Wang, Ben Wang, Jonathan Ward, Jason Wei, CJ Weinmann, Akila Welihinda, Peter Welinder, Jiayi Weng, Lilian Weng, Matt Wiethoff, Dave Willner, Clemens Winter, Samuel Wolrich, Hannah Wong, Lauren Workman, Sherwin Wu, Jeff Wu, Michael Wu, Kai Xiao, Tao Xu, Sarah Yoo, Kevin Yu, Qiming Yuan, Wojciech Zaremba, Rowan Zellers, Chong Zhang, Marvin Zhang, Shengjia Zhao, Tianhao Zheng, Juntang Zhuang, William Zhuk, and Barret Zoph. Gpt-4 technical report, 2024. URL https://arxiv.org/abs/2303.08774.

Albert Örwall. Moatless tools, jun 2024. URL https://github.com/aorwall/moatless-tools. Accessed: 2024-07-16.

Long Ouyang, Jeff Wu, Xu Jiang, Diogo Almeida, Carroll L. Wainwright, Pamela Mishkin, Chong Zhang, Sandhini Agarwal, Katarina Slama, Alex Ray, John Schulman, Jacob Hilton, Fraser Kelton, Luke Miller, Maddie Simens, Amanda Askell, Peter Welinder, Paul Christiano, Jan Leike, and Ryan Lowe. Training language models to follow instructions with human feedback, 2022. URL https://arxiv.org/abs/2203.02155.

Liangming Pan, Alon Albalak, Xinyi Wang, and William Yang Wang. Logic-lm: Empowering large language models with symbolic solvers for faithful logical reasoning, 2023. URL https://arxiv.org/abs/2305.12295.

Maria Rigaki, Carlos Catania, and Sebastian Garcia. Hackphyr: A local fine-tuned llm agent for network security environments, 2024. URL https://arxiv.org/abs/2409.11276.

Swarnadeep Saha, Archiki Prasad, Justin Chih-Yao Chen, Peter Hase, Elias Stengel-Eskin, and Mohit Bansal. System-1.x: Learning to balance fast and slow planning with language models, 2024. URL https://arxiv.org/abs/2407.14414.

David Silver, Aja Huang, Chris J. Maddison, Arthur Guez, Laurent Sifre, George van den Driessche, Julian Schrittwieser, Ioannis Antonoglou, Veda Panneershelvam, Marc Lanctot, Sander Dieleman, Dominik Grewe, John Nham, Nal Kalchbrenner, Ilya Sutskever, Timothy Lillicrap, Madeleine Leach, Koray Kavukcuoglu, Thore Graepel, and Demis Hassabis. Mastering the game of go with deep neural networks and tree search. Nature, 529(7587):484–489, 1 2016a. ISSN 1476-4687. doi: 10.1038/nature16961. URL https://doi.org/10.1038/nature16961.

David Silver, Aja Huang, Chris J. Maddison, Arthur Guez, Laurent Sifre, George van den Driessche, Julian Schrittwieser, Ioannis Antonoglou, Vedavyas Panneershelvam, Marc Lanctot, Sander Dieleman, Dominik Grewe, John Nham, Nal Kalchbrenner, Ilya Sutskever, Timothy P. Lillicrap, Madeleine Leach, Koray Kavukcuoglu, Thore Graepel, and Demis Hassabis. Mastering the game of go with deep neural networks and tree search. Nat., 529(7587):484–489, 2016b. doi: 10.1038/NATURE16961. URL https://doi.org/10.1038/nature16961.

David Silver, Thomas Hubert, Julian Schrittwieser, Ioannis Antonoglou, Matthew Lai, Arthur Guez, Marc Lanctot, Laurent Sifre, Dharshan Kumaran, Thore Graepel, Timothy Lillicrap, Karen Simonyan, and Demis Hassabis. A general reinforcement learning algorithm that masters chess, shogi, and go through self-play. Science, 362(6419):1140–1144, 2018. doi: 10.1126/science.aar6404. URL https://www.science.org/doi/abs/10.1126/science.aar6404.

Charlie Snell, Jaehoon Lee, Kelvin Xu, and Aviral Kumar. Scaling llm test-time compute optimally can be more effective than scaling model parameters, 2024. URL https://arxiv.org/abs/2408.03314.

Guanzhi Wang, Yuqi Xie, Yunfan Jiang, Ajay Mandlekar, Chaowei Xiao, Yuke Zhu, Linxi Fan, and Anima Anandkumar. Voyager: An open-ended embodied agent with large language models, 2023. URL https://arxiv.org/abs/2305.16291.

Xingyao Wang, Yangyi Chen, Lifan Yuan, Yizhe Zhang, Yunzhu Li, Hao Peng, and Heng Ji. Executable code actions elicit better llm agents, 2024a. URL https://arxiv.org/abs/2402.01030.

Xingyao Wang, Boxuan Li, Yufan Song, Frank F. Xu, Xiangru Tang, Mingchen Zhuge, Jiayi Pan, Yueqi Song, Bowen Li, Jaskirat Singh, Hoang H. Tran, Fuqiang Li, Ren Ma, Mingzhang Zheng, Bill Qian, Yanjun Shao, Niklas Muennighoff, Yizhe Zhang, Binyuan Hui, Junyang Lin, Robert Brennan, Hao Peng, Heng Ji, and Graham Neubig. Opendevin: An open platform for ai software developers as generalist agents, 2024b. URL https://arxiv.org/abs/2407.16741.

Jason Wei, Yi Tay, Rishi Bommasani, Colin Raffel, Barret Zoph, Sebastian Borgeaud, Dani Yogatama, Maarten Bosma, Denny Zhou, Donald Metzler, et al. Emergent abilities of large language models. arXiv preprint arXiv:2206.07682, 2022.

Chunqiu Steven Xia, Yinlin Deng, Soren Dunn, and Lingming Zhang. Agentless: Demystifying llm-based software engineering agents, 2024. URL https://arxiv.org/abs/2407.01489.

An Yang, Baosong Yang, Binyuan Hui, Bo Zheng, Bowen Yu, Chang Zhou, Chengpeng Li, Chengyuan Li, Dayiheng Liu, Fei Huang, Guanting Dong, Haoran Wei, Huan Lin, Jialong Tang, Jialin Wang, Jian Yang, Jianhong Tu, Jianwei Zhang, Jianxin Ma, Jianxin Yang, Jin Xu, Jingren Zhou, Jinze Bai, Jinzheng He, Junyang Lin, Kai Dang, Keming Lu, Keqin Chen, Kexin Yang, Mei Li, Mingfeng Xue, Na Ni, Pei Zhang, Peng Wang, Ru Peng, Rui Men, Ruize Gao, Runji Lin, Shijie Wang, Shuai Bai, Sinan Tan, Tianhang Zhu, Tianhao Li, Tianyu Liu, Wenbin Ge, Xiaodong Deng, Xiaohuan Zhou, Xingzhang Ren, Xinyu Zhang, Xipin Wei, Xuancheng Ren, Xuejing Liu, Yang Fan, Yang Yao, Yichang Zhang, Yu Wan, Yunfei Chu, Yuqiong Liu, Zeyu Cui, Zhenru Zhang, Zhifang Guo, and Zhihao Fan. Qwen2 technical report, 2024a. URL https://arxiv.org/abs/2407.10671.

John Yang, Carlos E. Jimenez, Alexander Wettig, Kilian Lieret, Shunyu Yao, Karthik Narasimhan, and Ofir Press. Swe-agent: Agent-computer interfaces enable automated software engineering, 2024b. URL https://arxiv.org/abs/2405.15793.

Shunyu Yao, Dian Yu, Jeffrey Zhao, Izhak Shafran, Tom Griffiths, Yuan Cao, and Karthik Narasimhan. Tree of thoughts: Deliberate problem solving with large language models. In Alice Oh, Tristan Naumann, Amir Globerson, Kate Saenko, Moritz Hardt, and Sergey Levine (eds.), Advances in Neural Information Processing Systems 36: Annual Conference on Neural Information Processing Systems 2023, NeurIPS 2023, New Orleans, LA, USA, December 10 - 16, 2023, 2023. URL http://papers.nips.cc/paper_files/paper/2023/hash/271db9922b8d1f4dd7aaef84ed5ac703-Abstract-Conference.html.

Kexun Zhang, Weiran Yao, Zuxin Liu, Yihao Feng, Zhiwei Liu, Rithesh Murthy, Tian Lan, Lei Li, Renze Lou, Jiacheng Xu, Bo Pang, Yingbo Zhou, Shelby Heinecke, Silvio Savarese, Huan Wang, and Caiming Xiong. Diversity empowers intelligence: Integrating expertise of software engineering agents, 2024a. URL https://arxiv.org/abs/2408.07060.

Yao Zhang, Zijian Ma, Yunpu Ma, Zhen Han, Yu Wu, and Volker Tresp. Webpilot: A versatile and autonomous multi-agent system for web task execution with strategic exploration, 2024b. URL https://arxiv.org/abs/2408.15978.

Yiqun Zhang, Xiaocui Yang, Shi Feng, Daling Wang, Yifei Zhang, and Kaisong Song. Can llms beat humans in debating? a dynamic multi-agent framework for competitive debate, 2024c. URL https://arxiv.org/abs/2408.04472.

Yuntong Zhang, Haifeng Ruan, Zhiyu Fan, and Abhik Roychoudhury. Autocoderover: Autonomous program improvement, 2024d. URL https://arxiv.org/abs/2404.05427.

A REPRODUCIBILITY

All models and data used in our work are publicly available. We additionally provide hyperparameter details in **Appendix 2**. The code will be released as a public repository upon publication.

B ADDITIONAL IMPLEMENTATION DETAILS

Moatless-Adapted is an extended version of the moatless-tools library with support for a tree structure, the ability to revert to earlier versions of the codebase, and the capability to run tests.

The standard implementation of moatless-tools is based on a finite state machine structure where a state holds information about file context and properties set in the configuration or from previous states. It can then transition to a new state when an action is executed. The request that initiates the action is created by an LLM. This follows a linear structure where one state can transition to another state. In Moatless-Adapted, this model is extended so that a state can expand by using actions to create more states. The connections between states are then represented in a tree structure with nodes.

Each state has a file context associated with it. This file context will be included in the prompt sent to an LLM. To limit the size of the prompt, files are divided into ”spans,” where a span could be, for example, a section of code (e.g., imports), a class, or a function. These are identified by span IDs. Thus, the LLM sees a limited part of the code at a time but can request more context by searching for or adding files and spans. The file context therefore changes over time, and a specific state of file context is linked to a specific state. In the standard implementation of moatless-tools, changes to the codebase are made linearly, and each change is saved directly to the file system. In Moatless-Adapted, however, there is a need to be able to revert to earlier states and thus return to a previous version of the codebase. To handle this, the code is stored in a git repository where each change is committed, and each state has a reference to a commit as well as the current patch of the diff from the initial commit that existed before starting. This way, one can go back to an earlier state by specifying the state ID, and the commit that was current at that time will be checked out.

The test files present in the file context are run each time the Plan state is initiated, and the test results are provided to the state. The tests are then run in Docker images built via the SWE-bench library. To use this approach in a benchmark where a larger number of instances should be able to run simultaneously, a solution is used where these images are run as pods in a Kubernetes cluster. Moatless-tools communicates with the testbed by applying patches and running commands via an API. When a new instance starts, a pod is created which is then reset at each run, applying the current patch and running tests according to the test command specified in the SWE-bench library. It’s important to add here that the agent is not aware of the `PASS_TO_PASS` or `FAIL_TO_PASS` tests in the SWE-bench harness, but only knows how to run the tests. This corresponds to a real engineering environment where each project can have its own test commands.

C MCTS HYPERPARAMETERS

The Monte Carlo Tree Search (MCTS) algorithm used in this study employs several hyperparameters.

Table 2: MCTS Hyperparameters

Hyperparameter	**Description**	**Default**
c_param	UCT exploration parameter	1.41
max_expansions	Max children per node	5
max_iterations	Max MCTS iterations	100
provide_feedback	Enable feedback	True
best_first	Use best-first strategy	True
value_function_temperature	Value function temperature	0.2
max_depth	Max tree depth	20
UCT Score Calculation Parameters		
exploration_weight	UCT exploration weight	1.0
depth_weight	Depth penalty weight	0.8
depth_bonus_factor	Depth bonus factor	200.0
high_value_threshold	High-value node threshold	55.0
low_value_threshold	Low-value node threshold	50.0
very_high_value_threshold	Very high-value threshold	75.0
high_value_leaf_bonus_constant	High-value leaf bonus	20.0
high_value_bad_children_bonus_constant	High-value bad children bonus	20.0
high_value_child_penalty_constant	High-value child penalty	5.0
Action Model Parameters		
action_model_temperature	Action model temperature	0.2
Discriminator Parameters		
number_of_agents	Number of Discriminator Agents	5
number_of_round	Number of debate rounds	3
discriminator_temperature	Discriminator temperature	1.0

These hyperparameters can be adjusted to fine-tune the MCTS algorithm's performance for specific problem domains or computational constraints. The values listed here are the defaults as defined in the `TreeSearchSettings` class and the MCTS implementation.

D ABILITY OF MCTS TO ESCAPE UNPRODUCTIVE LOOPS VS. BASELINE

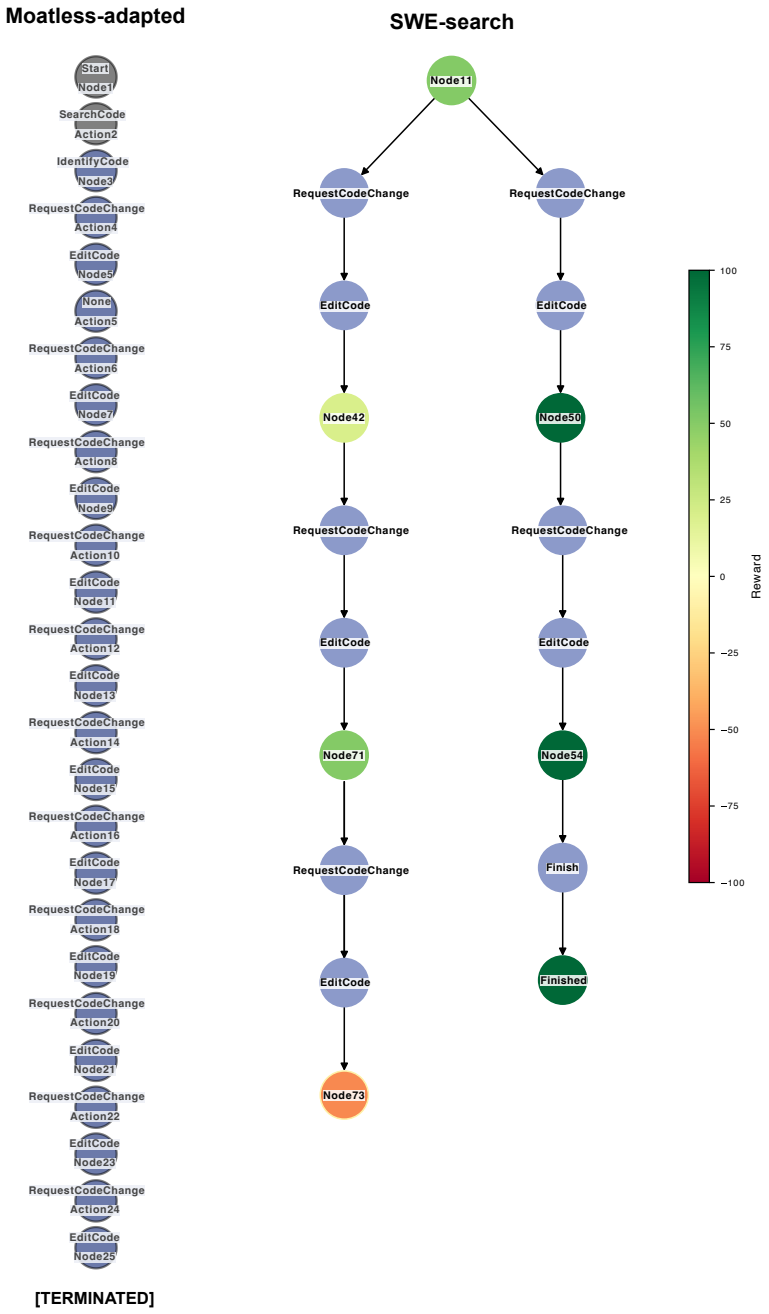

Figure 6: **Avoiding Repetitive Actions, django__django__10914.** We found that the base agent can often get stuck performing repetitive actions that do not bring it closer to solving the issue, and which commonly lead to unresolvable dead-ends. In this example, the base agent was stuck implementing wrong tests which continuously returned errors. In contrast, when this happens in SWE-Search, the Value Agent recognizes this, terminating these trajectories quickly, as happens in Node 73 (orange).

E MODEL INSTANCE RESOLUTION UNIQUENESS

To understand the complementary strengths of different models in resolving software issues, we analyzed how unique their resolved issue subsets where. Figure 7 illustrates the resolution patterns for each model across five of the codebases in SWE-bench-lite.

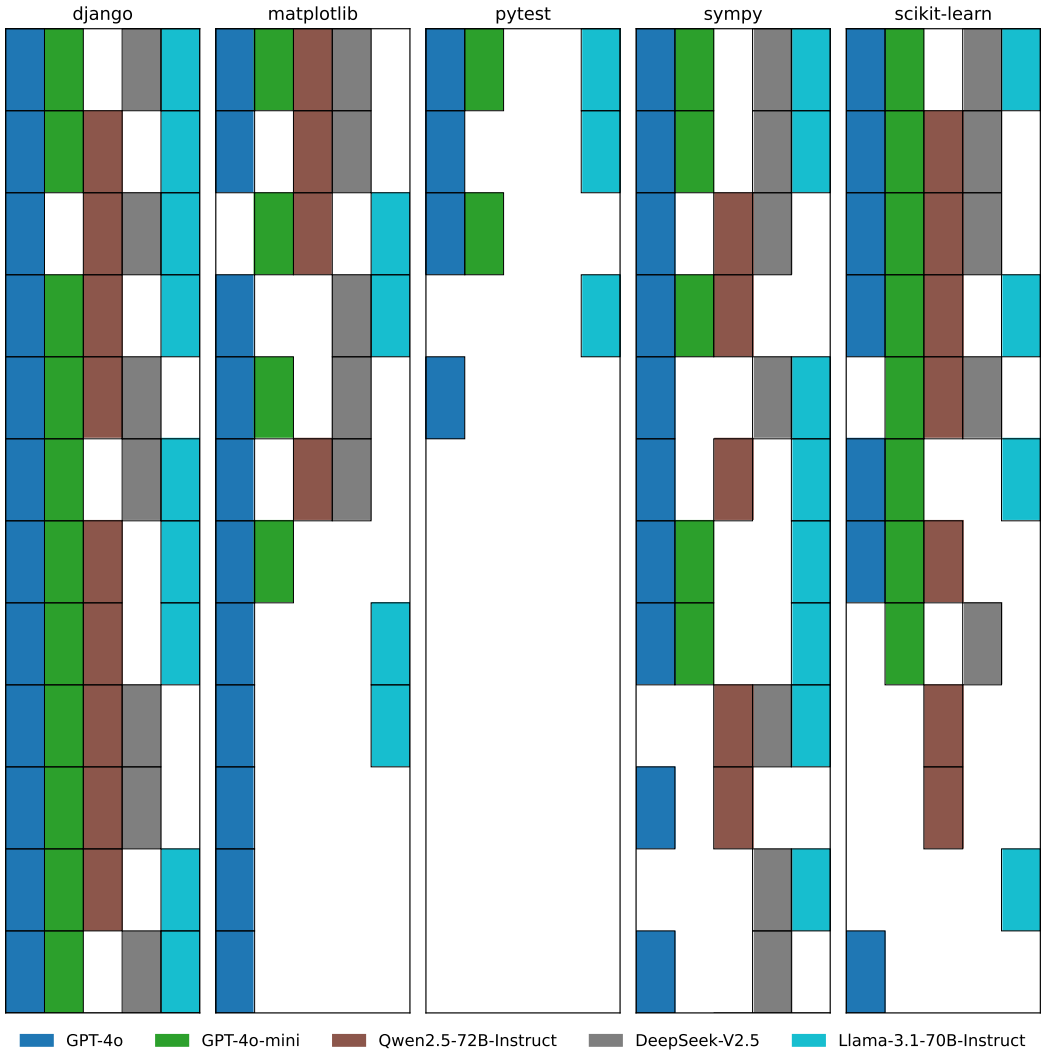

Figure 7: **Unique Issue Resolution Patterns Across Models and Libraries.** Each column represents a different Python repository, and each row within a column represents a specific issue. Colored blocks indicate successful resolution by the corresponding model (see legend). White spaces denote unresolved issues. This visualization highlights the diverse problem-solving capabilities of different models across various software domains, demonstrating that no single model dominates across all issues and libraries.

F ABILITY OF VALUE FUNCTION TO DISCERN SUCCESSFUL TRAJECTORIES

Before implementing SWE-Search, we conducted a general study across many models to evaluate the models' ability to differentiate states which led to resolved vs. unresolved issues. Figure 8 shows the results of this study. We found that in general, models assigned higher rewards to states which eventually led to resolved issues. Of particular interest was the Deepseek model, which seemed to identify critical errors in trajectories effectively. This was also observed in the final agent (see Fig. 5a).

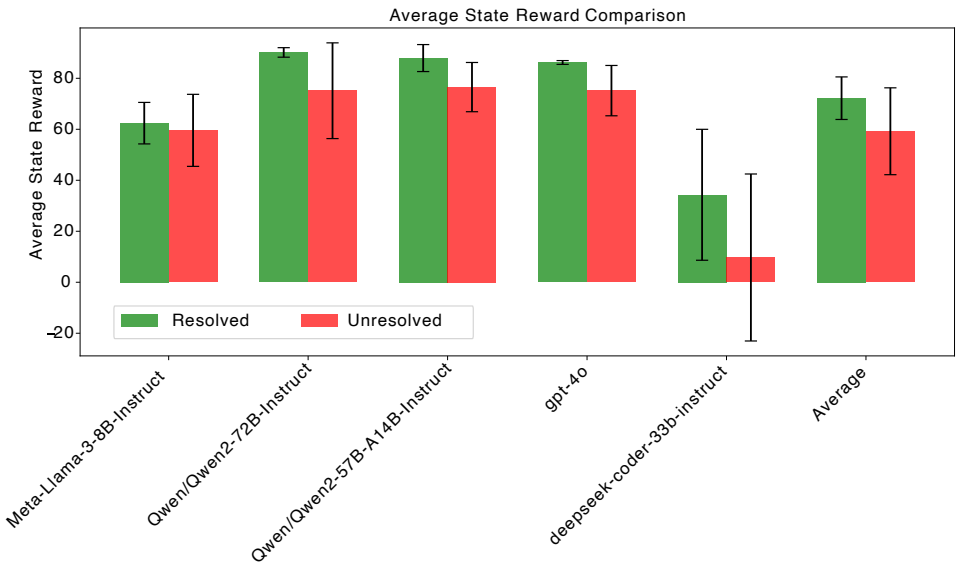

Figure 8: **Average State Reward Comparison Across Models.** This graph compares the average state rewards assigned by different language models for resolved (green) and unresolved (red) issues. Error bars indicate standard deviation. Most models consistently assign higher rewards to states leading to resolved issues, with the exception of the. The 'Average' column represents the mean across all models, demonstrating a clear distinction between resolved and unresolved states.

G VALUE FUNCTION PROMPTS

Value Function Search Prompt

Your task is to evaluate a search action executed by an AI agent, considering the search parameters, the resulting file context, and the identified code from the search results. Your evaluation will focus on whether the search action was well-constructed, whether the resulting file context is relevant and useful for solving the problem at hand, and whether the identified code is appropriate and helpful.

You will be provided with four inputs:

- **Problem Statement**: This will be provided within the `<problem_statement>` XML tag and contains the initial message or problem description the coding agent is trying to solve.
- **The Search Request**: This will be provided within the `<search_request>` XML tag and contains the search parameters used by the agent to define the search.
- **The Search Result**: The content retrieved based on the search parameters provided within a `<search_results>` XML tag.
- **Identified Code**: The specific code identified from the search results, provided within the `<identified_code>` XML tag.

Search request parameters:

- **File Pattern** (file_pattern): Glob patterns (e.g., **/*.py) to filter search results to specific files or directories.
- **Query** (query): A natural language query for semantic search.
- **Code Snippet** (code_snippet): Specific code snippets for exact matching.
- **Class Names** (class_names): Specific class names to include in the search.
- **Function Names** (function_names): Specific function names to include in the search.

Evaluation Criteria:

Search Parameters:

- Are they appropriately defined to focus the search on relevant files or code?
- Do they align well with the problem statement?

Resulting File Context:

- Does it contain relevant and useful information for solving the problem?
- Are there missing or irrelevant results indicating a need to refine the search?

Identified Code Review (most crucial):

- Is the identified code directly related to the problem?
- Does it provide the necessary functionality to address the issue?

Overall Relevance:

- Does the combination of search parameters, file context, and identified code effectively address the problem?
- Could there be a better approach or improvements?

Reward Scale and Guidelines:

Assign a single integer value between -100 and 100 based on how well the search action, resulting file context, and identified code addressed the task at hand. Use the following scale:

100:

- Search Parameters: Precisely match the problem needs; no irrelevant or missing elements.
- Identified Code: Completely and accurately solves the problem with no issues.

75 to 99:

- Search Parameters: Well-defined and mostly relevant; minor improvements possible.
- Identified Code: Effectively addresses the problem with minor issues that are easily fixable.

0 to 74:

- Search Parameters: Partially relevant; noticeable inaccuracies or omissions.
- Identified Code: Partially solves the problem but has significant gaps or errors.

-1 to -49:

- Search Parameters: Misaligned with the problem; poorly defined.
- Identified Code: Fails to address the problem effectively; may cause confusion.

-50 to -100:

- Search Parameters: Irrelevant or incorrect; hinders problem-solving.
- Identified Code: Unrelated to the problem; provides no useful information.

Output Format:

Please ensure your output strictly adheres to the following structure:
`<Explanation>` [A brief explanation of the evaluation in max one paragraph.]
`<Reward>` [A single integer reward value between -100 and 100]

Value Function Plan Prompt

Your role is to evaluate the executed action of the search tree that our AI agents are traversing, to help us determine the best trajectory to solve a programming issue. The agent is responsible for identifying and modifying the correct file(s) in response to the problem statement.

Input Data Format:

- **Problem Statement**: This will be provided within the `<problem_statement>` XML tag and contains the initial message or problem description the coding agent is trying to solve.
- **File Context**: The relevant code context will be provided within the `<file_context>` XML tag and pertains to the state the agent is operating on.
- **History**: The sequence of state transitions and actions taken prior to the current state will be contained within the `<history>` XML tag. This will include information on the parts of the codebase that were changed, the resulting diff, test results, and any reasoning or planned steps.
- **Executed Action**: The last executed action of the coding agent will be provided within the `<executed_action>` XML tag, this includes the proposed changes and the resulting diff of the change.
- **Full Git Diff**: The full Git diff up to the current state will be provided within the `<full_git_diff>` XML tag. This shows all changes made from the initial state to the current one and should be considered in your evaluation to ensure the modifications align with the overall solution.
- **Test Results**: The results of any test cases run on the modified code will be provided within the `<test_results>` XML tag. This will include information about passed, failed, or skipped tests, which should be carefully evaluated to confirm the correctness of the changes.

Evaluation Criteria:

Code Correctness: Evaluate whether the implemented code correctly addresses the problem. This includes verifying that the correct lines or sections of code have been identified and modified appropriately. Ensure that the changes are both syntactically and logically correct, and that the diffs accurately represent the intended modifications without introducing unrelated changes. Assess whether the modifications effectively solve the problem without introducing new issues or inefficiencies.

Mistakes in Editing Code: Identify any errors made during the code editing process. This involves checking for unintended deletions, incorrect modifications, or syntax errors introduced through the changes. Ensure that the Git diffs maintain integrity by only including the intended modifications and no accidental alterations to unrelated parts of the codebase.

Testing: Assess the proposed changes against existing test cases. Determine if the changes pass all relevant tests and evaluate whether any test failures could have been reasonably foreseen and avoided by the agent. Consider whether the agent anticipated potential test outcomes and addressed them proactively in the solution.

History and Action Evaluation: Review the agent's previous state transitions and actions to determine if the current action contributes positively to solving the problem. Pay special attention to detect if the agent is engaging in repetitive actions without making meaningful progress. Evaluate whether the last executed action is appropriate and logical given the current progress and history of actions.

Reward Scale and Guidelines:

The reward value must be based on how confident you are that the agent's solution is the most optimal one possible with no unresolved issues or pending tasks. The scale ranges from -100 to 100, where:

100: You are fully confident that the proposed solution is the most optimal possible, has been thoroughly tested, and requires no further changes.

75-99: The approach is likely the best one possible, but there are minor issues or opportunities for optimization. All major functionality is correct, but some small improvements or additional testing may be needed. There might be some edge cases that are not covered.

0-74: The solution has been partially implemented or is incomplete or there are likely alternative approaches that might be better, i.e., this is likely not the most optimal approach. The core problem might be addressed, but there are significant issues with tests, logical flow, or side effects that need attention. There are likely alternative approaches that are much better.

0: The solution is not yet functional or is missing key elements. The agent's assertion that the task is finished is incorrect, and substantial work is still required to fully resolve the issue. Modifying the wrong code, unintentionally removing or altering existing code, introducing syntax errors, or producing incorrect diffs fall into this range.

-1 to -49: The proposed solution introduces new issues or regresses existing functionality, but some elements of the solution show potential or may be salvageable. Repetitive actions without progress fall into this range.

-50 to -100: The solution is entirely incorrect, causing significant new problems, or fails to address the original issue entirely. Immediate and comprehensive changes are necessary. Persistent repetitive actions without progress should be heavily penalized.

Output Format:

Please ensure your output strictly adheres to the following structure:
`<Explanation>` [Your brief explanation of the evaluation in max one paragraph.]
`<Reward>` [A single integer reward value between -100 and 100]

Value Function Request More Context Prompt

Your role is to evaluate the executed action of the search tree that our AI agents are traversing, specifically for the RequestMoreContext action. This action is used when the agent requests to see code that is not in the current context, potentially revealing an understanding that relevant code is wholly or partially not visible, and enabling the agent to uncover important missing information.

Evaluation Criteria:

- **Relevance**: Are the requested files and code spans likely to be relevant to the problem at hand?
- **Necessity**: Is the additional context truly needed, or is the agent unnecessarily expanding the scope?
- **Specificity**: Has the agent been specific in its request, or is it asking for overly broad sections of code?
- **Contextual Understanding**: Does the request demonstrate a good understanding of the codebase structure and the problem domain?
- **Efficiency**: Is the agent making targeted requests, or is it asking for too much unnecessary information?
- **Progress**: Does this request seem likely to move the problem-solving process forward?

Input Data Format:

- **Problem Statement**: Provided within the `<problem_statement>` XML tag, containing the initial problem description.
- **File Context**: The current code context within the `<file_context>` XML tag.
- **History**: Previous state transitions and actions within the `<history>` XML tag.
- **Executed Action**: The RequestMoreContext action details within the `<executed_action>` XML tag, including the files and code spans requested.

Reward Scale and Guidelines: Assign a single integer value between -100 and 100 based on how well the RequestMoreContext action addresses the task at hand:

100: Perfect request that is highly likely to provide crucial missing information.

75-99: Good request with minor improvements possible in specificity or relevance.

0-74: Partially relevant request, but with noticeable inaccuracies or potential for better targeting.

-1 to -49: Poor request that is likely to provide mostly irrelevant information or expand the scope unnecessarily.

-50 to -100: Very poor request that is entirely irrelevant or demonstrates a fundamental

misunderstanding of the problem or codebase structure.

Output Format: Please ensure your output strictly adheres to the following structure:

`<Explanation>` [Your explanation of the evaluation in max two paragraphs.]
`<Reward>` [A single integer reward value between -100 and 100]

Value Function Edit Prompt

Your role is to evaluate the executed action of the search tree that our AI agents are traversing, with the goal of ensuring that a complete and verified solution is in place. The agent believes that it has finished solving the programming issue.

Evaluation Criteria

Solution Correctness and Quality: Verify that the proposed changes logically address the problem statement. Ensure the changes fit contextually within the existing codebase without introducing new issues. Confirm syntactic correctness and that there are no syntax errors or typos. Assess whether the solution represents an overall improvement and is the most optimal approach possible.

Accuracy of Code Modifications: Check that the agent correctly identified the appropriate code spans to modify. Ensure the changes made are accurate and do not include unintended modifications. Look for any alterations to unrelated parts of the code that could introduce new problems.

Testing and Test Results Analysis:

- **Importance of Test Updates:** It is crucial that the agent updated existing tests or added new tests to verify the solution. Failure to do so should be heavily penalized. The agent should ensure that code changes are validated by appropriate tests to confirm correctness and prevent regressions.
- **Assess Test Coverage:** Evaluate whether the agent has adequately tested the solution, including adding new tests for new functionality or changes. Verify that the tests cover relevant cases and edge conditions.
- **Penalization for Lack of Testing:** When calculating the reward, heavily penalize the agent if they failed to update or add necessary tests to verify the solution.

Consideration of Alternative Approaches: Always assess whether there could be a better alternative approach to the problem. Mention any potential alternative solutions in your explanation if they are applicable.

Identification and Explanation of Mistakes: If the agent made incorrect actions, identify exactly where and why the mistakes occurred. Explain the impact of any syntax errors, incorrect code modifications, or unintended changes.

Assessment of Agent's Completion Assertion: Verify if the agent's assertion that the task is finished is accurate. Determine if substantial work is still required to fully resolve the issue and address this in your evaluation.

Input Data Format:

- **Problem Statement**: This will be provided within the `<problem_statement>` XML tag and contains the initial message or problem description the coding agent is trying to solve.
- **File Context**: The relevant code context will be provided within the `<file_context>` XML tag and pertains to the state the agent is operating on.
- **History**: The sequence of state transitions and actions taken prior to the current state will be contained within the `<history>` XML tag. This will include information on the parts of the codebase that were changed, the resulting diff, test results, and any reasoning or planned steps.
- **Reasoning for Completion**: The reasoning provided by the agent for why the task is finished will be provided within the `<reasoning_for_completion>` XML tag. This includes the agent's explanation of why no further changes or actions are necessary.
- **Full Git Diff**: The full Git diff up to the current state will be provided within the `<full_git_diff>` XML tag. This shows all changes made from the initial state to the current one and should be considered in your evaluation to ensure the modifications align with the overall solution.
- **Test Results**: The results of any test cases run on the modified code will be provided within the `<test_results>` XML tag. This will include information about passed, failed, or skipped tests, which should be carefully evaluated to confirm the correctness of the changes.

Reward Scale and Guidelines:

The reward value must be based on how confident you are that the agent's solution is the most optimal one possible with no unresolved issues or pending tasks. It is important that the agent updated or added new tests to verify the solution; failure to do so should be heavily penalized. The scale ranges from -100 to 100, where:

100: You are fully confident that the proposed solution is the most optimal possible, has been thoroughly tested (including updated or new tests), and requires no further changes.

75-99: The approach is likely the best one possible, but there are minor issues or opportunities for optimization. All major functionality is correct, but some small improvements or additional testing may be needed. There might be some edge cases that are not covered.

0-74: The solution has been partially implemented or is incomplete, or there are likely alternative approaches that might be better. The core problem might be addressed, but there are significant issues with tests (especially if the agent did not update or add new tests), logical flow, or side effects that need attention.

0: The solution is not yet functional or is missing key elements. The agent's assertion that

the task is finished is incorrect, and substantial work is still required to fully resolve the issue.

-1 to -49: The proposed solution introduces new issues or regresses existing functionality, but some elements show potential or may be salvageable. Modifying the wrong code, unintentionally removing or altering existing code, introducing syntax errors, producing incorrect diffs, or failing to update or add necessary tests fall into this range.

-50 to -100: The solution is entirely incorrect, causing significant new problems or failing to address the original issue entirely. Immediate and comprehensive changes are necessary. Persistent repetitive actions without progress, or failure to update or add tests when necessary, should be heavily penalized.

Output Format: Please ensure your output strictly adheres to the following structure:

`<Explanation>` [Your explanation of the evaluation in max two paragraphs.]
`<Reward>` [A single integer reward value between -100 and 100]

H MOATLESS TOOLS STATE RIGIDITY

The Moatless-tools version (v0.0.2) enforces a rigid transition structure where agents must follow a specific sequence (search → identify → plan → edit). The implementation of this state transition system can be found here: [2].

H.1 STATE TRANSITION SYSTEM

The transition system is configured through a function that accepts three optional parameters:

- `max_tokens_in_edit_prompt`: Controls the token limit for edit operations
- `global_params`: Defines parameters applicable across all states
- `state_params`: Specifies state-specific parameters

H.2 STATE FLOW

The system defines a directed graph of states with specific transition rules:

1. **Search Phase** (`SearchCode`):
   - Initial state for code operations
   - Can transition to `IdentifyCode` upon successful search
   - Can move directly to `PlanToCode` when complete
2. **Identification Phase** (`IdentifyCode`):
   - Processes search results
   - Can return to `SearchCode` if needed
   - Progresses to `DecideRelevance` when finished
3. **Decision Phase** (`DecideRelevance`):
   - Evaluates identified information
   - Can trigger new searches

[2] https://github.com/aorwall/moatless-tools/blob/8ec5d5193b6dce88ec6273c7ec31f9ea3a0bba6f/moatless/transitions.py#L184

- Transitions to planning when ready, excluding message field

This rigid structure ensures that tools are accessed in a predictable sequence, preventing conflicts while maintaining system integrity. Additional transitions defined in `CODE_TRANSITIONS` complete the state machine's behavior set.

I COST ANALYSIS

Table 3 presents the API costs for Moatless-Adapted and SWE-Search across different models. Search-based exploration of multiple solutions results in higher computational costs.

Model	Moatless-Adapted	SWE-Search
GPT-4o	$40.86	$576.00
GPT-4o-mini	$9.90	$52.34
Qwen-2.5-72b-Instruct*	$8.50	$42.50
DeepseekCoderV2.5	$3.66	$18.37
Llama-3.1-70b-Instruct*	$9.00	$45.00

*Estimated costs based on comparable API pricing

Table 3: Cost comparison (USD) between Moatless-Adapted and SWE-Search

J COMPUTE-MATCHING ANALYSIS

Table 4 compares SWE-Search against compute-matched baselines. SWE-Search Pass@5 uses the 5 generated answers in 1 run, while for Moatless-Adapted uses the 5 generated solutions across 5 runs. We avoid doing the comparison on GPT-4o to avoid exorbitant API costs.

Model	SWE-Search		Moatless-Adapted
	Pass@1	Pass@5	Pass@5
GPT-4o	31.0	34.0	-
GPT-4o-mini	17.0	22.3	17.0
Qwen-2.5-72b-Instruct	24.7	25.7	22.3
DeepseekCoderV2.5	21.0	23.3	22.0
Llama-3.1-70b-Instruct	17.7	22.3	21.7

Table 4: Performance comparison (%) between SWE-Search and compute-matched baselines

K INTERACTIVE DEMO

To help visualize the search process and provide transparency into our method, we provide an interactive demo at `http://74.241.196.91`. The demo presents a tree visualization where each node represents a state/action pair in the search process. Clicking on a node reveals detailed information including:

- Complete LLM interactions and tool calls
- State-specific value function outputs and reasoning
- Context information used for decision-making
- File changes and test results where applicable
- Test creation/execution and their outputs

This interface allows readers to explore how the search algorithm navigates through different states, makes decisions, and evaluates potential solutions. The visualization particularly highlights how state-specific value functions guide the exploration process and how the discriminator compares candidate solutions.

L DISCRIMINATOR DEBATE PROMPTS

Solution Comparison Debate Round Prompt

Below are a series of suggested changes to address the ¡Problem Statement¿. Your task is to carefully evaluate each change and decide which one is the most appropriate to address the issue. **Input Format:**

- **Problem Statement**: Original issue to be solved
- **Solutions**: Multiple candidate solutions, each with:
  - Unique solution ID
  - Git patch showing code changes

Task: Evaluate each proposed solution and identify which one most effectively addresses the problem statement. Consider the completeness, correctness, and efficiency of each approach. **Output Format:**

- `<Explanation>`: Comprehensive explanation and reasoning behind your decision
- `<ID>`: The ID of the change you believe is the most appropriate

Solution Comparison Conclusion Prompt

Based on the Problem Statement and previous responses from the debate, determine the optimal solution. **Input Format:**

- **Initial Context**: Original problem statement
- **Agent Answers**: Evaluations and solution ID choices from the debate phase

Task: Synthesize the evaluations to identify the most appropriate solution. Report your conclusion without referencing individual debate participants. **Output Format:**

- `<Explanation>`: Reasoning for the selected solution
- `<ID>`: Final chosen solution ID