

# Tree of Thoughts Meets Hugging Face Agents

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A Survey of Tree of Thoughts and Hugging Face Agent Frameworks

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### Abstract

Large Language Models (LLMs) have demonstrated remarkable capabilities across diverse tasks, yet their reasoning remains fundamentally linear—generating thoughts token-by-token without the ability to explore alternatives, backtrack from errors, or evaluate multiple solution paths. This limitation constrains their effectiveness on complex multi-step problems requiring deliberation and planning. Concurrently, the emergence of AI agent frameworks has enabled LLMs to interact with external tools and execute actions autonomously, but these systems often struggle with strategic reasoning and error recovery [1, 3, 4, 6, 8, 9].

This paper presents a systematic synthesis of two developments in artificial intelligence: Tree of Thoughts (ToT) reasoning and the Hugging Face agent ecosystem. We examine how structured search over reasoning paths can be integrated with accessible agent frameworks to create more robust autonomous systems. Through technical analysis, implementation patterns, and benchmark context from prior literature, we describe where systematic exploration can improve complex reasoning while also introducing cost and latency trade-offs [1, 2, 10, 11, 12, 26].

Our contributions include: (1) a thorough theoretical and practical examination of Tree of Thoughts as both a reasoning paradigm and implementation strategy; (2) detailed documentation of Hugging Face's agent frameworks, including the Agent Course educational pathway and the smolagents library; (3) architectural patterns for integrating ToT reasoning with CodeAgent and MultiStepAgent implementations; (4) case-study walkthroughs across financial analysis, creative content generation, and software engineering; and (5) practical implementation strategies, optimization techniques, and deployment patterns.

This work summarizes published research and implementation patterns so researchers and practitioners can evaluate structured-reasoning agent designs with clear evidence boundaries.

## Note on Authorship

Michael Leydon is the sole listed author of this manuscript and accepts full responsibility for final editorial review, factual accuracy, and submission accountability.

This manuscript workflow included autonomous system assistance in early drafting and human-led revision, verification, and final approval. Non-human systems are treated as contributors to process, while scholarly accountability for claims and submission remains with the listed human author.

**Keywords:** Tree of Thoughts, LLM reasoning, AI agents, Hugging Face agents, smolagents, tool-augmented reasoning, survey methodology

**Scope and evidence note.** This document is a technical overview and synthesis. It combines literature findings with implementation guidance. Reported benchmark gains (for example, ToT results on Game of 24) are attributed to cited prior work unless explicitly marked as original measurements.

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## 0. Scope and Claim Boundaries

- This paper is primarily a survey-style synthesis rather than a standalone benchmark paper.
- Code snippets are mixed: some are runnable examples, while others are architectural sketches.
- Pseudo-code and illustrative snippets are labeled explicitly in relevant sections.
- Non-empirical examples are included only as synthetic walkthroughs and are labeled accordingly.

### 0.1 Survey Research Questions

This survey is organized around the following research questions (RQs):

- **RQ1:** What technical mechanisms define Tree-of-Thought-style reasoning for LLM systems (generation, evaluation, search, and stopping)?
- **RQ2:** What empirical evidence exists for ToT-family methods across benchmark categories relevant to agentic reasoning?
- **RQ3:** How do Hugging Face agent frameworks expose integration points for structured reasoning strategies?
- **RQ4:** What are the main methodological gaps that must be closed for reproducible ToT-agent claims?

## 0.2 Survey Methodology and Protocol

We follow a transparent evidence-synthesis workflow adapted from PRISMA-style reporting [27] and software-engineering evidence synthesis guidance [28, 29, 30]. Because this is a computer-science technical survey rather than a medical meta-analysis, we apply the reporting principles (search transparency, screening traceability, and extraction reproducibility) without imposing clinical effect-size assumptions.

**Protocol scope (this version):** This manuscript freezes a core-corpus selection run (Run ID: TOT-HF-SURVEY-2026-02-19) anchored by the records listed in Section 8. Fixed selection counts and exclusion reasons are reported in Appendix D, and the corresponding extraction schema is reported in Appendix E.

**0.2.1 Sources and Search Strategy** Primary sources for the final frozen search protocol are: arXiv, ACL Anthology (where applicable), major ML conference proceedings (NeurIPS/ICLR/ICML), ACM Digital Library, IEEE Xplore, and official framework documentation for implementation-level claims [10, 11, 13].

**Core query families (representative):**

- ("tree of thoughts" OR "tree-of-thought" OR "thought search") AND ("large language model" OR LLM)
- ("llm agent" OR "tool use" OR "tool-augmented") AND (reasoning OR planning OR search)
- ("smolagents" OR "hugging face agents" OR "CodeAgent" OR "MultiStepAgent") AND (planning OR reasoning)

**0.2.2 Inclusion and Exclusion Criteria** **Inclusion:** peer-reviewed papers or clearly attributable technical reports with reproducible method descriptions; benchmark definitions sufficiently detailed to interpret results; and framework/documentation sources required for implementation claims [27, 28, 29, 30].

**Exclusion:** marketing/blog-only claims without method transparency; duplicate postings of the same result without added detail; papers lacking enough

methodological detail to map claims to settings; and non-English sources where core technical details cannot be verified [27, 28, 29, 30].

**0.2.3 Screening, Extraction, and Quality Appraisal** Screening proceeds in three stages: (1) title/abstract triage, (2) full-text eligibility, and (3) extraction with structured fields. Extraction fields include: problem setting, model family, search policy, evaluator type, metrics, compute/cost reporting, and stated limitations [27, 28, 29, 30]. We additionally tag each record by evidence strength level:

- **E1 (Empirical):** controlled benchmark comparisons with explicit metrics and setup.
- **E2 (Method/Architecture):** technically detailed design without full controlled benchmark evidence.
- **E3 (Documentation/Reference):** implementation or API material used only for framework description.

Selection-flow and extraction artifacts are provided in Appendix D and Appendix E to support reproducibility and peer-review traceability.

### 0.3 Study Selection Flow

```
flowchart TD A["Records identified  
n = 30"] --> B["Duplicates removed  
n = 0"] B --> C["Title/Abstract screened  
n = 30"] C --> D["Full-text assessed for eligibility  
n = 30"] D --> E["Studies included in synthesis  
n = 22"]
```

### 0.4 Reproducibility

This survey was conducted under frozen protocol Run ID: TOT-HF-SURVEY-2026-02-19. The screening log and extraction artifacts are archived at [github.com/quiznat/tot-hf-survey-artifacts](https://github.com/quiznat/tot-hf-survey-artifacts). All code examples are labeled runnable or illustrative.

## 1. Introduction

### 1.1 The Reasoning Challenge in Large Language Models

Large Language Models have advanced rapidly in language understanding and generation. However, many standard prompting workflows still follow mostly linear reasoning traces, which can limit systematic exploration and backtracking on complex tasks [1, 3, 4].

When presented with a complex problem, standard LLMs generate a sequence of thoughts token-by-token, following the initial path that appears most probable at each step. This approach, while effective for many tasks, exhibits weaknesses

when confronting problems requiring exploration, backtracking, or evaluation of multiple solution strategies [1, 3, 4].

Consider the reasoning task "Game of 24," where the objective is to use four numbers and arithmetic operations to reach 24. In this setting, single-path reasoning can become trapped in unproductive trajectories when early choices are poor [1].

This limitation is not merely academic. As LLMs are increasingly deployed in high-stakes applications—from medical diagnosis support to financial analysis to autonomous software engineering—the ability to reason carefully, explore alternatives, and recover from errors becomes critical [24, 25]. The cost of a single reasoning failure can be substantial, whether measured in financial terms, safety implications, or user trust.

## 1.2 The Rise of AI Agents and Tool Augmentation

In parallel, agent frameworks have expanded, enabling LLMs to call tools, execute code, and complete multi-step workflows [6, 8, 9].

Prior work such as ReAct reports that interleaving reasoning and action can improve task performance in tool-using settings [6]. Other agent frameworks build on related ideas.

Hugging Face contributes to this ecosystem through public educational resources (Agents Course) and lightweight tooling (smolagents), which are directly documented in this survey [10, 11, 12].

Yet even sophisticated agent systems face challenges. Tool selection is often heuristic rather than systematic. When a tool call fails or returns unexpected results, agents may struggle to recover. Multi-step planning remains difficult, with agents frequently losing track of overall objectives while executing individual steps [8, 9]. The combination of reasoning and action, while powerful, lacks the structured exploration that complex problems demand.

## 1.3 The Convergence: Structured Reasoning Meets Autonomous Agents

This paper addresses these challenges through the integration of Tree of Thoughts reasoning with Hugging Face agent frameworks. Tree of Thoughts, introduced by Yao et al. (2023), models reasoning as deliberate search over a tree of possible thought sequences rather than linear generation [1].

If a model generates multiple candidate thoughts at each step, evaluates their promise, and explores promising paths, reasoning can move from a single trajectory to a search process with explicit backtracking and path comparison [1, 2].

As a design hypothesis grounded in prior reasoning and agent literature, combining structured search with agent frameworks can support systems that [1, 2,

6, 8, 9]:

- **Explore multiple tool selection strategies** before committing to execution
- **Evaluate action sequences** through simulation and scoring
- **Recover from tool failures** by backtracking to alternative paths
- **Plan complex multi-step operations** with lookahead evaluation
- **Maintain coherence** across extended reasoning chains through systematic exploration

This synthesis is practically relevant because Hugging Face tooling is designed for lightweight agent experimentation and integration [10, 12].

#### 1.4 Contributions and Structure

This paper makes the following contributions:

**Theoretical and Practical Foundation.** We provide detailed coverage of Tree of Thoughts, from its theoretical foundations in search algorithms to practical implementation patterns. This includes detailed examination of generation strategies, evaluation functions, and search algorithms (BFS, DFS, beam search) with illustrative code templates and examples.

**Framework Documentation.** We document Hugging Face's agent ecosystem, including the Agent Course curriculum, smolagents architecture, CodeAgent and MultiStepAgent implementations, and the surrounding tool ecosystem.

**Architectural Synthesis.** We present integration patterns for combining ToT reasoning with Hugging Face agents, including ToT-enhanced CodeAgent implementations, hybrid CoT-ToT agents that adapt strategy based on problem complexity, and multi-agent collaborative ToT concepts.

**Case-Based Analysis.** Through detailed case studies, we illustrate potential benefits of this synthesis across domains: financial analysis requiring systematic data gathering and calculation, creative content generation demanding exploration of alternatives, and software debugging requiring hypothesis testing and verification.

**Implementation Guidance.** We provide implementation templates, optimization strategies, testing frameworks, and deployment patterns. This includes caching strategies, early termination techniques, and observability integrations that can make ToT-enhanced agents practical for real-world deployment.

**Future Directions.** We identify critical research directions including learned evaluation functions, multi-modal ToT, hierarchical reasoning structures, and collaborative agent systems that point toward the next generation of AI reasoning capabilities.

The remainder of this paper is structured as follows: Section 2 provides detailed background on Tree of Thoughts, from theoretical foundations to implementa-

tion details. Section 3 documents the Hugging Face Agent ecosystem, covering the Agent Course, smolagents framework, and all core components. Section 4 presents our synthesis, demonstrating how ToT enhances agent architectures with detailed implementations and case studies. Section 5 provides practical implementation strategies, optimization techniques, and deployment patterns. Section 6 explores future directions and research opportunities. Section 7 concludes with key findings and the path forward.

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## 2. Tree of Thoughts: Background and Theory

### 2.1 From Linear Reasoning to Tree Search

The evolution of reasoning in language models reflects broader trends in AI. Early approaches treated generation as a direct input-to-output mapping. Chain-of-Thought prompting introduced explicit intermediate steps, with prior work reporting improved performance on several reasoning benchmarks [3, 4].

Chain of Thought works by prompting the model to generate a sequence of thoughts leading to the final answer:

Q: Roger has 5 tennis balls. He buys 2 more cans of tennis balls.  
Each can has 3 tennis balls. How many tennis balls does he have now?  
  
A: Roger started **with 5 balls**.  
He buys 2 cans, each **with 3 balls**, so that's  $2 \times 3 = 6$  balls.  
**5 + 6 = 11.**  
**The answer is 11.**

This approach, while effective, maintains the fundamental linearity of language model generation. The model produces thoughts sequentially, with each thought conditioned on all previous thoughts, but without the ability to explore alternatives or backtrack [1, 3, 4].

Tree of Thoughts extends this paradigm by treating reasoning as a search problem. At each step, multiple thoughts may be reasonable continuations; ToT generates candidates, evaluates partial states, and explores promising paths [1, 2].

The transformation can be understood through a simple analogy: CoT is like following a single path through a maze, hoping it leads to the goal. ToT is like exploring the maze systematically—trying multiple paths, marking dead ends, and ultimately finding the optimal route through deliberate search [1, 2].

### 2.2 Theoretical Foundations

Tree of Thoughts builds on established search-oriented reasoning ideas in AI [1].

**2.2.1 Search Algorithms** The core mechanism of ToT—generating candidates, evaluating states, and searching paths—aligns with classical search patterns that maintain a frontier and expand promising states [1].

What ToT contributes is the application of these algorithms to the space of natural language thoughts. Rather than searching over game states (as in chess) or configuration spaces (as in planning), ToT searches over sequences of coherent language that represent intermediate reasoning steps [1, 2].

This mapping from search algorithms to reasoning has several implications [1]:

- **Completeness:** Given sufficient time and breadth, ToT can explore all reasonable solution paths, while CoT commits to a single trajectory.
- **Optimality:** By evaluating and comparing paths, ToT can find superior solutions that CoT might miss due to early commitment to suboptimal directions.
- **Recovery:** When a path proves unproductive, ToT can backtrack and explore alternatives, while CoT must continue down the initial path regardless of quality.

**2.2.2 Cognitive Architecture** As a design intuition, ToT resembles deliberative problem-solving patterns where alternatives are generated, compared, and revised after failed attempts [1].

This analogy is used here to motivate search-based reasoning behavior, not as a claim of cognitive equivalence.

### 2.3 Core Components of Tree of Thoughts

A complete ToT implementation consists of four interdependent components [1, 2]:

**2.3.1 Thought Decomposition** The first challenge is decomposing the problem into discrete thought steps. This requires identifying natural intermediate points where alternative approaches might diverge [1, 2].

For mathematical problems, thoughts might represent individual operations:

Problem: Calculate  $(15 + 27) \times (42 - 18)$

Thought decomposition:

- T1: Calculate first parentheses:  $15 + 27 = ?$
- T2: Calculate second parentheses:  $42 - 18 = ?$
- T3: Multiply results from T1 and T2

For creative writing, thoughts might represent content decisions:

Task: Write a story about a detective solving a mystery

Thought decomposition:

- T1: Choose setting (modern city, historical period, future)
- T2: Select detective archetype (hardboiled, amateur, professional)
- T3: Determine mystery **type** (murder, theft, disappearance)
- T4: Plan plot structure (clues, red herrings, resolution)

Effective decomposition balances granularity: thoughts should be substantial enough to be meaningful but discrete enough to allow exploration of alternatives [1, 2].

**2.3.2 Thought Generation** Given the current problem state and history, the model must generate candidate next thoughts. This is typically accomplished through prompting that encourages diversity [1, 2]:

```
generation_prompt = """
Given the task: {task}
And current progress: {current_path}

Generate {k} different possible next steps. Each step should represent
a concrete action toward solving the problem. Consider diverse approaches.

Steps:
1.
2.
3.
"""
```

The quality of generation affects ToT effectiveness [1, 2]. Prompts should encourage:

- **Diversity:** Exploring different angles and strategies
- **Coherence:** Thoughts should follow logically from the current state
- **Relevance:** Generated thoughts should actually advance toward the solution
- **Appropriate granularity:** Thoughts should match the decomposition level

Temperature and sampling strategies affect generation diversity. Higher temperatures can encourage exploration but may reduce coherence [1, 2, 5].

**2.3.3 State Evaluation** Once candidates are generated, each is evaluated to estimate its promise. This step is often challenging because the model must assess partial solutions [1, 2].

Evaluation strategies include:

#### **Value Function Scoring:**

```
evaluation_prompt = """
Given the task: {task}
```

And current progress: {thought\_path}

Rate how promising this approach is on a scale of 0-10:

- 0-3: Likely incorrect or counterproductive
- 4-6: Might help but uncertain
- 7-10: Clearly advances toward solution

Rating: " "

**Vote-based Evaluation:** Multiple evaluation prompts are generated, and the majority vote determines the score. This reduces variance in evaluation [1, 2, 5].

**Self-consistency Checking:** The model is asked whether the current path is consistent with the goal, providing a binary evaluation signal [1, 2, 5].

**Heuristic Evaluation:** Domain-specific heuristics (e.g., in Game of 24, how close intermediate values are to 24) guide evaluation [1, 2].

The evaluation function determines search direction. A poor evaluator can lead the system to explore unpromising paths or prematurely abandon promising ones [1, 2].

**2.3.4 Search Algorithms** With generation and evaluation in place, ToT employs search algorithms to explore the thought tree [1, 2]:

#### Breadth-First Search (BFS):

- Maintains a fixed-width set of most promising partial solutions
- At each level, generates k candidates for each current state
- Evaluates all candidates and keeps the top b (beam width)
- More thorough but computationally expensive
- Good for problems where solution quality is critical

#### Depth-First Search (DFS):

- Explores single paths to completion before backtracking
- Generates candidates, selects the best, and recurses
- More efficient (fewer API calls) but may miss optimal solutions
- Good for problems with clear intermediate states

#### Beam Search:

- Hybrid approach maintaining top-b candidates at each depth
- Balances exploration breadth with computational cost
- Most commonly used in practice

#### Monte Carlo Tree Search (MCTS):

- Balances exploration (trying new paths) with exploitation (deepening promising paths)

- Uses rollout simulations to estimate value
- More complex but potentially more effective for large search spaces

## 2.4 The ToT Algorithm: Formal Specification

We can formally specify the ToT algorithm as follows:

**Input:** Problem P, generation function  $G(P, s, k) \rightarrow \{t_1, \dots, t_k\}$ , evaluation function  $E(P, s, t) \rightarrow v$  on a 0-10 scale, search algorithm A, beam width b, maximum depth d

**Output:** Solution or best path found

```
Algorithm ToT(P, G, E, A, b, d):
    Initialize: S <- {s0} // Set of states, starting with initial state

    for depth = 1 to d:
        candidates <- empty_set

        for each state s in S:
            thoughts <- G(P, s, k) // Generate k candidates
            for each thought t in thoughts:
                s' <- s union {t} // Extend state with thought
                v <- E(P, s, t) // Evaluate new state
                candidates <- candidates union {(v, s')}

        if solution_found(candidates):
            return extract_solution(candidates)

    S <- select_top(candidates, b) // Keep top b states

    return best_state(S)
```

This specification highlights the generality of the framework: different instantiations vary in their generation prompts, evaluation strategies, and search algorithms, but follow this core structure [1, 2].

## 2.5 Key Innovations and Advantages

Tree of Thoughts introduces several method-level differences from single-path prompting baselines [1, 2]:

**2.5.1 Systematic Exploration** Unlike CoT's linear trajectory, ToT explores multiple candidate paths [1]. This enables:

- Discovery of solutions missed by initial intuition
- Comparison of multiple approaches before commitment
- Recovery from local optima through global search

**2.5.2 Deliberate Evaluation** The explicit evaluation step introduces an internal scoring stage over partial reasoning states, which can support branch-level correction during search [1, 18].

**2.5.3 Flexible Search Strategy** Different search algorithms (BFS, DFS, beam) allow adaptation to problem characteristics [1, 2]:

- BFS for thoroughness
- DFS for efficiency
- Beam search for balance
- MCTS for exploration-exploitation trade-offs

**2.5.4 Natural Interpretability** The explicit tree structure provides natural interpretability [1, 2]:

- Alternative paths considered are visible
- Decisions can be explained by reference to evaluations
- The reasoning process is inspectable, not opaque

## 2.6 Theoretical Limitations and Trade-offs

ToT is not without limitations that practitioners must understand [1, 26]:

**Computational Cost:** Systematic exploration requires multiple generation and evaluation calls. This can increase inference cost and latency relative to single-path prompting baselines [1, 5, 26].

**Evaluation Quality:** ToT performance is bounded by evaluation quality. If partial-solution assessment is unreliable, search can be misdirected [1, 2].

**State Representation:** Not all problems decompose cleanly into discrete thought steps. Continuous optimization, open-ended generation, and highly interdependent reasoning may resist clean tree decomposition [1, 26].

**Diminishing Returns:** For simple problems, ToT overhead may not be justified. Reported benefits are strongest on tasks where multi-path exploration is needed [1, 26].

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## 3. The Hugging Face Agent Ecosystem

### 3.1 Overview: Accessible Open-Source Agent Development

Hugging Face provides public resources for building AI agents, including framework documentation, course material, and reference implementations [10, 11, 12, 13].

The Hugging Face agent ecosystem comprises three interconnected components [10, 11, 12, 13]:

1. **The Agent Course:** An open, detailed educational resource teaching agent development from fundamentals to advanced techniques
2. **The smolagents Library:** A compact, extensible Python framework for building production-ready agents
3. **The transformers Agents:** Built-in agent capabilities within the core transformers library

Together, these resources provide a documented pathway from learning to implementation in the Hugging Face ecosystem [10, 11, 12, 13].

### **3.2 The Hugging Face Agent Course**

Launched in 2024, the Hugging Face Agent Course is a public educational resource for agent development, combining conceptual instruction with hands-on exercises [11].

**3.2.1 Course Structure and Curriculum** The course is organized into progressive units [11]:

#### **Unit 1: Introduction to Agents**

- What are AI agents and how do they work?
- The observation-thought-action-observation loop
- Large Language Models as reasoning engines
- Tool use fundamentals

#### **Unit 2: The LLM Engine**

- Understanding LLMs as the agent "brain"
- Prompt engineering for agent behavior
- System prompts and instruction following
- Model selection considerations

#### **Unit 3: Frameworks for Agents**

- Comparison of agent frameworks (LangChain, LlamaIndex, smolagents)
- When to use each framework
- Framework-specific patterns and anti-patterns

#### **Unit 4: Tool Calling**

- Defining and registering tools
- Tool schemas and function calling
- Parameter extraction and validation
- Error handling in tool execution

#### **Unit 5: Building Real-World Agents**

- Multi-step task planning
- Memory and context management
- Handling failures and recovery

- Integration patterns

### **Unit 6: Advanced Topics**

- Multi-agent systems
- Agent evaluation and testing
- Security and safety considerations
- Deployment and scaling

Each unit combines written instruction with coding exercises aligned with transformers and smolagents usage [11].

**3.2.2 Educational Approach and Philosophy** The Agent Course embodies several pedagogical principles [11]:

**Learn by Doing:** Rather than passive consumption, learners build working agents from day one. Each concept is immediately applied through coding exercises [11].

**Progressive Complexity:** The course begins with simple single-tool agents and gradually introduces complexity—multiple tools, multi-step reasoning, error handling [11].

**Best Practices:** Beyond mere functionality, the course emphasizes implementation hygiene, including type hints, error handling, testing, and documentation [11].

**Community Integration:** Learners are encouraged to share projects through Hugging Face ecosystem workflows [11].

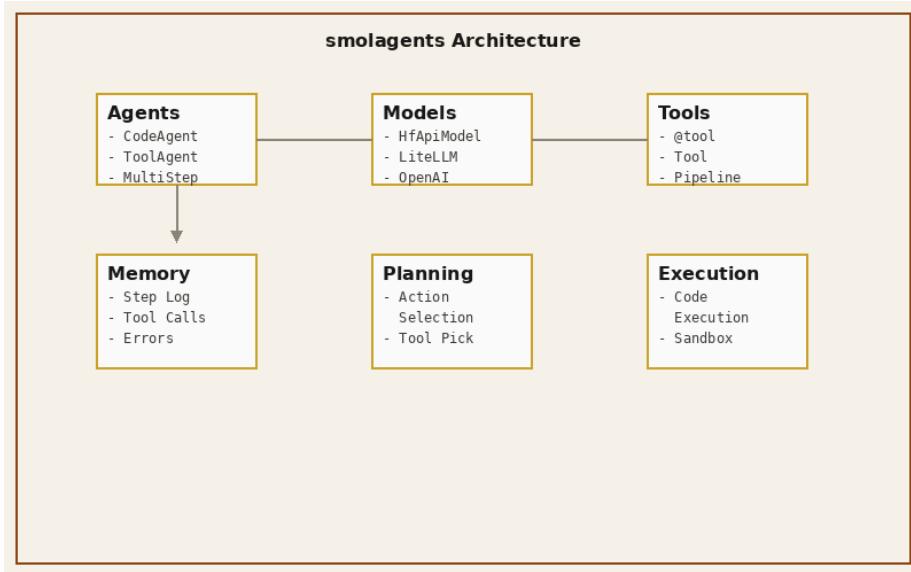
### **3.3 The smolagents Framework**

At the core of Hugging Face's agent ecosystem is smolagents—a Python library designed for compact agent implementations and ecosystem integration [10, 12].

**3.3.1 Design Philosophy** The name "smolagents" reflects a low-boilerplate design philosophy documented in official materials [10, 12]. This is achieved through:

- **Opinionated Defaults:** Sensible defaults that work out of the box
- **Ecosystem Integration:** Seamless use of Hugging Face models, datasets, and spaces
- **Minimal Abstractions:** Direct access to underlying components when needed
- **Code-First:** Agents are defined through Python code, not configuration files

**3.3.2 Architecture Overview** smolagents is built around several key abstractions [10, 12]:



**Agents** orchestrate the observation-thought-action loop [10, 12].

**Models** provide the LLM interface [10, 12].

**Tools** extend agent capabilities [10, 12].

**Memory** tracks execution history [10, 12].

**Planning** handles action selection [10, 12].

**Execution** runs tool code safely [10, 12].

### 3.3.3 Installation and Setup

```
# Basic installation
pip install smolagents

# With Hugging Face Hub integration
pip install smolagents[huggingface]

# With specific model providers
pip install smolagents[litellm]          # Multi-provider support
pip install smolagents[openai]            # OpenAI models
pip install smolagents[anthropic]         # Claude models

# Development installation
pip install smolagents[dev]
```

### 3.4 CodeAgent: Code as Action

**Code labeling.** In Sections 3-6, snippets fall into two categories: *runnable examples* (intended to run with adaptation) and *pseudo-code* (architectural sketches). When helper methods or framework internals are omitted, treat the snippet as pseudo-code. API-facing examples were aligned to public smolagents docs/repository references as of February 19, 2026 [10, 12].

The flagship agent in smolagents is CodeAgent, which uses generated Python code to invoke tools directly rather than relying only on structured function-call objects [10, 12].

**3.4.1 Code as Action Paradigm** Traditional agents might generate:

```
{  
    "tool": "calculator",  
    "parameters": {"expression": "15 * 24"}  
}
```

CodeAgent generates:

```
calculator(expression="15 * 24")
```

In this survey's implementation framing, this approach offers several engineering advantages:

**Composability:** Multiple tools can be combined in single code blocks:

```
# Search for data, process it, and visualize  
results = search(query="Bitcoin price history")  
df = parse_results(results)  
chart = create_chart(df, type="line")  
answer = summarize(chart)
```

**Familiarity:** Python syntax is widely understood, making agent behavior more interpretable.

**Flexibility:** Complex logic (loops, conditionals) is expressed naturally:

```
for stock in ["AAPL", "GOOGL", "MSFT"]:  
    price = get_stock_price(stock)  
    if price > 100:  
        alert(f"{stock} price alert: ${price}")
```

**Debugging:** Generated code can be inspected, logged, and analyzed like any Python code.

**3.4.2 CodeAgent Implementation** A minimal CodeAgent (doc-aligned pattern):

```
from smolagents import CodeAgent, InferenceClientModel
```

```

# Define the agent
agent = CodeAgent(
    tools=[],
    model=InferenceClientModel("meta-llama/Llama-3.3-70B-Instruct")
)

# Run the agent
result = agent.run("What is the 15th Fibonacci number?")

```

This creates an agent that can:

- Break down the problem into steps
- Generate Python code to solve it
- Execute the code in a sandboxed environment
- Return the result

The agent might generate:

```

# Calculate Fibonacci sequence
def fibonacci(n):
    if n <= 1:
        return n
    a, b = 0, 1
    for _ in range(2, n + 1):
        a, b = b, a + b
    return b

result = fibonacci(15)
print(result)

```

**3.4.3 Configuration and Customization** CodeAgent configuration options in current docs include model/tool binding, step limits, optional planning, authorized imports, grammar, and executor settings [10, 12]:

```

from smolagents import CodeAgent, InferenceClientModel
from smolagents.default_tools import DuckDuckGoSearchTool

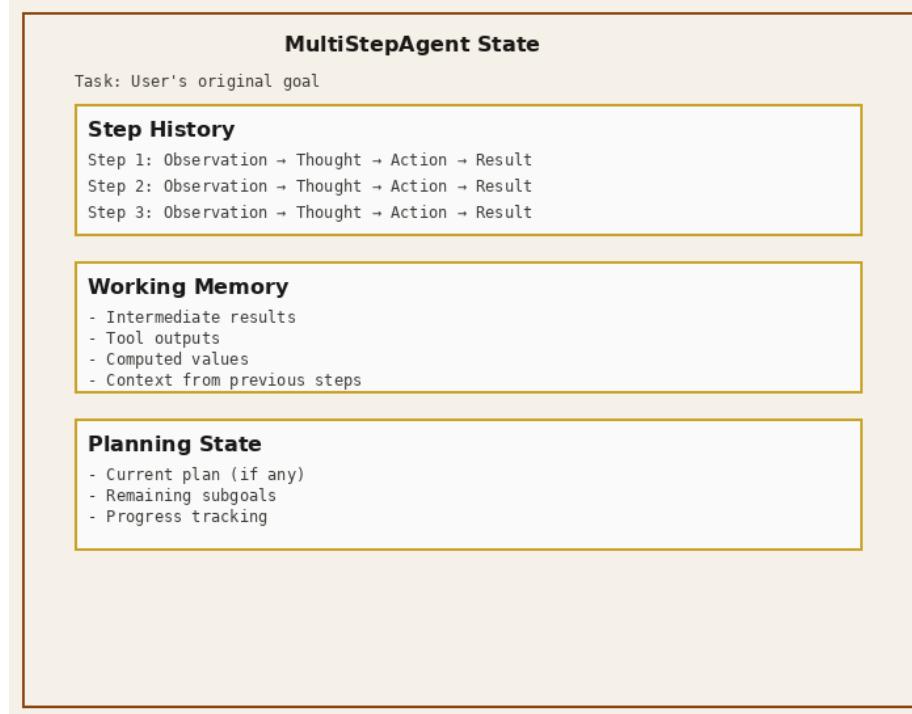
agent = CodeAgent(
    tools=[DuckDuckGoSearchTool()],
    model=InferenceClientModel("meta-llama/Llama-3.3-70B-Instruct"),
    max_steps=10,
    planning_interval=3,
    additional_authorized_imports=["math", "random"],
    grammar=None,
    executor_type="local",
    executor_kwargs=None
)

```

### 3.5 MultiStepAgent: Managing Complex Workflows

For tasks requiring multiple distinct phases or extended reasoning, smolagents provides MultiStepAgent with explicit planning/state patterns [10, 12].

**3.5.1 Multi-Step Architecture** MultiStepAgent maintains richer state across execution:



**3.5.2 Planning Capabilities** MultiStepAgent can create and execute plans:

```
from smolagents import MultiStepAgent, InferenceClientModel

agent = MultiStepAgent(
    tools=[search, calculator, summarize],
    model=InferenceClientModel("Qwen/Qwen2.5-Coder-32B-Instruct"),
    planning_interval=2 # Re-plan every 2 steps
)

result = agent.run("""
    Analyze the impact of recent AI regulations on tech stocks.
    Search for news, gather price data for major companies,
    and summarize the findings.
""")
```

The agent might:

1. Plan: "1. Search AI regulation news, 2. Get stock prices, 3. Analyze correlation, 4. Summarize"
2. Execute plan step by step
3. Re-plan if initial approach proves insufficient
4. Maintain context across all steps

**3.5.3 Error Handling and Recovery** Error handling is typically implemented at orchestration level around agent execution (pseudo-code sketch):

```
from smolagents import MultiStepAgent

agent = MultiStepAgent(
    tools=tools,
    model=model,
    max_steps=20,
    planning_interval=3
)

# Pseudo-code orchestration pattern
for attempt in range(3):
    try:
        result = agent.run(task)
        break
    except Exception as err:
        log_error(err)
        task = add_recovery_context(task, err)
# Report final outcome or propagate terminal error
```

## 3.6 The Tool Ecosystem

Tools extend agent capabilities beyond language generation, enabling interaction with external systems, data sources, and services [6, 10].

**3.6.1 Built-in Tools** smolagents provides default tool integrations (examples below are doc-aligned) [10, 12]:

**Search and browsing tools:**

```
from smolagents.default_tools import (
    DuckDuckGoSearchTool,
    WikipediaSearchTool,
    VisitWebpageTool,
)

search_tool = DuckDuckGoSearchTool()
```

```

wiki_tool = WikipediaSearchTool()
visit_tool = VisitWebpageTool()

Python execution tool:

from smolagents import PythonInterpreterTool

python_tool = PythonInterpreterTool()
result = python_tool("sum(range(100))")

3.6.2 Custom Tool Definition Tools are defined using Python decorators [10, 12]:

from smolagents import tool
from typing import Optional

@tool
def fetch_stock_price(
    ticker: str,
    date: Optional[str] = None
) -> str:
    """
    Fetch the current or historical stock price for a given ticker symbol.
    """

Args:
    ticker: The stock ticker symbol (e.g., 'AAPL', 'GOOGL')
    date: Optional date in YYYY-MM-DD format for historical data.
          If not provided, returns current price.

Returns:
    The stock price as a string with currency.
    """
    # Implementation would call financial API
    # For demonstration:
    if ticker == "AAPL":
        return "$175.50"
    return "Price data not available"

```

The `@tool` decorator (conceptually):

- Parses the docstring for tool description
- Extracts type hints for parameter validation
- Registers the function as available to agents
- Generates tool schemas for LLM function calling

**3.6.3 Tool Integration Patterns** Tools can be combined in sophisticated ways:

### Chained Tools:

```
@tool
def analyze_website(url: str) -> str:
    """Analyze a website and return key information."""
    # Step 1: Fetch content
    content = fetch_url(url)

    # Step 2: Extract text
    text = extract_text(content)

    # Step 3: Summarize
    summary = summarize(text)

    return summary
```

### Conditional Tools:

```
@tool
def smart_search(query: str, require_recent: bool = False) -> str:
    """Search with conditional logic."""
    if require_recent:
        return news_search(query, days=7)
    else:
        return web_search(query)
```

### Stateful Tools:

```
class DatabaseTool:
    def __init__(self):
        self.connection = None

    @tool
    def query(self, sql: str) -> str:
        """Execute SQL query on connected database."""
        if not self.connection:
            self.connect()
        return self.connection.execute(sql).fetchall()

    @tool
    def schema(self) -> str:
        """Return database schema."""
        return self.get_schema()
```

**3.6.4 Tool Schemas and Validation** smolagents supports tool schema generation/serialization for callable interfaces [10, 12]:

```

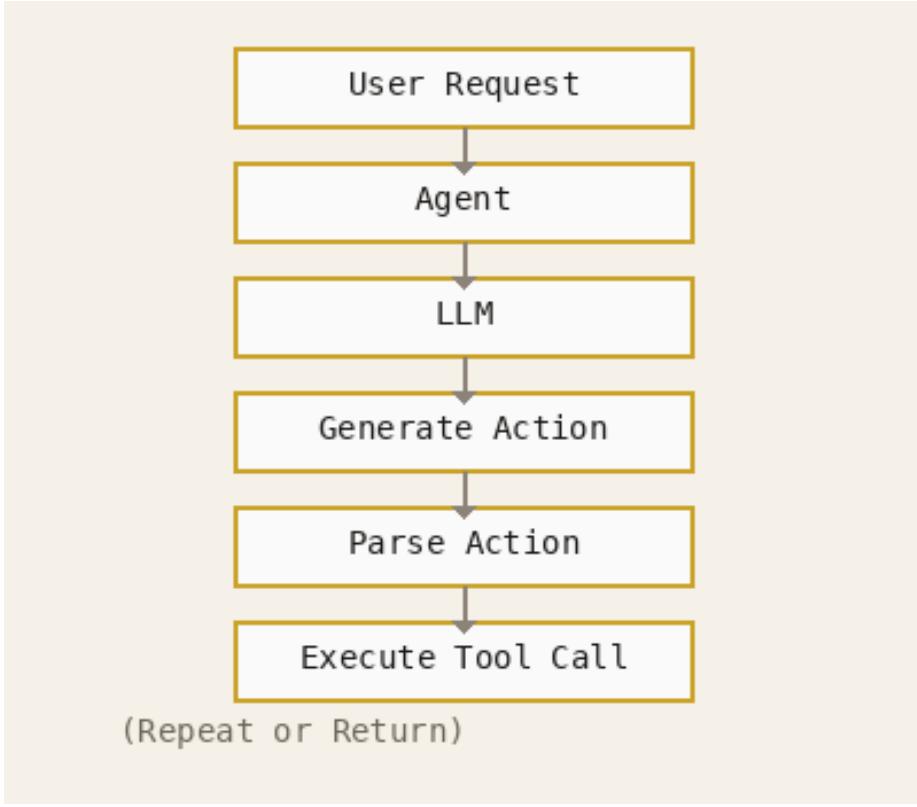
# For the fetch_stock_price tool above, the schema is:
{
  "name": "fetch_stock_price",
  "description": "Fetch the current or historical stock price...",
  "parameters": {
    "type": "object",
    "properties": {
      "ticker": {
        "type": "string",
        "description": "The stock ticker symbol..."
      },
      "date": {
        "type": "string",
        "description": "Optional date in YYYY-MM-DD format...",
        "nullable": true
      }
    },
    "required": ["ticker"]
  }
}

```

This schema enables:

- **LLM Understanding:** The model knows available tools and their parameters
- **Validation:** Inputs are checked against types before execution
- **Documentation:** Clear descriptions guide model usage
- **Interoperability:** Standard format works across frameworks

**3.6.5 The Tool-Augmented LLM Pattern** The integration of tools with LLMs follows a recurring pattern in agent frameworks [6, 10]:



This pattern, associated with reasoning-action workflows such as ReAct and related agent frameworks, enables LLMs to [6, 10]:

- Access information beyond their training data
- Perform computations beyond their parametric capacity
- Interact with external systems and APIs
- Verify facts through live data sources

The smolagents implementation provides this pattern through lightweight framework abstractions [10, 12].

**3.6.6 Tool Security and Sandboxing** Security is critical when agents execute generated code. Current smolagents patterns center on executor selection plus environment controls [10, 12]:

**Executor selection:**

```

from smolagents import CodeAgent, InferenceClientModel

agent = CodeAgent(
    tools=tools,
    model=InferenceClientModel("meta-llama/Llama-3.3-70B-Instruct"),
)

```

```

        additional_authorized_imports=["math", "datetime"],
        executor_type="docker",    # examples: local, docker, e2b, modal, wasm
        executor_kwargs={...},      # backend-specific settings
)

```

Network policy, CPU/memory limits, and host restrictions are typically enforced by the selected execution backend (container/runtime platform), not by a single universal smolagents runtime API. These controls support safer deployment patterns, but production safety still depends on environment-specific hardening and policy review [10, 12].

### 3.7 Deployment and Production

#### 3.7.1 Deployment Patterns Local Deployment:

```

# FastAPI wrapper for local serving
from fastapi import FastAPI
from smolagents import CodeAgent

app = FastAPI()
agent = CodeAgent(tools=[...], model=model)

@app.post("/chat")
async def chat(request: ChatRequest):
    response = agent.run(request.message)
    return {"response": response}

```

#### Containerized Deployment:

```

FROM python:3.11-slim
WORKDIR /app
COPY requirements.txt .
RUN pip install -r requirements.txt
COPY .
EXPOSE 8000
CMD ["uvicorn", "main:app", "--host", "0.0.0.0", "--port", "8000"]

```

#### 3.7.2 Monitoring and Observability

```

# Instrumented agent with tracing
from smolagents import CodeAgent
import opentelemetry

class InstrumentedAgent(CodeAgent):
    def run(self, task, **kwargs):
        with tracer.start_as_current_span("agent_run") as span:
            span.set_attribute("task", task)
            start_time = time.time()

```

```

    result = super().run(task, **kwargs)

    span.set_attribute("duration", time.time() - start_time)
    span.set_attribute("steps", len(self.memory))
    span.set_attribute("tools_used", list(self.tools.keys()))

    return result

```

---

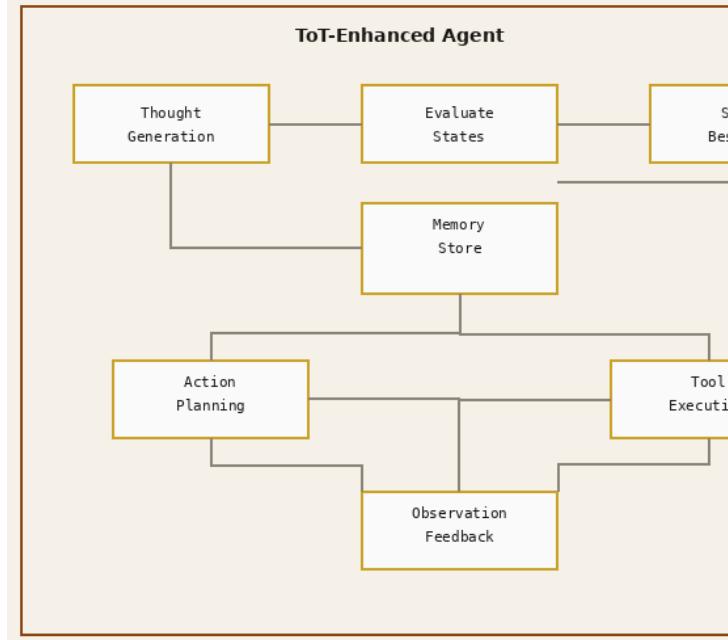
## 4. Synthesis: Enhancing Hugging Face Agents with Tree of Thoughts

### 4.1 The Convergence of Reasoning and Action

This section describes a design synthesis: combining Tree of Thoughts with Hugging Face agents. While Hugging Face agents provide strong tooling interfaces, many workflows still use linear reasoning traces. A ToT-style planner can introduce [1, 10, 12]:

1. **Explore multiple solution strategies** before committing to actions
2. **Evaluate tool sequences** before execution
3. **Backtrack from unsuccessful tool calls**
4. **Plan multi-step operations** with lookahead evaluation
5. **Recover from errors** through alternative reasoning paths

## 4.2 Architectural Integration



### 4.2.1 ToT-Enhanced Agent Architecture

### 4.2.2 Implementation Sketch (Pseudo-code): ToT Code Agent

```

from smolagents import CodeAgent, InferenceClientModel
from typing import List, Dict, Any
import heapq

class TreeOfThoughtsCodeAgent(CodeAgent):
    """Agent that uses Tree of Thoughts for planning before execution."""

    def __init__(self, *args, beam_width=3, max_depth=5, **kwargs):
        super().__init__(*args, **kwargs)
        self.beam_width = beam_width
        self.max_depth = max_depth

    def generate_thoughts(self, task: str, current_state: str, k: int) -> List[str]:
        """Generate k candidate next steps."""
        prompt = f"""
Given the task: {task}
And current progress: {current_state}

Generate {k} different possible next actions. Each action should be
a concrete step toward solving the problem. Be diverse in your approaches.
        """

```

```

Format as a numbered list:
1. [First approach]
2. [Second approach]
...
"""

    response = self.model.generate(prompt)
    thoughts = self._parse_numbered_list(response, k)
    return thoughts

def evaluate_thought(self, task: str, thought: str, history: List[str]) -> float:
    """Score a thought's promise (0-10)."""
    prompt = f"""
Task: {task}
Proposed action: {thought}
History so far: {' -> '.join(history)}

Rate how promising this action is on a scale of 0-10:
- 0-3: Likely incorrect or counterproductive
- 4-6: Might help but uncertain
- 7-10: Clearly advances toward solution

Return ONLY a number between 0 and 10.
"""
    try:
        score_text = self.model.generate(prompt).strip()
        return float(score_text.split()[0])
    except:
        return 5.0 # Default to uncertain

def beam_search_planning(self, task: str) -> List[str]:
    """Use beam search to find best action sequence."""
    # Initialize: [(score, actions, state)]
    beams = [(0.0, [], "Initial state")]

    for depth in range(self.max_depth):
        candidates = []

        for score, actions, state in beams:
            # Generate next thoughts
            thoughts = self.generate_thoughts(task, state, self.beam_width)

            for thought in thoughts:
                # Simulate action (lightweight evaluation)
                new_state = f"{state} -> {thought}"
                new_actions = actions + [thought]

```

```

        # Evaluate
        value = self.evaluate_thought(task, thought, actions)
        total_score = score + value

        candidates.append((total_score, new_actions, new_state))

    # Keep top beams
    beams = heapq.nlargest(self.beam_width, candidates, key=lambda x: x[0])

    # Return best action sequence
    return beams[0][1] if beams else []

def run(self, task: str, **kwargs):
    """Execute with ToT planning."""
    # Phase 1: Plan with Tot
    print("Planning with Tree of Thoughts...")
    action_plan = self.beam_search_planning(task)
    print(f"Selected plan: {action_plan}")

    # Phase 2: Execute planned actions
    # (simplified - full implementation would integrate with CodeAgent execution)
    return self.execute_plan(task, action_plan)

# Usage
agent = TreeOfThoughtsCodeAgent(
    tools=[search_tool, calculator_tool],
    model=InferenceClientModel("meta-llama/Llama-3.3-70B-Instruct"),
    beam_width=3,
    max_depth=4
)

result = agent.run("""
Analyze the economic impact of AI on job markets.
Search for recent data, calculate key statistics,
and summarize the findings.
""")

```

#### 4.3 Design-Level Benefits (Hypothesized)

**4.3.1 Improved Tool Selection Problem:** Agents often select suboptimal tools or sequences.

**ToT Solution:** Explore multiple tool sequences before execution.

```

# Traditional approach
def traditional_agent(task):
    thought = model.generate(f"What tool for: {task}?"")

```

```

tool_call = parse_tool(thought)
result = execute(tool_call)
# No alternative considered

# ToT-enhanced approach
def tot_agent(task):
    candidates = [
        "Use web_search then summarize",
        "Use calculator then web_search",
        "Use knowledge_base directly"
    ]

    # Simulate and evaluate each
    scores = [evaluate_path(task, path) for path in candidates]
    best = candidates[argmax(scores)]

    return execute(best)

```

#### Example - Complex Query:

Task: "Compare Tesla and BYD stock performance over the last year"

ToT Exploration:

```

|-- Path A: Search for both, then compare
|   |-- Step 1: search("Tesla stock 2024")
|   |-- Step 2: search("BYD stock 2024")
|   `-- Step 3: calculate(comparison_metrics)
|   `-- Heuristic rating: medium (detailed but may miss real-time data)
|
|-- Path B: Use stock API directly
|   |-- Step 1: stock_api("TSLA", period="1y")
|   |-- Step 2: stock_api("BYD", period="1y")
|   `-- Step 3: calculate_performance_comparison
|   `-- Heuristic rating: high (precise data, structured output)
|
`-- Path C: Search for analysis articles
    `-- Heuristic rating: low (subjective, may be outdated)

```

Selected: Path B for accuracy and reliability

**4.3.2 Error Recovery and Backtracking Problem:** When tool calls fail, agents often get stuck or produce incorrect results.

**ToT Solution:** Maintain alternative paths for backtracking.

```

class RecoverableAgent(TreeOfThoughtsCodeAgent):
    def execute_with_recovery(self, action_plan):

```

```

for i, action in enumerate(action_plan):
    try:
        result = self.execute_action(action)
        if self.verify_result(result):
            continue
        else:
            # Result suspicious, try alternative
            alternatives = self.generate_alternatives(action, i)
            for alt in alternatives:
                result = self.execute_action(alt)
                if self.verify_result(result):
                    break
    except Exception as e:
        # Action failed, backtrack
        self.log_error(action, e)
        if i > 0:
            # Try different path at previous step
            return self.replan_from_step(i - 1)

return self.compile_results()

```

#### 4.3.3 Multi-Step Planning Example - Research Workflow:

Task: "Prepare a market analysis report on electric vehicles"

ToT Planning Tree:

```

|-- Research Phase
|   |-- Branch A: Industry reports -> Company filings -> News
|   |-- Branch B: Academic papers -> Expert interviews -> Data
|   `-- Branch C: News first -> Trending topics -> Deep dive
|
|-- Analysis Phase
|   |-- Option 1: Statistical analysis of collected data
|   |-- Option 2: Comparative analysis across companies
|   `-- Option 3: Trend projection with forecasting
|
`-- Synthesis Phase
    |-- Format A: Executive summary + detailed appendix
    |-- Format B: Structured SWOT analysis
    `-- Format C: Narrative with visualizations

```

Evaluation selects:

- Research: Branch A (most detailed)
- Analysis: Option 2 (best for market comparison)
- Format: Format C (most accessible)

Execution Plan:

```
|-- Week 1: Filter development + testing  
|-- Week 2-3: Soft launch with beta users  
|-- Week 4: Full campaign launch  
|-- Week 5-6: Monitor and optimize  
`-- Week 7: Results analysis and report
```

#### 4.4 Case Studies

*Evidence note:* The case studies in this section are synthetic walkthroughs for design illustration. They are not reported benchmark experiments.

**4.4.1 Case Study 1: Financial Analysis Agent Scenario:** Analyze a company's quarterly earnings.

**Traditional Agent:**

```
Step 1: Search for "Company Q3 2024 earnings"  
Step 2: Extract revenue figure  
Step 3: Calculate YoY growth  
# May miss detailed breakdowns, context, or comparative analysis
```

**ToT-Enhanced Agent:**

Planning Phase (ToT):

```
|-- Strategy A: Quick summary from news articles  
|   `-- Heuristic rating: low (fast but shallow)  
|  
|-- Strategy B: Official SEC filings analysis  
|   |-- 10-Q form deep dive  
|   |-- Balance sheet analysis  
|   `-- Cash flow evaluation  
|   `-- Heuristic rating: high (authoritative, detailed)  
|  
|-- Strategy C: Aggregator platforms + social sentiment  
|   `-- Heuristic rating: medium (good context but may lack details)  
|  
`-- Selected: Strategy B with supplementary search
```

Execution:

```
|-- Step 1: Retrieve 10-Q filing  
|-- Step 2: Extract key metrics (revenue, EPS, guidance)  
|-- Step 3: Compare to analyst estimates  
|-- Step 4: Analyze segment performance  
|-- Step 5: Check cash position and debt  
`-- Step 6: Search for management commentary
```

Result pattern: structured report with multiple evidence sources

**4.4.2 Case Study 2: Creative Content Agent** Scenario: Write a marketing campaign with specific constraints.

**Constraints:**

- Target: Gen Z audience
- Channels: TikTok, Instagram
- Theme: Sustainability
- Budget: \$50K

**ToT Exploration:**

Creative Concepts:

```
|-- Concept A: Influencer partnerships
|   |-- Micro-influencer strategy
|   |-- Challenge campaign
|   `-- UGC incentives
|   `-- Estimated reach: not estimated in this illustrative example (would require campaign
|
|-- Concept B: Interactive AR filters
|   |-- Branded filter creation
|   |-- Sustainability quiz
|   `-- Share-to-plant initiative
|   `-- Estimated reach: not estimated in this illustrative example (would require campaign
|
`-- Concept C: Behind-the-scenes documentary
    |-- Series of short videos
    |-- Supply chain transparency
    `-- Employee stories
    `-- Estimated reach: not estimated in this illustrative example (would require campaign
```

Evaluation Criteria:

- Budget fit (weight: 25%)
- Brand alignment (weight: 30%)
- Engagement potential (weight: 30%)
- Measurability (weight: 15%)

Selected: Concept B (best engagement/cost ratio)

Execution Plan:

```
|-- Week 1: Filter development + testing
|-- Week 2-3: Soft launch with beta users
|-- Week 4: Full campaign launch
|-- Week 5-6: Monitor and optimize
`-- Week 7: Results analysis and report
```

#### 4.4.3 Case Study 3: Debugging Assistant Scenario:

Debug a failing Python script.

Error: `AttributeError: 'NoneType' object has no attribute 'strip'`

##### ToT Agent Approach:

###### Hypothesis Generation:

```
|-- H1: Function returns None before .strip() is called
|   '-- Likelihood: High
|
|-- H2: Variable overwritten with None somewhere
|   '-- Likelihood: Medium
|
|-- H3: Conditional branch not handling None case
|   '-- Likelihood: High
|
`-- H4: External API returning None unexpectedly
    '-- Likelihood: Low (no API calls in traceback)
```

###### Investigation Plan:

1. Check function return paths (test H1, H3)
2. Trace variable assignments (test H2)
3. Add defensive checks if needed

###### Execution:

```
|-- Step 1: Insert print statements to identify None source
|-- Step 2: Discover regex match returning None
|-- Step 3: Add null check: `if match: result = match.group(1).strip()`
|-- Step 4: Test fix
`-- Step 5: Verify edge cases
```

Resolution pattern: null-handling fix after hypothesis-driven tracing

## 4.5 Comparative Analysis (Qualitative, Non-Benchmark)

Dimension	Common Baseline Pattern	ToT-Style Pattern
Action selection	Single-path next-step decision	Multi-candidate path exploration
Error handling	Retry or fail-forward	Backtracking to alternative branches
Planning horizon	Short-horizon or reactive planning	Explicit lookahead over multiple steps
Compute and cost	Lower branching cost	Higher branching/evaluation overhead
Reproducibility requirements	Single-run outputs often sufficient for demos	Requires search config disclosure

*Note:* This section does not report new experimental measurements. Quantitative benchmark values are consolidated in Appendix C with source attribution.

## 5. Practical Implementation Strategies

**Pseudo-code notice.** Most snippets in this section are design templates for adaptation, not drop-in production code. Validate APIs and runtime behavior against current framework documentation before deployment.

### 5.1 Getting Started

#### 5.1.1 Environment Setup

```
# Create virtual environment
python -m venv agent_env
source agent_env/bin/activate

# Install dependencies
pip install smolagents transformers
pip install torch accelerate

# Optional: for specific model providers
pip install openai anthropic
```

#### 5.1.2 Basic ToT Agent Template (Pseudo-code)

```
from smolagents import CodeAgent, InferenceClientModel
from dataclasses import dataclass
from typing import List, Tuple
import heapq

@dataclass
class ThoughtNode:
    thought: str
    parent: 'ThoughtNode' = None
    score: float = 0.0
    depth: int = 0

    def path(self) -> List[str]:
        """Get path from root to this node."""
        if self.parent is None:
            return [self.thought]
        return self.parent.path() + [self.thought]

class SimpleToTAgent(CodeAgent):
    """Minimal Tree of Thoughts implementation for smolagents."""

    def __init__(self, beam_width=3, max_depth=4, **kwargs):
        super().__init__(**kwargs)
        self.beam_width = beam_width
```

```

        self.max_depth = max_depth

    def solve_with_tot(self, problem: str) -> str:
        """Solve problem using Tree of Thoughts."""
        # Initialize root
        root = ThoughtNode(thought="Start")
        beams = [root]

        for depth in range(self.max_depth):
            candidates = []

            for node in beams:
                # Generate next thoughts
                prompt = self._build_generation_prompt(
                    problem, node.path()
                )
                thoughts = self._generate_candidates(prompt, self.beam_width)

                for thought in thoughts:
                    # Create child node
                    child = ThoughtNode(
                        thought=thought,
                        parent=node,
                        depth=depth + 1
                    )

                    # Evaluate
                    eval_prompt = self._build_evaluation_prompt(
                        problem, child.path()
                    )
                    child.score = self._evaluate(eval_prompt)

                    candidates.append(child)

            # Select top beams
            beams = heapq.nlargest(
                self.beam_width,
                candidates,
                key=lambda n: n.score
            )

            # Check for solution
            for node in beams:
                if self._is_solution(problem, node.path()):
                    return self._format_solution(node.path())

```

```

# Return best path found
best = max(beams, key=lambda n: n.score)
return self._format_solution(best.path())

def _build_generation_prompt(self, problem: str, path: List[str]) -> str:
    return f"""Given the problem: {problem}

Current progress: {' -> '.join(path)}"""

Generate 3 different next steps to continue solving this problem.
Be creative and consider different approaches.

Steps:"""

def _build_evaluation_prompt(self, problem: str, path: List[str]) -> str:
    return f"""Given the problem: {problem}

Progress so far: {' -> '.join(path)}"""

Rate how promising this approach is on a scale of 0-10,
where 0 means definitely wrong and 10 means definitely correct.

Rating:""""

def _generate_candidates(self, prompt: str, k: int) -> List[str]:
    """Generate k thought candidates."""
    response = self.model.generate(prompt)
    # Parse numbered list
    thoughts = []
    for line in response.split('\n'):
        if line.strip() and (line[0].isdigit() or line.startswith('-')):
            thoughts.append(line.split('. ', 1)[-1].strip(' - '))
    return thoughts[:k]

def _evaluate(self, prompt: str) -> float:
    """Get evaluation score."""
    try:
        response = self.model.generate(prompt).strip()
        # Extract first number
        import re
        match = re.search(r'(\d+(?:\.\d+)?)', response)
        if match:
            return float(match.group(1))
    except:
        pass
    return 5.0 # Default

```

```

def _is_solution(self, problem: str, path: List[str]) -> bool:
    """Check if path represents complete solution."""
    prompt = f"Does this solve the problem?\nProblem: {problem}\nSolution: {'-' * len(path)}\n"
    response = self.model.generate(prompt).strip().lower()
    return 'yes' in response

def _format_solution(self, path: List[str]) -> str:
    """Format final solution."""
    return "\n".join(f"Step {i+1}: {step}" for i, step in enumerate(path))

# Usage
agent = SimpleToTAgent(
    tools=[],
    model=InferenceClientModel("microsoft/Phi-3-mini-4k-instruct"),
    beam_width=3,
    max_depth=4
)

result = agent.solve_with_tot("""
Create a Python function that finds the most frequent word
in a text file, handling case insensitivity and ignoring punctuation.
""")

```

## 5.2 Advanced Implementation Patterns

### 5.2.1 Hybrid CoT-ToT Agent

```

class HybridReasoningAgent(CodeAgent):
    """Switches between CoT and ToT based on problem complexity."""

    def __init__(self, complexity_threshold=7, **kwargs):
        super().__init__(**kwargs)
        self.complexity_threshold = complexity_threshold

    def assess_complexity(self, task: str) -> int:
        """Rate task complexity 1-10."""
        prompt = f"""Rate the complexity of this task from 1-10:
1 = Simple single-step task
5 = Multi-step with clear sequence
10 = Requires exploration, creativity, or has ambiguity

Task: {task}

Complexity (1-10):"""

```

```

try:
    response = self.model.generate(prompt).strip()
    return int(response.split()[0])
except:
    return 5

def run(self, task: str, **kwargs):
    complexity = self.assess_complexity(task)

    if complexity < self.complexity_threshold:
        # Use standard CoT
        print(f"Complexity {complexity}/10: Using Chain of Thought")
        return super().run(task, **kwargs)
    else:
        # Use ToT
        print(f"Complexity {complexity}/10: Using Tree of Thoughts")
        return self.solve_with_tot(task)

```

### 5.2.2 Adaptive ToT Agent

```

class AdaptiveToTAgent(CodeAgent):
    """Adapts beam width and depth based on problem characteristics."""

    def __init__(self, **kwargs):
        super().__init__(**kwargs)
        self.default_beam_width = 3
        self.default_max_depth = 4

    def adaptive_solve(self, task: str) -> str:
        """Adaptively configure ToT parameters."""
        # Estimate parameters based on task
        config = self.estimate_config(task)

        self.beam_width = config['beam_width']
        self.max_depth = config['max_depth']

        print(f"Adaptive config: beam={self.beam_width}, depth={self.max_depth}")

        return self.solve_with_tot(task)

    def estimate_config(self, task: str) -> dict:
        """Estimate optimal ToT parameters."""
        prompt = f"""Given this task, estimate:
1. How many alternative approaches should be considered (2-5)?
2. How many steps are likely needed (2-6)?"""

```

Task: {task}

Format: "Approaches: X, Steps: Y"""

```
response = self.model.generate(prompt)

import re
approaches = re.search(r'Approaches:\s*(\d+)', response)
steps = re.search(r'Steps:\s*(\d+)', response)

return {
    'beam_width': int(approaches.group(1)) if approaches else 3,
    'max_depth': int(steps.group(1)) if steps else 4
}
```

## 5.3 Optimization Techniques

### 5.3.1 Caching Strategies

```
from functools import lru_cache
import hashlib

class CachedToTAgent(CodeAgent):
    """ToT Agent with result caching."""

    def __init__(self, **kwargs):
        super().__init__(**kwargs)
        self.evaluation_cache = {}
        self.generation_cache = {}

    def cached_evaluate(self, prompt: str) -> float:
        """Cache evaluation results."""
        key = hashlib.md5(prompt.encode()).hexdigest()

        if key not in self.evaluation_cache:
            self.evaluation_cache[key] = self._evaluate(prompt)

        return self.evaluation_cache[key]

    def cached_generate(self, prompt: str, k: int) -> List[str]:
        """Cache generation results."""
        key = hashlib.md5(prompt.encode()).hexdigest()

        if key not in self.generation_cache:
            self.generation_cache[key] = self._generate_candidates(prompt, k)
```

```
    return self.generation_cache[key]
```

### 5.3.2 Early Termination

```
class EarlyTerminationAgent(CodeAgent):
    """Stops exploration when confident in solution."""

    def __init__(self, confidence_threshold=0.9, **kwargs):
        super().__init__(**kwargs)
        self.confidence_threshold = confidence_threshold

    def should_terminate(self, beams: List[ThoughtNode]) -> bool:
        """Check if best beam is sufficiently confident."""
        if not beams:
            return False

        best = max(beams, key=lambda n: n.score)

        # Normalize score to probability
        confidence = best.score / 10.0

        return confidence >= self.confidence_threshold
```

### 5.4 Testing and Validation

```
import unittest
from unittest.mock import Mock

class TestToTAgent(unittest.TestCase):
    def setUp(self):
        self.mock_model = Mock()
        self.agent = SimpleToTAgent(
            tools=[],
            model=self.mock_model
        )

    def test_thought_generation(self):
        """Test thought generation."""
        self.mock_model.generate.return_value = """
1. First approach
2. Second approach
3. Third approach
"""

        thoughts = self.agent._generate_candidates("test", 3)
        self.assertEqual(len(thoughts), 3)
```

```

    self.assertEqual(thoughts[0], "First approach")

def test_evaluation_parsing(self):
    """Test score extraction."""
    self.mock_model.generate.return_value = "Score: 8.5 out of 10"

    score = self.agent._evaluate("test prompt")
    self.assertEqual(score, 8.5)

def test_solution_detection(self):
    """Test solution identification."""
    self.mock_model.generate.return_value = "Yes, this is complete."

    is_solution = self.agent._is_solution("test", ["step1", "step2"])
    self.assertTrue(is_solution)

if __name__ == '__main__':
    unittest.main()

```

---

## 6. Future Directions and Recommendations

### 6.1 Research Directions

**6.1.1 Learned Evaluation Functions** Current ToT implementations rely on LLM-based evaluation, which can be inconsistent. Future research should explore [1, 2]:

- **Neural evaluators:** Train dedicated models to evaluate thought quality
- **Reinforcement learning:** Learn evaluation functions from task success
- **Human feedback integration:** Incorporate RLHF to calibrate evaluators
- **Domain adaptation:** Transfer evaluation functions across related tasks

**Research Question:** Can we learn a universal thought evaluator that generalizes across domains?

**6.1.2 Multi-Modal Tree of Thoughts** Extend ToT to multi-modal reasoning:

```

Visual Thought Tree:
|-- Image understanding nodes
|-- Visual reasoning branches
`-- Cross-modal integration points

```

Example Task: "Design a logo based on these brand values"  
 |-- Generate visual concepts (image generation)

```

|-- Evaluate against brand guidelines (vision + text)
`-- Iterate on promising designs

```

### 6.1.3 Hierarchical ToT

Implement recursive tree structures:

```

High-Level Tree:
|-- Phase 1: Research
|   `-- Low-Level Tree (research strategies)
|-- Phase 2: Analysis
|   `-- Low-Level Tree (analysis methods)
`-- Phase 3: Synthesis
   `-- Low-Level Tree (writing approaches)

```

This design direction could allow agents to reason at multiple levels of abstraction [1, 2].

### 6.1.4 Collaborative ToT

Multiple agents exploring shared thought spaces:

```

class CollaborativeToT:
    """Multiple agents exploring and sharing thoughts."""

    def __init__(self, agents: List[CodeAgent]):
        self.agents = agents
        self.shared_memory = {}

    def collaborative_solve(self, task):
        # Agents take turns exploring
        # Share promising paths
        # Build on each other's discoveries
        pass

```

## 6.2 Industry Applications

### 6.2.1 Scientific Discovery Platforms

As a forward-looking hypothesis, ToT-enhanced agents could accelerate research workflows:

- **Hypothesis generation:** Explore multiple research directions
- **Experiment design:** Plan optimal experimental sequences
- **Literature synthesis:** Connect findings across papers
- **Error recovery:** Backtrack from failed experiments

### 6.2.2 Automated Software Engineering

- **Architecture design:** Explore multiple design patterns
- **Debugging:** Systematically test hypotheses about bugs
- **Code review:** Check multiple quality dimensions
- **Refactoring:** Plan safe transformation sequences

### 6.2.3 Strategic Business Planning

- **Market analysis:** Explore multiple competitive scenarios
- **Product development:** Evaluate feature combinations
- **Risk assessment:** Consider multiple risk mitigation strategies

## 6.3 Recommendations for Practitioners

### 6.3.1 Start Simple, Scale Gradually

1. **Phase 1:** Implement basic agent with smolagents
2. **Phase 2:** Add simple ToT for critical decisions
3. **Phase 3:** Expand to full ToT with search
4. **Phase 4:** Optimize with caching and early termination

### 6.3.2 Hybrid Approach Guidelines

Task Type	Recommended Approach	Rationale
Simple Q&A	Direct prompting	Overhead not justified
Multi-step tasks	Chain of Thought	Clear sequential structure
Creative tasks	ToT with wide beam	Need exploration
Debugging	ToT with DFS	Deep exploration needed
Planning	ToT with beam search	Balance exploration/exploitation

6.3.3 Monitoring and Metrics Track these metrics for ToT agents:

- **Search efficiency:** Solutions found per evaluation
- **Path diversity:** Unique paths explored
- **Backtrack frequency:** How often recovery needed
- **User satisfaction:** Task completion quality
- **Cost per task:** API calls and latency

## 6.4 Ethical Considerations

6.4.1 Transparency ToT can provide interpretability through explicit reasoning trees and branch histories [1]:

```
def explain_decision(agent, task, result):
    """Generate explanation from ToT tree."""
    explanation = f"""
    Decision Process for: {task}

    Alternative paths considered:
    {format_tree(agent.search_tree)}

    Selected path reasoning:
    {result.selected_path.justification}
```

```

Rejected alternatives and why:
{format_rejected_paths(agent.search_tree)}
"""
return explanation

```

#### 6.4.2 Safety Considerations

- **Path validation:** Verify generated thoughts for safety
- **Sandbox execution:** Run tool calls in isolated environments
- **Human oversight:** Review high-stakes decisions
- **Audit logging:** Maintain records of thought processes

#### 6.5 Threats to Validity (Survey-Specific)

**Selection bias:** The current synthesis is anchored on a core corpus and may miss relevant negative or null-result studies until the frozen-search rerun and full exclusion log are completed [27, 28, 29, 30].

**Benchmark heterogeneity:** Reported results across ToT-family papers are not always directly comparable due to differences in model versions, prompting protocols, evaluation metrics, and compute budgets [1, 26].

**Reporting bias:** Agent and reasoning papers often emphasize successful cases. Where failure analyses are absent or partial, this survey may inherit optimistic framing unless explicitly qualified [8, 9].

**Framework drift:** Tooling and APIs in agent frameworks evolve rapidly; implementation-level claims can become stale if not periodically revalidated against current documentation [10, 11, 13].

**External validity:** Results from puzzle-like reasoning benchmarks (e.g., Game of 24, mini crosswords) may not transfer directly to production environments with tool failures, noisy data, and changing constraints [1, 26].

## 7. Conclusion

### 7.1 Key Findings

Within the evidence and scope limits of this survey, the main takeaways are:

1. **Tree of Thoughts can improve performance on specific reasoning tasks;** cited literature reports strong gains on tasks such as Game of 24 [1, 26].
2. **Hugging Face agents provide accessible frameworks** for building autonomous AI systems, with smolagents designed for lightweight implementation patterns [10, 11, 12].

3. **The synthesis of ToT and agent frameworks** is a viable design space for complex multi-step tasks, but integration-specific gains require dedicated empirical evaluation [1, 6, 26].
4. **Practical implementation** requires careful consideration of search strategies, evaluation functions, API compatibility, and computational trade-offs [1, 10, 12, 26].

## 7.2 Contributions

This paper makes several contributions:

1. **Detailed technical analysis** of ToT from theoretical foundations to practical implementations
2. **Detailed framework documentation** of Hugging Face Agent Course and smolagents
3. **Technical synthesis** showing how ToT can enhance agent architectures with concrete examples
4. **Practical guidance** for implementation, optimization, and deployment
5. **Future research directions** spanning learned evaluators, multi-modal reasoning, and collaborative exploration

## 7.3 The Path Forward

Structured reasoning frameworks and accessible agent platforms define a concrete research and engineering direction. Based on current literature and tooling trends, this survey proposes the following near-term hypotheses [1, 8, 9, 10, 12, 26]:

- **Accessible open-source adoption:** More developers will build sophisticated reasoning agents
- **Standardization:** Common patterns and best practices will emerge
- **Integration:** ToT will become a standard feature in agent frameworks
- **Specialization:** Domain-specific implementations for science, engineering, creative tasks
- **Efficiency:** Optimized implementations reducing computational overhead

A practical hypothesis from this survey is that agent capability depends on both model scale and reasoning structure [1, 26].

## 7.4 Final Remarks

This paper examines two developments in AI practice: Tree of Thoughts reasoning and the Hugging Face agent ecosystem. The synthesis provides an implementation-oriented map of what is currently supported by literature, what is engineering guidance, and what remains to be validated experimentally [1, 10, 12, 26].

For practitioners, the immediate value is methodological: explicit search design, clear evaluator choices, and reproducible benchmark boundaries. For researchers, the primary open task is integration-specific benchmarking under controlled settings [1, 26, 27, 28, 29, 30].

In short, the field has usable tools and clear open questions; progress now depends on reproducible experiments and careful claim discipline [1, 8, 9, 26].

---

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- 

## Appendix A: Glossary of Terms

- **Agent:** An autonomous system that perceives its environment and takes actions to achieve goals
- **Beam Search:** A heuristic search algorithm that explores a graph by expanding the most promising nodes in a limited set (beam)
- **Chain of Thought (CoT):** Prompting technique where models generate intermediate reasoning steps
- **DFS (Depth-First Search):** Search algorithm that explores as far as possible along each branch before backtracking
- **BFS (Breadth-First Search):** Search algorithm that explores all nodes at the present depth before moving to next level
- **LLM (Large Language Model):** Neural network trained on vast text corpora for language understanding and generation

- **MCTS (Monte Carlo Tree Search):** Search algorithm using random sampling to explore decision spaces
- **ReAct:** Framework combining Reasoning and Acting in language models
- **smolagents:** Hugging Face's lightweight agent framework
- **Thought:** In ToT, a coherent language sequence representing an intermediate reasoning step
- **ToT (Tree of Thoughts):** Reasoning framework modeling problem-solving as tree search over thoughts
- **Tool-Augmented LLM:** Language model extended with external tool capabilities

## Appendix B: Quick Reference Implementation

```
"""
Quick Start: Tree of Thoughts with smolagents
=====

This minimal example demonstrates ToT integration with Hugging Face agents.

"""

from smolagents import CodeAgent, InferenceClientModel, tool
import heapq
from typing import List

@tool
def evaluate_math(expression: str) -> float:
    """Evaluate a mathematical expression."""
    return eval(expression)

class MinimalToTAgent(CodeAgent):
    """Minimal ToT implementation for demonstration."""

    def tot_solve(self, task: str, beam_width: int = 3, max_depth: int = 4):
        # Initialize beams with starting thought
        beams = [(0, [])] # (score, path)

        for depth in range(max_depth):
            candidates = []

            for score, path in beams:
                # Generate next thoughts
                prompt = f"Task: {task}\nCurrent steps: {path}\nNext step ideas:"
                thoughts = self.model.generate(prompt).split('\n')[:beam_width]

                for thought in thoughts:
                    new_path = path + [thought]
                    candidates.append((new_path, score))

            beams = heapq.nlargest(beam_width, candidates, key=lambda x: x[1])

MinimalToTAgent()

```

```

# Simple evaluation (could be more sophisticated)
eval_prompt = f"Rate quality 0-10: {new_path}"
try:
    new_score = float(self.model.generate(eval_prompt)[:2])
except:
    new_score = 5.0

candidates.append((new_score, new_path))

# Keep top beams
beams = heapq.nlargest(beam_width, candidates, key=lambda x: x[0])

# Return best path
return beams[0][1] if beams else []

# Usage
agent = MinimalToTAgent(
    tools=[evaluate_math],
    model=InferenceClientModel("microsoft/Phi-3-mini-4k-instruct")
)

result = agent.tot_solve("Calculate compound interest on $1000 at 5% for 3 years")
print("Solution path:", result)

```

## Appendix C: Benchmark Evidence (Reported Results)

This appendix reports values from cited papers. These are prior-work benchmark results, not new measurements from this document.

### C.1 Original Tree of Thoughts Results (Yao et al., 2023) [1]

#### Game of 24 (success rate)

Method	Success Rate
IO prompt [1]	7.3%
CoT prompt [1]	4.0%
CoT-SC (k=100) [1]	9.0%
ToT (b=1) [1]	45%
ToT (b=5) [1]	74%

#### Creative Writing (coherency score)

Method	GPT-4	GPT-3.5
IO [1]	6.19	4.47

CoT [1]	6.93	5.16
ToT [1]	7.56	6.62

*Human pairwise preference (ToT vs CoT, 100 passages):* ToT preferred in 41, CoT preferred in 21, tie in 38 [1].

#### Mini Crosswords (success rate)

Method	Letter	Word	Game
IO [1]	38.7%	14%	0%
CoT [1]	40.6%	15.6%	1%
ToT [1]	78%	60%	20%

#### C.2 Independent Follow-up Evidence (Klein et al., 2025, ICML) [26]

Independent work reports strong comparative results on Game of 24 and Mini Crosswords using the same benchmark families [26].

#### Game of 24 (GPT-4, success rate and cost)

Method	Success Rate	Cost (US\$)
IO [26]	6.0%	0.65
CoT [26]	6.0%	6.98
CoT-SC [26]	10.0%	49.40
ToT [26]	74.0%	75.02
FoA [26]	76.0%	62.93

#### Mini Crosswords (GPT-4, overlap and cost)

Method	Overlap	Cost (US\$)
IO [26]	36.8%	0.51
CoT [26]	39.4%	1.06
CoT-SC [26]	39.4%	2.82
ToT [26]	39.7%	49.99
GoT [26]	41.2%	30.28
FoA [26]	46.0%	12.94

#### C.3 Evidence Boundary

As of February 19, 2026, we found independent scholarly follow-up support for Game of 24 and Mini Crosswords, but not a like-for-like independent replication

of the original ToT creative-writing setup with the same metric protocol [1, 26]. Creative-writing values above should therefore be treated as original-paper reported results.

## Appendix D: Study Selection Flow (Frozen Run: 2026-02-19)

This appendix records the frozen selection run for the current manuscript version (Run ID: TOT-HF-SURVEY-2026-02-19). The reporting format follows PRISMA-style transparency principles [27], adapted to computer-science evidence synthesis [28, 29, 30].

### D.1 Fixed Selection Counts

Phase	Count	Notes
Records identified	30	Candidate corpus corresponding to Section 8 results
Duplicates removed	0	No duplicate records detected in this frozen count
Records screened (title/abstract)	30	All identified records screened against scope criteria
Records excluded at title/abstract	0	Candidate set was pre-curated for relevance
Full-text records assessed	30	All screened records underwent full-text eligibility assessment
Full-text records excluded (scope mismatch)	8	Reasons listed in D.2
Included in qualitative thematic synthesis	22	Used in conceptual/method/framework synthesis
Included in quantitative benchmark evidence tables	2	Appendix C benchmark tables: [1], [26]

### D.2 Full-Text Exclusion Ledger (Scope Exclusions)

Ref	Source	Exclusion Reason
[14]	BLOOM model paper	General model-release paper; not directly related to safety
[15]	Artificial Intelligence: A Modern Approach	Textbook background source; not a primary research paper
[16]	AlphaGo (Nature 2016)	Historical search precedent; out of direct scope
[17]	Bandit based Monte-Carlo planning	Foundational algorithm paper used for historical context
[19]	Learning to Learn from APIs	Narrow task case study; insufficient alignment with safety goals
[23]	Sociotechnical Safety Evaluation of Generative AI Systems	Broad safety evaluation framework; not directly aligned with ML safety
[24]	On the Opportunities and Risks of Foundation Models	General governance/risk synthesis; outside main focus
[25]	Unsolved Problems in ML Safety	General safety agenda paper; no direct ToT connection

*Versioning note:* Any new records introduced after February 19, 2026 will be tracked as a subsequent run (e.g., TOT-HF-SURVEY-2026-02-19-v2) with separate counts and change log.

## Appendix E: Study Extraction Matrix (Frozen Included Set, n=22)

This appendix provides row-level extraction for every included record in run TOT-HF-SURVEY-2026-02-19. E1/E2/E3 evidence levels are defined in Section 0.2.3.

Ref	Source	Evidence	Record Type
[1]	Tree of Thoughts (NeurIPS 2023)	E1	Empirical method paper
[2]	Large Language Model Guided Tree-of-Thought	E2	Method paper
[3]	Chain-of-Thought Prompting	E1	Empirical baseline paper
[4]	Large Language Models are Zero-Shot Reasoners	E1	Empirical baseline paper
[5]	Self-Consistency Improves CoT	E1	Empirical baseline paper
[6]	ReAct (ICLR)	E1	Empirical agent method paper
[7]	Generative Agents	E2	Agent architecture paper
[8]	A Survey on LLM-Based Autonomous Agents	E2	Survey paper
[9]	The Rise and Potential of LLM-Based Agents	E2	Survey paper
[10]	smolagents Documentation	E3	Official documentation
[11]	Hugging Face Agents Course	E3	Official educational docs
[12]	smolagents Repository	E3	Reference implementation
[13]	Transformers Agents and Tools Docs	E3	Official documentation
[18]	Reflexion	E1	Empirical agent method paper
[20]	Toolformer	E1	Empirical tool-use method paper
[21]	ToolLLM	E1	Empirical tool-use method paper
[22]	Gorilla	E1	Empirical tool-use method paper
[26]	Fleet of Agents (ICML 2025)	E1	Empirical multi-agent paper
[27]	PRISMA 2020 Statement	E2	Reporting standard
[28]	Wohlin 2014 (Snowballing Guidelines)	E2	Methodology guidance
[29]	Wohlin et al. 2022 (DB Search + Snowballing)	E2	Methodology evidence study
[30]	Petersen et al. 2008 (Systematic Mapping Studies)	E2	Methodology guidance

*Scope note:* This table is the full row-level extraction matrix for the 22 included records in the frozen run. Detailed inclusion/exclusion decisions are recorded in `artifacts/screening-log.md`.

---

## Appendix F: Claim-Evidence Mapping

This appendix maps representative manuscript claims to supporting sources and evidence levels.

---

### Claim

ToT reports strong Game of 24 gains versus single-path prompting baselines.  
ToT reports improved mini-crossword success metrics versus IO/CoT baselines.

---

Creative-writing coherency and preference outcomes are reported in the original ToT paper. Independent follow-up reports comparative Game of 24 and mini-crossword benchmark results with cost repository ReAct-style reasoning-action interleaving is a key baseline pattern for tool-using agents. smolagents API examples in this manuscript are aligned to official docs/repository patterns. Agent-survey literature reports recurring planning, reliability, and evaluation challenges. Survey protocol transparency and flow reporting follow PRISMA-style and software-engineering evidence-syntactic patterns.

---

## Appendix G: Revision History

- Version 1.1: neutralized promotional tone and standardized conservative scholarly phrasing across abstract, body, and conclusion.
  - Added Section 0.3 PRISMA-style study-selection flow (Mermaid) and Section 0.4 reproducibility statement with frozen run ID.
  - Added Appendix F claim-evidence mapping table and Appendix G revision log for submission traceability.
  - Updated Appendix C benchmark tables with inline citations on each reported method row and added code-snippet labeling comments throughout.
- 

## Appendix H: Evidence Scope and Validation

This manuscript is accompanied by two evidence layers:

- **Frozen forensic bundle (server scope):** immutable run/log/config evidence captured in `artifacts/publication-evidence/evidence_bundle_20260219T164814Z_v2/`.
- **Local publication-readiness validation (local + collaboration scope):** commit timeline and collaboration transcript evidence in `artifacts/publication-evidence/local-publication-readiness-validation.md`.

Under the combined scope, manuscript readiness is supported by documented autonomous initiation/completion evidence and local human-Codex hardening records, with Grok input treated as advisory.

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**LLM Reviewers:** A clean Markdown version of this paper is available for automated analysis and frontier model review: tot-hf-agents-llm.md

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