

Planning and Reasoning

Week 4: Enabling Agents to Think Before Acting

PhD Course in Agentic Artificial Intelligence

Bloom's Taxonomy Levels

- **Remember:** Define planning, reasoning, reflection in agent context
- **Understand:** Explain hierarchical task decomposition
- **Apply:** Implement Reflexion-style self-improvement
- **Analyze:** Compare planning strategies (LATS = tree search, Plan-and-Solve)
- **Evaluate:** Assess when planning helps vs. hinders performance
- **Create:** Design planning systems for complex tasks

transforms reactive agents into deliberative problem solvers.

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Reactive Agent Limitations

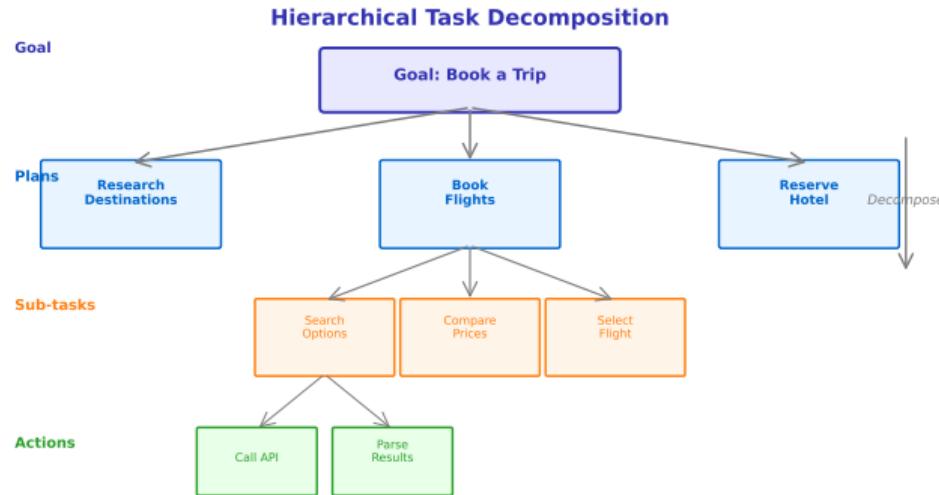
- Single-step responses miss complex dependencies
- No lookahead leads to suboptimal paths
- Hard to recover from early mistakes

Planning Enables

- Multi-step goal decomposition
- Anticipation of obstacles
- Backtracking and alternative paths
- Resource-aware execution

= thinking before acting. Essential for complex tasks.

Hierarchical Task Decomposition



complex goals into manageable sub-tasks and executable actions.

Break

Key Idea (Wang et al., 2023)

- Explicit planning step before execution
- “Devise a plan to solve the problem”
- Extract relevant variables first

Template Structure

- ① Understand the problem
- ② Extract relevant information
- ③ Devise step-by-step plan
- ④ Execute plan with verification

and-Solve improves over zero-shot CoT on math and reasoning.

Key Idea (Zhou et al., 2024)

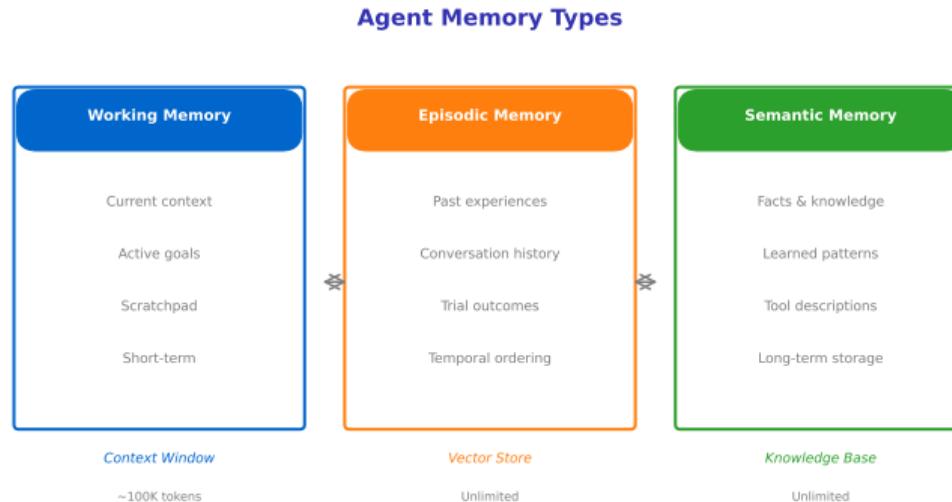
- Combines LLM reasoning with MCTS (Monte Carlo Tree Search)
- Explores multiple reasoning paths in parallel
- Uses value function to guide search

Components

- **Selection:** Choose promising nodes
- **Expansion:** Generate child actions
- **Simulation:** Evaluate outcomes
- **Backpropagation:** Update value estimates

achieves state-of-the-art on HotpotQA (QA) and WebShop benchmarks.

Agent Memory Types



enables learning from past experiences and maintaining context.

Mem

Key Idea (Shinn et al., 2023)

- Verbal reinforcement learning
- Agent reflects on failures and generates insights
- Insights stored in memory for future attempts

Reflexion Loop

- ① Attempt task
- ② Evaluate outcome
- ③ Generate verbal reflection
- ④ Store in episodic memory
- ⑤ Retry with reflection context

improves pass@1 (first-try success) on HumanEval code benchmark: 80% to 91%.

Key Idea (Madaan et al., 2023)

- Iterative self-improvement without external feedback
- Generate, critique, refine cycle
- Single LLM plays multiple roles

Process

- ① **Generate:** Initial output
- ② **Feedback:** Self-critique the output
- ③ **Refine:** Improve based on critique
- ④ Repeat until satisfactory

Refine works for code, math, summarization, and more.

RAP: Reasoning via Planning (Hao et al., 2023)

- LLM as both world model and reasoning agent
- Simulates future states before acting
- Uses MCTS for strategic exploration

Key Components

- **World Model:** Predicts next state given action
- **Reward Model:** Evaluates state quality
- **Search Algorithm:** Explores action space

models enable lookahead reasoning and counterfactual analysis.

When Planning Helps (and Hurts)

Planning Beneficial

- Multi-step reasoning tasks
- Tasks with irreversible actions
- Resource-constrained execution
- Novel problem domains

Planning Overhead

- Simple, well-defined tasks
- Time-critical responses
- Highly dynamic environments
- When exploration cost exceeds benefit

planning depth to task complexity and time constraints.

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Plan-First Architecture

- Generate complete plan before execution
- Good for stable, predictable tasks
- Risk: Plan may be invalid by execution time

Interleaved Planning

- Plan a few steps, execute, replan
- Adapts to changing conditions
- Higher overhead but more robust

Hierarchical Execution

- High-level planner + low-level executor
- Separates strategic and tactical decisions

architecture based on task dynamics and failure costs.

Required Readings

This Week

- Shinn et al. (2023). "Reflexion." arXiv:2303.11366

Supplementary

- Wang et al. (2023). "Plan-and-Solve." arXiv:2305.04091
- Zhou et al. (2024). "LATS." arXiv:2310.04406
- Hao et al. (2023). "RAP." arXiv:2305.14992
- Madaan et al. (2023). "Self-Refine." arXiv:2303.17651

is required; others provide alternative planning approaches.

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Summary and Key Takeaways

Key Concepts

- **Hierarchical Planning:** Decompose goals into sub-tasks
- **Reflexion:** Learn from verbal self-reflection
- **Tree Search:** Explore multiple reasoning paths (LATS)
- **Memory:** Working, episodic, semantic for context

Design Decisions

- Plan-first vs. interleaved planning
- Depth of planning vs. execution speed
- When to reflect and when to retry

Next Week: Multi-Agent Architectures

transforms reactive LLMs into deliberative agents.

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