4.3 Conditional planning

Conditional planning in AI involves creating plans that are flexible and can adapt to uncertain or dynamic environments where information is incomplete or unpredictable. Instead of a fixed sequence of steps, a conditional plan is a "tree" of actions with different branches that are executed based on specific conditions, allowing an agent to respond to various possible outcomes of its actions or changes in its environment.

How it Works

Handles Uncertainty: Conditional planning is designed for situations where an agent doesn't have full knowledge of the environment or where actions can have unpredictable outcomes.

Branching Plans: It generates plans that branch out, with each branch representing a specific scenario or outcome.

Conditional Steps: These plans incorporate "if-then-else" conditions to check the environment at certain points and decide which path to take next.

Continuous Updates: The planning process is ongoing; the agent continually updates and revises its plan as new information becomes available or as the environment changes.

Key Characteristics

Incomplete Information: It's essential for partially observable environments where the true state of the world is not always known.

Non-Deterministic Environments: It can handle non-deterministic actions, where the outcome isn't guaranteed but the possible outcomes are known

(e.g., flipping a coin).

Action and Sensing: It plans for both "actuation actions" (performing an action) and "sensing actions" (gathering information).

Key concepts of conditional planning

Non-deterministic environments: The outcome of an action is not always certain. For example, a "turn wheel" action for a car might not perfectly align with the intended angle due to road conditions.

Partial observability: The agent may not have complete information about the current state of the world. Sensing actions are required to gain more knowledge and reduce uncertainty.

Sensing actions: These are special actions that gather information from the environment. Their outcomes are non-deterministic, and the plan must be prepared for any of the possible results.

Conditional branches: The plan explicitly includes conditional statements (if <condition> then <plan A> else <plan B>) to specify different courses of action for different observed states.

Applications

Conditional planning is used in AI systems that need to operate autonomously and robustly in the real world:

Robotics: A robot navigating a warehouse might have to adjust its path based on the location of newly placed boxes or the presence of people. In service robotics, conditional planning is used to integrate sensing and action for tasks like manipulation and navigation.

Self-driving cars: These vehicles constantly adapt their plans for navigation, recalculating routes based on traffic conditions, unexpected obstacles, or accidents.

Smart assistants: An AI assistant might check a user's location to provide location-specific weather reports. It can then make conditional suggestions, such as advising them to take an umbrella if rain is predicted.

Real-time game strategies: In a dynamic game, an AI opponent can use conditional planning to develop strategies that depend on the uncertain actions of the human player.

Challenges

Computational complexity: The search space for a conditional plan is significantly larger and more complex than for a classical plan. It must account for every possible action outcome, which can lead to a state space that is exponential in size.

Scaling: As the complexity of the environment increases, so does the computational cost of finding a robust conditional plan. This can make it difficult to scale conditional planning to large-scale, real-world problems.

Problem definition: Defining the non-deterministic actions and observation models accurately can be a difficult and time-consuming process.

Infinite loops: For problems that require repeated attempts, such as trying to "clean" a spot until it is done, the planning process must account for and avoid infinite loops.

Conditional planning vs. classical planning

Feature	Conditional planning	Classical planning
Environment assumptions	Assumes the environment is fully observable and deterministic (predictable).	Designed for environments that are non-deterministic (uncertain outcomes) and partially observable (incomplete information).
Plan structure	Generates a single, fixed sequence of actions.	Generates a tree-like structure with conditional branches and sensing actions
Response to uncertainty	Cannot adapt to unexpected outcomes during execution. Any deviation requires a full re-plan.	Anticipates potential outcomes and includes contingency plans to handle them as they occur.