

# Chapter X -Planning and Acting in the Real World

## 10.1 Time, Schedules, and Resources

In real-world planning, actions often have temporal constraints, resource limitations, and interdependencies. Planning must consider **time**, **schedules**, and **resources** in order to create effective and feasible plans.

### Key Concepts:

#### 1. Temporal Constraints:

- Some tasks cannot be started before a certain time or need to be completed within a specific time window.
- **Temporal Planning** involves reasoning about the timing of events and actions.

#### 2. Resource Constraints:

- **Resources** such as materials, machines, and human labor may be limited and must be allocated efficiently across tasks.
- **Resource Planning** involves managing the allocation and scheduling of these resources.

#### 3. Scheduling:

- **Scheduling** is a subset of planning that focuses on determining when and in what order actions should be performed.
- Real-world problems, like manufacturing or logistics, require scheduling algorithms that ensure all resources are used effectively and actions are completed on time.

### Example:

In a manufacturing plant, the planning system must schedule tasks for different machines and workers while ensuring that the resources (e.g., raw materials, labor) are available at the right times.

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## 10.2 Hierarchical Planning

**Hierarchical Planning** involves decomposing complex tasks into smaller, more manageable sub-tasks. This approach is essential for dealing with problems that involve high-level goals and actions that require multiple intermediate steps.

## Key Concepts:

### 1. Task Decomposition:

- A high-level task is broken down into sub-tasks, which can further be decomposed into even smaller actions.
- Each level of the hierarchy corresponds to a different level of abstraction, with more concrete actions appearing at lower levels.

### 2. HTN Planning (Hierarchical Task Network):

- HTN is a form of hierarchical planning where complex tasks are decomposed into simpler, executable actions.
- The planner operates at various levels of abstraction, making it easier to handle large and complex problems.

### 3. Planning with Constraints:

- Hierarchical planning is often used in domains where tasks must be broken down into smaller, more feasible actions, and these actions need to be scheduled with respect to temporal and resource constraints.

## Example:

For the task "Organize a conference," the high-level task "Set up venue" might be decomposed into sub-tasks like "Book location," "Set up seating," and "Arrange audiovisual equipment." Each sub-task can be further broken down into even smaller actions.

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## 10.3 Planning and Acting in Non-Deterministic Domains

In **non-deterministic domains**, the outcome of an action is not always predictable. This introduces uncertainty into the planning process, which requires more sophisticated techniques to handle.

## Key Concepts:

### 1. Non-Determinism in Actions:

- Actions may lead to different outcomes depending on factors not fully controlled by the agent, such as environmental conditions or the actions of other agents.

### 2. Contingency Planning:

- **Contingency Planning** involves preparing multiple plans for different possible outcomes of an action.
- Planners generate **alternative plans** that account for different contingencies, ensuring that the agent can adapt to unforeseen changes in the environment.

### 3. Partially Observable Environments:

- In many non-deterministic domains, the agent may not have complete information about the environment, which is known as **partial observability**.
- **Belief-State Planning** addresses this by maintaining a representation of the agent's beliefs about the state of the world and planning accordingly.

### Example:

In a delivery system, the exact timing of arrival at the destination may be uncertain due to traffic conditions. The agent may need to generate different plans depending on how the traffic evolves.

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## 10.4 Multi-Agent Planning

In **multi-agent systems**, multiple agents must plan and act collaboratively or competitively to achieve their goals. Multi-agent planning adds complexity due to the need for coordination between agents.

### Key Concepts:

#### 1. Cooperative Multi-Agent Planning:

- Agents may work together to achieve a common goal. For instance, multiple robots could coordinate to transport objects in a warehouse.
- **Coordination** involves sharing information, synchronizing actions, and ensuring that agents don't interfere with each other's tasks.

#### 2. Competitive Multi-Agent Planning:

- In competitive settings (e.g., games, auctions), agents may have conflicting goals. Agents must plan strategies to maximize their own utility while considering the actions of other agents.

#### 3. Negotiation and Conflict Resolution:

- In multi-agent systems, agents may need to negotiate for resources or actions. Conflict resolution methods are necessary when agents' goals conflict, such as resolving scheduling disputes or competing for limited resources.

#### 4. Distributed Planning:

- In large-scale systems, the planning process may be distributed across multiple agents. Each agent is responsible for planning parts of the overall task but must share and synchronize information to ensure global consistency.

### Example:

In a warehouse, multiple robots must cooperate to move products to a storage area. Each robot plans its own actions (e.g., pick up product, move to location), but they must coordinate to avoid collisions and work efficiently.

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## Exercises

### 1. Time and Resource Planning Exercise:

Consider a project where you need to schedule several tasks that require different resources. Each task has a time duration and a specific resource requirement. Develop a scheduling plan that ensures all tasks are completed on time without overloading resources.

### 2. Hierarchical Planning Exercise:

Take a complex task (e.g., "Plan a vacation") and break it down into hierarchical sub-tasks. How would you decompose this task into smaller actions? Use HTN planning to represent the task at multiple levels of abstraction.

### 3. Non-Deterministic Planning Exercise:

Imagine a robot navigating through an environment with obstacles. The outcome of the robot's movements is uncertain due to the possibility of unexpected obstacles. Develop a contingency plan that allows the robot to adapt to changes in its environment.

### 4. Multi-Agent Planning Exercise:

In a multi-agent system where several robots are working to complete a warehouse task, develop a plan where the robots must coordinate their actions. How would you handle conflicts, such as two robots trying to access the same resource?

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This chapter covered **planning and acting in the real world**, emphasizing the challenges and techniques needed when dealing with real-world planning problems. Topics like **time**, **schedules**, **resources**, **hierarchical planning**, **non-deterministic domains**, and **multi-agent planning** highlight the complexity of applying classical planning techniques to dynamic and uncertain environments.