Expectation-based Learning in Design

Dan L. Grecu, David C. Brown

Artificial Intelligence in Design Group
Worcester Polytechnic Institute
Worcester, MA

WPI WORCESTER POLYTECHNIC INSTITUTE

CHARACTERISTICS OF DESIGN PROBLEMS

1) Problem spaces are typically **very large.**

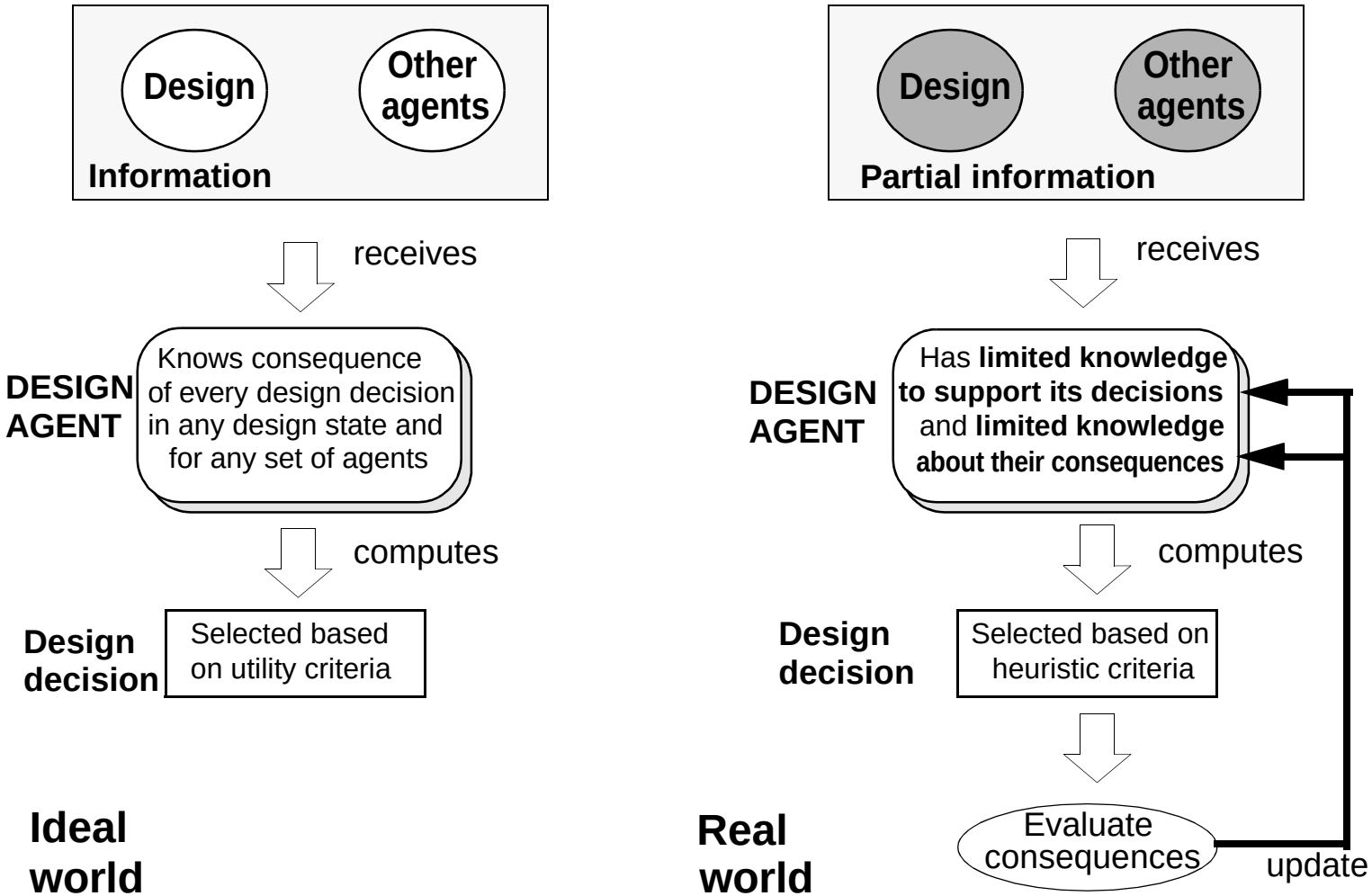
2) Design solutions integrate decisions generated through **a variety of problem-solving strategies**, based in **different domains**.

3) Ordering of decisions is **not pre-defined**.

4) Problem-solvers (agents) act in **various roles**: decision-makers, critics, evaluators etc.

A global approach to solution improvement through learning is difficult to design and implement.

MULTI-AGENT LEARNING IN DESIGN



LEARNING IN DESIGN NEEDS TO BE FLEXIBLE

Flexible learning requires design agents to know

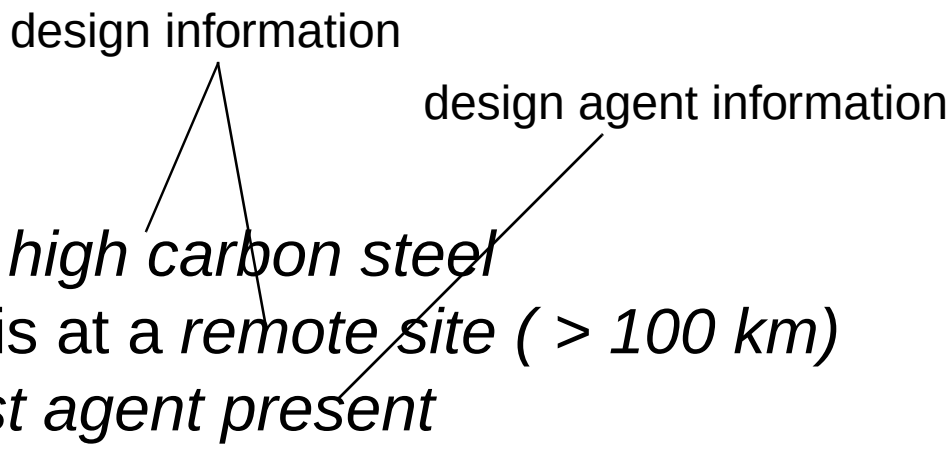
- **when** there is a **need** for learning,
- **how** to respond to a need for learning in terms of:
  - supporting **information sources**, e.g.,
    design parameters, dependencies, etc.
  - defining the **learning target**, e.g.,
    the material strength in a manufacturing process
  - selecting the **learning strategy/algorithm**, e.g.,
    induction, EBL
- **when** a learning process should be **stopped**.

EXPECTATIONS IN DESIGN

Expectation = an agent's belief that an event will occur in a pre-defined way

- captures the conditions that will generate a specific situation

Example:



IF

The material is *high carbon steel*
Manufacturing is at a *remote site (> 100 km)*
There is no *cost agent present*

THEN

The resulting component price will exceed $45.00

CHARACTERIZING EXPECTATIONS

Expectations

- have an **empirical character** in that often there is no deductive connection between the observed conditions and the situation that is predicted

- are **a tentative** form of knowledge that has to be:
  - set up
  - monitored and up-dated
  - validated or rejected

- are **learned as concepts**, i.e., conditions that characterize an event, and are **used as rules**

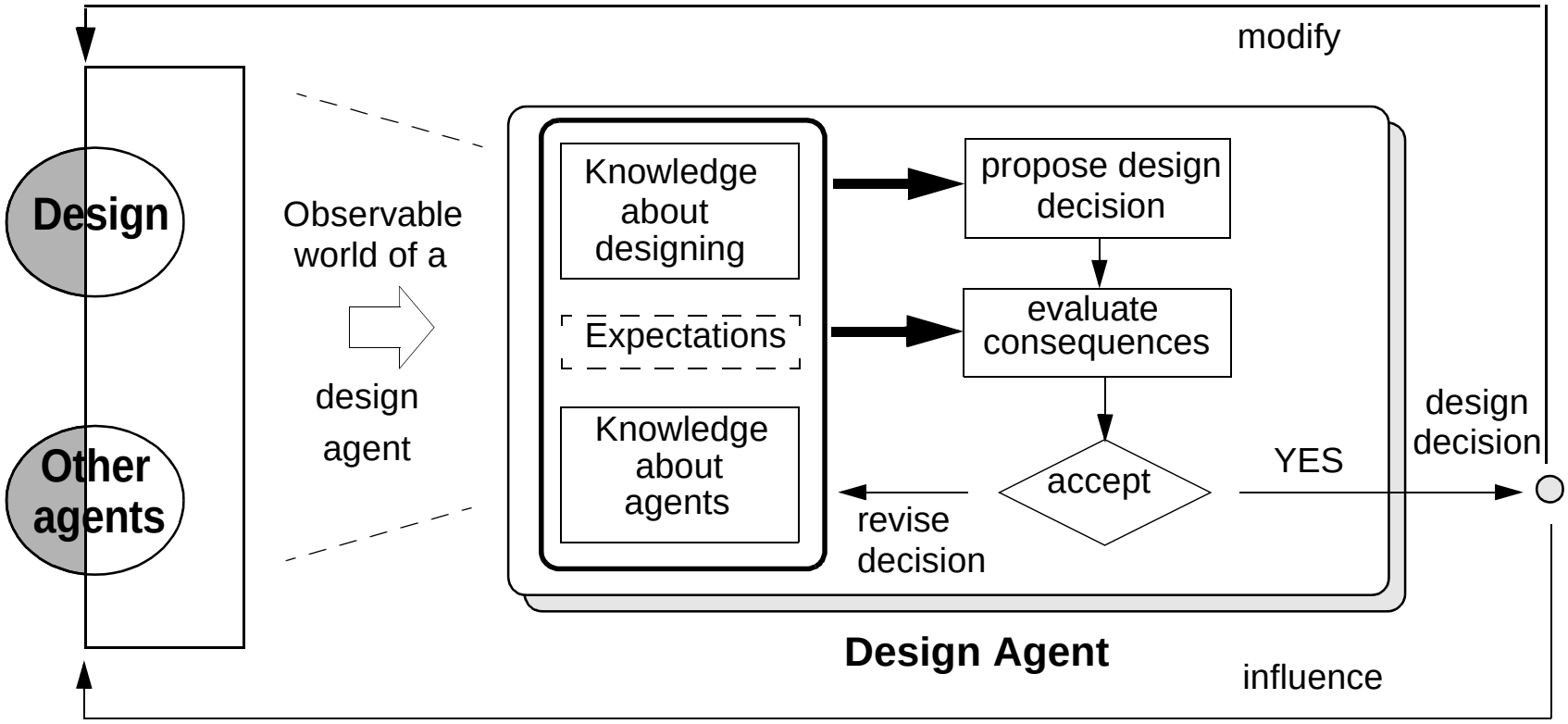
THE OBSERVABLE WORLD OF AN AGENT

The collection of features, in the design domain and in the agent environment, that an agent can 'perceive', such as

- the roles/specializations of other agents
- the posted design decisions
- the conflicts between agents

- ➟ Delimits the basis of learning (learning bias)
- ➟ Is constrained by an agent's functionality and specialization.
- ➟ Is restricted by physical information distribution factors.

EXPECTATION-BASED DESIGN DECISION-MAKING



Expectations are involved both in **proposing** a design decision and in **evaluating** its consequences.

ROLE OF EXPECTATIONS IN DESIGN

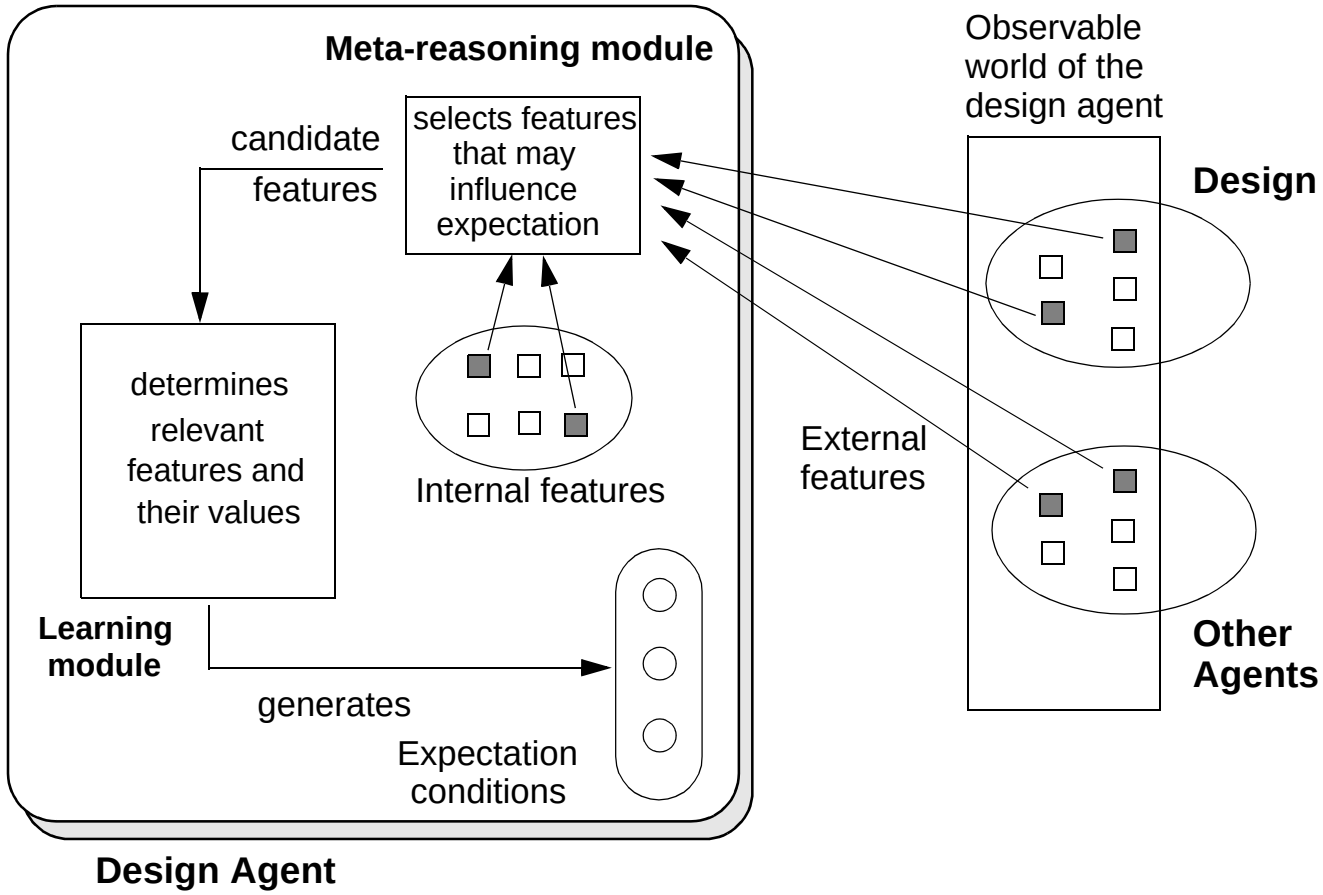
Expectations compensate for an agent's limited power to know or to infer what will happen in the design system.

- Expectations extend a design agent's *awareness*.
- Expectations enhance a design agent's *power of anticipation*.
- Expectations express an agent's *interests*.

⇩

Determine what may be learned.

LEARNING EXPECTATIONS



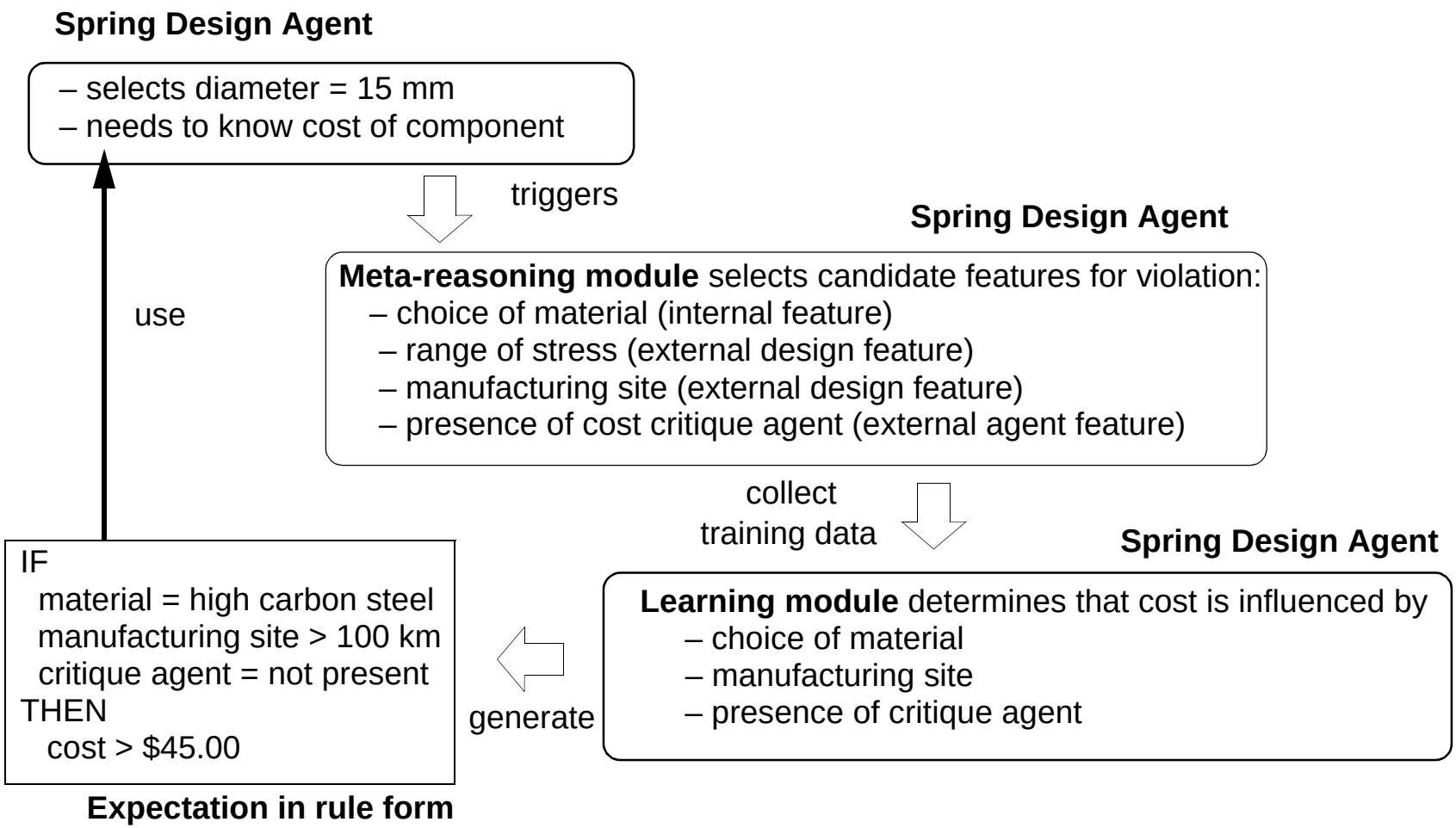
INITIATING EXPECTATION ACQUISITION

Part of the process of evaluating the consequences of a proposed design decision:

- The design agent tries to determine whether the proposed decision will
  - a) violate a constraint or requirement, and/or
  - b) satisfy/support a design goal

  - ⇨ The agent applies backward inference to verify goal/constraint satisfaction based on its current knowledge.
  - ⇨ Repeatedly ‘missing’ rule preconditions are posted as candidate targets for expectation.

LEARNING EXPECTATIONS – AN EXAMPLE

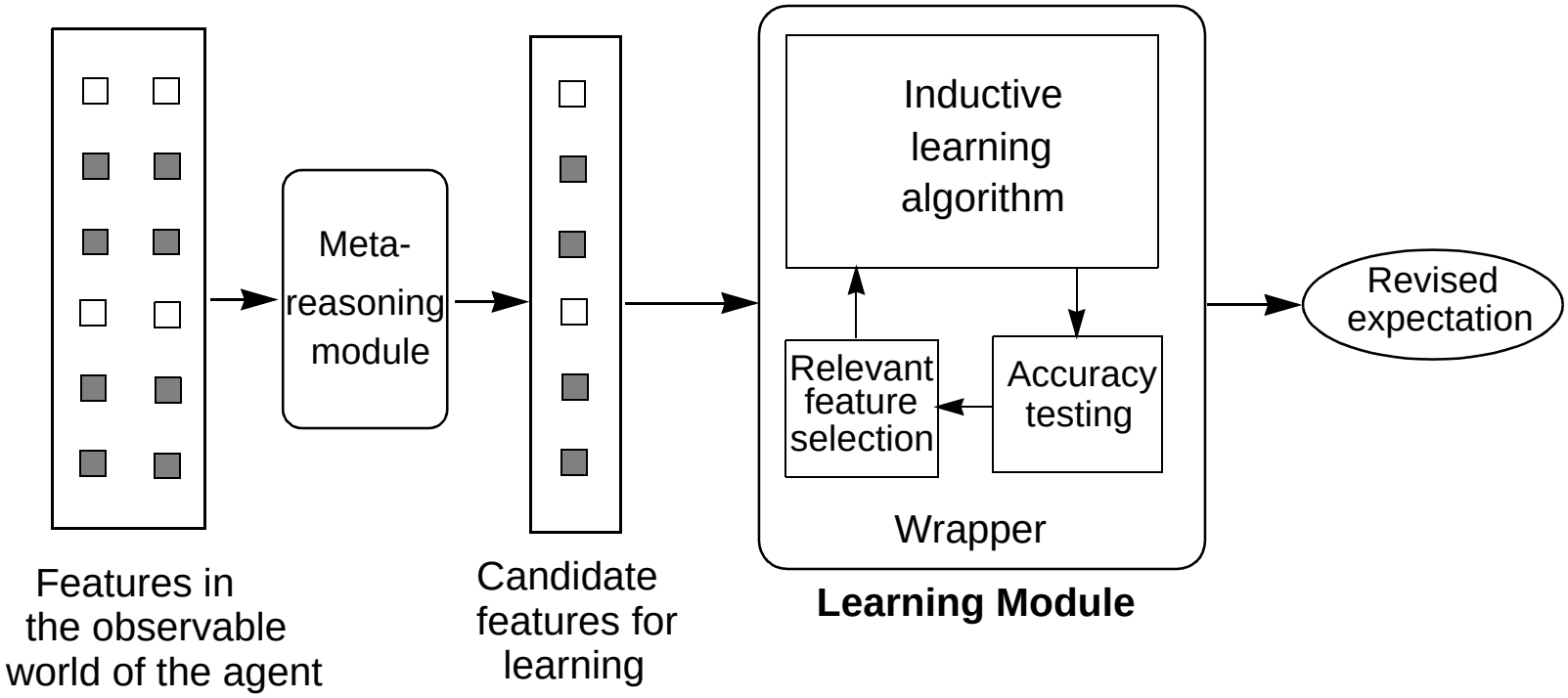


SELECTION OF CANDIDATE CONDITIONS

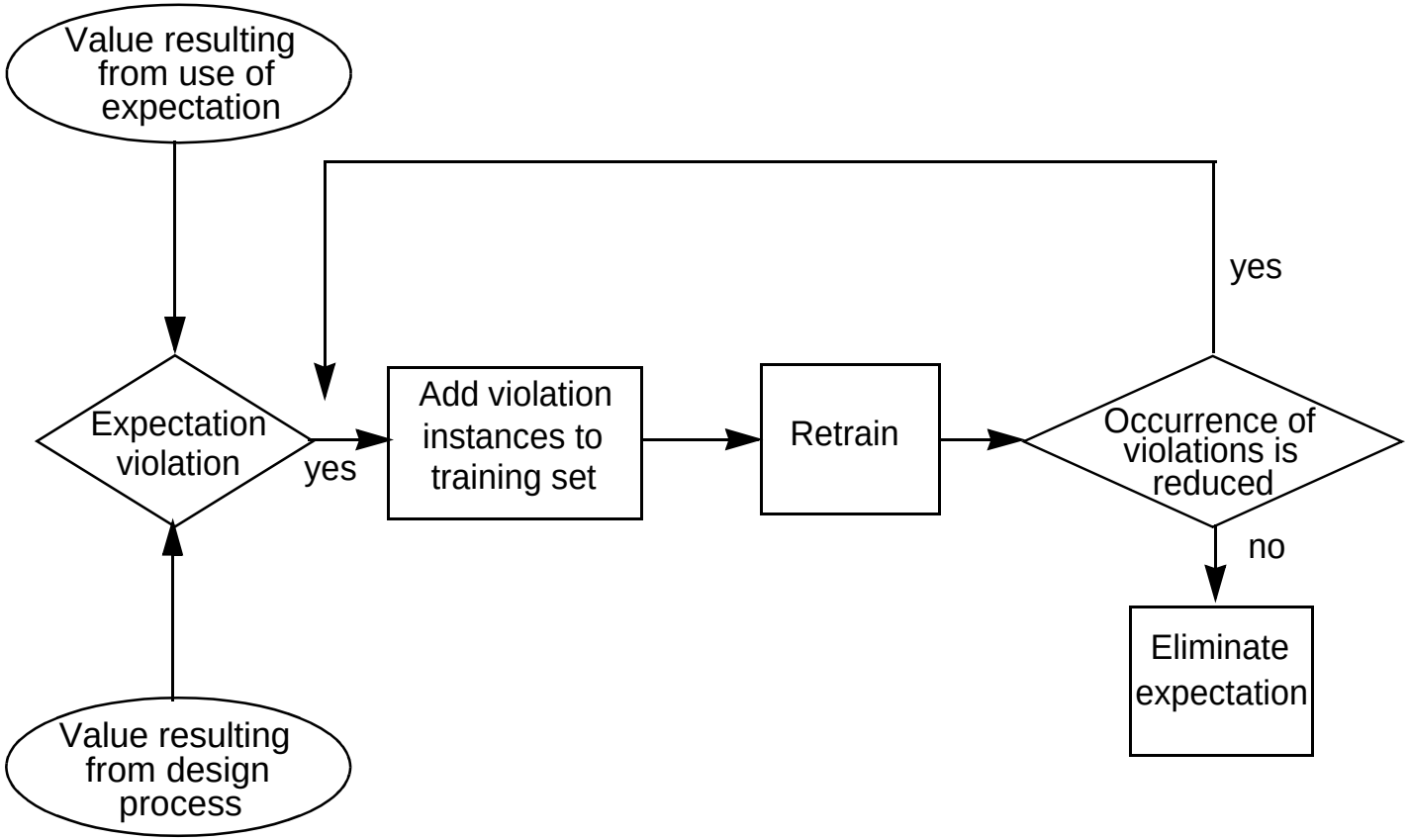
- Depends on the type of expectation that is being developed, i.e., design or design-process oriented
- Is based on **causal attribution** knowledge:

  - Known dependencies between design parameters
  - Actions of agents that include the object of the expectation in their domain
  - Occurrence of specific design process events, such as absence/presence of specific agents, conflicts, redesign phases

SELECTION OF RELEVANT CONDITIONS



MONITORING EXPECTATION VALIDITY



EVALUATION METHODOLOGY

Evaluation focuses on the design and design process impact resulting from

1. combining expectations about design and about the design process,

2. the size of the observable agent worlds,

3. the causal attribution knowledge,

4. the interferences between learning processes, and

5. the ‘moving targets’ created by learning.