Expectation-based Learning in Design

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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**

- **Design**
  - Information
  - Other agents
  - Knows consequence of every design decision in any design state and for any set of agents
  - Design decision
    - Selected based on utility criteria
  - Ideal world

- **Other agents**
  - Partial information
  - Has limited knowledge to support its decisions and limited knowledge about their consequences
  - Design decision
    - Selected based on heuristic criteria
  - Real world
  - Evaluate consequences
  - Update
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**.
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
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.
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

Meta-reasoning module

candidate features

determines relevant features and their values

selects features that may influence expectation

Learning module

generates Expectation conditions

Design Agent

Observable world of the design agent

Design

External features

Other Agents

Internal features
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**

**Spring Design Agent**
- Selects diameter = 15 mm
- Needs to know cost of component

**Meta-reasoning module** selects candidate features for violation:
- Choice of material (internal feature)
- Range of stress (external design feature)
- Manufacturing site (external design feature)
- Presence of cost critique agent (external agent feature)

**Learning module** determines that cost is influenced by
- Choice of material
- Manufacturing site
- Presence of critique agent

**Expectation in rule form**

IF
- Material = high carbon steel
- Manufacturing site > 100 km
- Critique agent = not present
THEN
- Cost > $45.00
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

Features in the observable world of the agent → Meta-reasoning module → Candidate features for learning → Inductive learning algorithm → Relevant feature selection → Accuracy testing → Revised expectation

Learning Module

Wrapper
**Monitoring Expectation Validity**

- Value resulting from use of expectation
  - Expectation violation
    - Add violation instances to training set
      - Retrain
        - Occurrence of violations is reduced
          - yes
            - Eliminate expectation
          - no
        - Retrain
      - no
    - Eliminate expectation
  - Value resulting from design process
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.