

# Case-Based Approximate Reasoning

Eyke Hüllermeier, Series: Theory and Decision Library B, Springer, 2007

David W. Aha

First-generation investigations of case-based reasoning (CBR) emphasized its roots in cognitive science, while current-day research usually features an applied problem-solving mindset. The field continues to mature, and has developed niches in a surprising breadth of research areas (e.g., health sciences, economics, recommender systems). Throughout this time, its unique emphasis has been a knowledge-based perspective on the interpretation and reuse of experience that complements other problem-solving frameworks. However, as with many subareas of artificial intelligence, it has evolved its own terminology, biases, and perspective, which complicates the task of communicating its capabilities to sibling communities. Yet its continued growth depends on establishing and disseminating formal descriptions of its foundations to theoreticians and practitioners of the greater AI community, thus facilitating comprehension and promoting collaboration.

In *Case-Based Approximate Reasoning*, Eyke Hüllermeier expertly fills this gap with his detailed analysis on the central CBR hypothesis that *similar problems tend to have similar solutions*, which has usually received only informal treatment. In contrast, he makes *case-based inference* (CBI) the focus of his analyses, and provides three valuable contributions. First, he formalizes this core tenet of CBR, relating it across popular similarity-based models and endowing it with a constraint-based foundation. In doing so, he shows how it can be used to model three types of prediction tasks (point-estimation, choosing a subset of possible outcomes, and assigning a valuation to a set of outcomes) for both deterministic and non-deterministic problem classes. He also shows how it

can be used for case-based approximation by employing similarity profiles and structures, introduces (and characterizes) algorithms for learning similarity hypotheses, and describes its application to statistical inferencing tasks.

Hüllermeier's second and particularly broad contribution is to embed the CBI model into three complementary frameworks for tolerating incomplete information and uncertainty. First, he describes a *probabilistic* extension of this model, which allows for the efficient data-driven derivation and reasoning from large sets of samples. Next, he formalizes this in a fuzzy set framework in which cases are interpreted as evidence for the degrees of *possibility* that can be assigned to hypothetical cases. This provides a means for incorporating domain knowledge to control the possibilistic extrapolation of the cases. Finally, CBI is formalized in terms of fuzzy implication rules using a constraint-based approach in which rules are used to discount dissimilar outcomes rather than support similar ones.

The final contribution of this book concerns the introduction of a case-based framework for agent decision-making that combines a CBI method with a generalization of expected utility theory based on belief functions. This leads to a framework for *experience-based decision-making* in which an agent predicts the utility of potential actions, which Hüllermeier realizes using satisficing decision trees.

For the CBR community, this work represents an important breakthrough in which the foundational hypothesis of CBR is explicitly modeled and placed into well-known formal frameworks for representing, learning from, and reasoning with uncertain and incomplete

data. This clarifies how CBR relates to these frameworks. Also, when leveraged appropriately, this will allow theories of CBR to benefit from these frameworks' features, which can lead to more efficient systems.

This book, which includes several empirical studies to complement its mathematical and logical analyses, should interest any CBR researcher or theoretician interested in the field and its relation with constraint-based reasoning, possibility theory, fuzzy set theory, and formal models of decision making. It contributes to the foundations of CBR and approximate reasoning.

Despite its obvious strengths, including that few (if any) books on CBR attempt to formalize its core concept, this book does have limitations. It is not an introductory volume; readers should be familiar with the basic concepts and notation underlying probabilistic reasoning, fuzzy sets, possibility theory, and related topics. Also, additional intuition could be provided at some points to guide the reader, and motivations for some of the formal discussions are not always clear.

Nonetheless, *Case-Based Approximate Reasoning* is an excellent treatise on CBR and its relation to other reasoning frameworks. Many researchers will look to it as a guide for clarifying CBR's foundations and its relationship to other frameworks for approximate reasoning.

## Contact

Dr. David W. Aha  
Navy Center for Applied Research in Artificial Intelligence, Naval Research Laboratory, Code 5514  
4555 Overlook Ave., SW  
Washington, DC