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Principle-based Non-Monotonic Reasoning - From Humans to Machines

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Abstract
A key challenge when developing intelligent agents is to instill behavior into computing systems that can be considered as intelligent from a *common-sense* perspective. Such behavior requires agents to diverge from typical decision-making algorithms that strive to maximize simple and often one-dimensional metrics. A striking parallel to this research problem can be found in the design of formal models of human decision-making in microeconomic theory. Traditionally, mathematical models of human decision-making also reflect the ambition to maximize expected utility or a preference function, which economists refer to as the *rational man* paradigm.
However, evidence suggests that these models are flawed, not only because human decision-making is subject to systematic fallacies, but also because the models depend on assumptions that do not hold in reality. Consequently, the research domain of formally modeling *bounded rationality* emerged, which attempts to account for these shortcomings by systematically relaxing the mathematical constraints of the formal model of economic rationality. Similarly, in the field of symbolic reasoning, approaches have emerged to systematically relax the notion of *monotony of entailment*, which stipulates (colloquially speaking) that when inferring a set of statements from a knowledge base, the addition of new knowledge to the knowledge base must not lead to the rejection of any of the previously inferred statements.
By drawing from these developments in microeconomic theory and symbolic reasoning, this thesis explores different principle-based approaches to decision-making and non-monotonic reasoning. Thereby, abstract argumentation is used as a fundamental method for reasoning in face of conflicting knowledge (or: *beliefs*) that reduces non-monotonic reasoning to the problem of drawing conclusions (*extensions*) from a directed graph, and hence provides a neat abstraction for theoretical exploration. In particular, the works collected in this thesis *i)* introduce the *consistent preferences* property of microeconomic theory, as well as some relaxed forms of monotony of entailment as mathematical principles to abstract argumentation-based inference; *ii)* show how to enforce some of these principles in dynamic environments; *iii)* devise a formal approach to maximize monotony of entailment, given the constraints imposed by an inference function; *iv)* extend and apply the aforementioned approaches to the domains of machine reasoning explainability and legal reasoning.

Keywords
Non-monotonic reasoning, formal argumentation, economic rationality

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