

Mixed constraint satisfaction: a framework for decision problems under incomplete knowledge

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Abstract

Constraint satisfaction is a powerful tool for representing and solving decision problems with complete knowledge about the world. We extend the CSP framework so as to represent decision problems under incomplete knowledge. The basis of the extension consists in a distinction between controllable and uncontrollable variables — hence the terminology “mixed CSP” — and a “solution” gives actually a conditional decision. We study the complexity of deciding the consistency of a mixed CSP. As the problem is generally intractable, we propose an algorithm for finding an approximate solution.

Introduction

Most of the time, solving a constraint satisfaction problem (CSP) means finding an assignment of the variables satisfying all the constraints, if such an assignment exists. Such a request often relies on the assumption (generally implicit) that the variables are *controllable*, i.e., that the agent has the power to fix their values. However, one may think to give variables a status of *uncontrollable*: the value of an uncontrollable variable is fixed by the external world and thus it is outside the control of the agent. In the rest of the paper we will refer to controllable variables as *decision variables* and to uncontrollable as *parameters*. If all variables of a CSP are controllable, the purpose of the resolution of the CSP is to find a good decision which the agent may apply: we will refer to this kind of CSP (which is the most common in the CSP literature) as *decision-oriented CSP*. If all variables are uncontrollable, the constraints represent pieces of knowledge about the possible actual values of the variables. In this case, what is expected is not necessarily to find a consistent assignment, but rather to find the *actual value* of each variable. This means that the resolution process has to be interpreted not in terms of decision but in terms of *reasoning* (as this is the case in most logical approaches for knowledge representation). We will refer to this kind of CSP as *reasoning-oriented CSP*. Examples of reasoning-oriented CSPs in the literature are far less numerous. For instance, CSP used for scene interpretation clearly belong in this class.

The fundamental difference between these two kinds of CSPs thus lies in the interpretation of the data (variables and constraints) and in the output of the resolution pro-

cess; interpreting the number of solutions is particularly worth of interest: if a *decision-oriented* CSP has *several* solutions, this is rather good news since the agent will be (in principle) happy with any of them; on the contrary, if a *reasoning-oriented* CSP has several solutions, which means that the knowledge is incomplete, giving only one solution means arbitrary selecting one possible situation, which is not necessarily the real one — giving all solutions could be more adequate. Now, if a decision-oriented CSP has no solution, the problem is over-specified; inconsistency for reasoning-oriented CSP has to be interpreted in a different way, since the variables *do* have a value in the actual world and therefore at least one of the constraints is not sound.

Now, beyond pure decision or reasoning-oriented problems, there are practical problems where a decision has to be taken, while the actual world is not completely known (which is the basic assumption in applications of decision theory). For instance, in scheduling, the decision (sequencing the tasks) may depend on ill-known parameters such as the reliability of some machines. Our motivation is to show that the CSP framework, which has been successfully developed and applied in the past years, can be extended in such a way that it can represent and solve problems of *decision making under incomplete knowledge*. These problems will be represented by so-called *mixed CSPs* involving both controllable and uncontrollable variables.

The definition of a *solution* of a mixed CSP depends crucially on the assumptions concerning the agent’s awareness of the parameter values (the state of the world) at the time the decision must be made (deadline for acting) — where a *decision* is an assignment of decision variables. We will consider these two epistemological assumptions:

FO (*full observability*): the actual world will be completely revealed to the agent *before* the deadline is reached (possibly, *just before*), so that it is useful to compute “off-line” a ready-to-use *conditional decision*, mapping possible cases to decisions, that the agent will be able to instantiate in real time, as soon as the actual world is known.

NO (*no observability*): the agent will never learn anything new about the actual state of the world before the deadline: all it will ever know is already encoded in the initial specification of the problem. In this case, it is useless to provide a conditional decision, and a suitable solution of the problem

Decision Theory And Incomplete Knowledge

Jack Minker



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descriptive theories to explain the psychological knowledge related to people's decision making behavior. It is called a theory but is actually a combination of various psychological theories for which no axiomatic systems such as those associated with the utility theory widely used in economics have been established. The utility theory is often limited to qualitative knowledge however as the studies of Nobel laureates H A Simon, D Kahneman and R Thaler have suggested the psychological methodology and knowledge of behavioral decision theory have been applied widely in such fields as economics, business administration and engineering and are expected to become even more useful in the future. Research into people's decision making represents an important part in those fields various aspects of which overlap with the scope of behavioral decision theory. This theory is closely related to behavioral economics and behavioral finance which have come into greater use in recent years. This book will appeal especially to graduate students, advanced undergraduate students and researchers who are interested in decision making phenomena.

Quantum Decision Theory and Complexity Modelling in Economics and Public Policy Anirban Chakraborti, Emmanuel Haven, Sudip Patra, Naresh Singh, 2023-09-21. This book is an outcome of the interdisciplinary conference held at OP Jindal Global University. Quantum Decision making and Complexity modeling and their possible applications in social sciences, economics, finance and public policy. The volume builds upon the emerging fields of Econophysics, Complexity theory and Quantum like modelling in cognition and social sciences and their plausible applications in economics and public policy. There can be deep linkages between the micro, meso and macro scales at which these paradigms operate. In this data driven age, greater amounts of information along with the facility to harvest, sort and process said information have permitted an expansion of the capability to study a society's various factors to a degree of detail and inclusiveness that has never before been available to researchers. As a result, an increasing number of throughlines is being discovered, revealing heretofore unknown connections between various disciplines and enhancing the study of such societal tropes as finance, language, shared behavior and many others. As the reader will see with clearer understanding of the interconnectedness of society's assorted parts, comes a clearer understanding of the society as a whole. We have received critical thoughts from noted experts in social and natural sciences to explore possible interconnections. The editors of this book earnestly hope that the critical reviews presented in this volume will stimulate further scholarly interest but also interest among policy practitioners for the purpose of exploring possibilities for creating a new paradigm for comprehending pressing issues of deep uncertainty and emergence in social dynamics.

Logic-Based Artificial Intelligence Jack Minker, 2012-12-06. The use of mathematical logic as a formalism for artificial intelligence was recognized by John McCarthy in 1959 in his paper on Programs with Common Sense. In a series of papers in the 1960's he expanded upon these ideas and continues to do so to this date. It is now 41 years since the idea of using a formal mechanism for AI arose. It is therefore appropriate to consider some of the research applications and implementations that have resulted from this idea. In early 1995 John McCarthy suggested to me that we have a workshop on Logic Based Artificial Intelligence (LBAI). In June 1999 the

Workshop on Logic Based Artificial Intelligence was held as a consequence of McCarthy's suggestion. The workshop came about with the support of Ephraim Glinert of the National Science Foundation IIS 952013S, the American Association for Artificial Intelligence who provided support for graduate students to attend and Joseph JaJa, Director of the University of Maryland Institute for Advanced Computer Studies who provided both manpower and financial support and the Department of Computer Science. We are grateful for their support. This book consists of refereed papers based on presentations made at the Workshop. Not all of the Workshop participants were able to contribute papers for the book. The common theme of papers at the workshop and in this book is the use of logic as a formalism to solve problems in AI.

Annual International Industrial Engineering Conference, 1988 **International Industrial Engineering Conference Proceedings**, 1988 *Concise Encyclopedia of Information Processing in Systems & Organizations* Andrew P. Sage, 1990. Begins a series addressing the increasingly important role of expert systems in management and decision making in industry and commerce. The 68 articles reflect recent research by practitioners of information processing and problem solving. They discuss knowledge acquisition and representation simulation.

A Bridge Between Control Science and Technology International Federation of Automatic Control. World Congress, 1985 **Assignments in Applied Statistics** Simon Conrad, 1989-08-15. This book is a practical approach to the use of statistics in a wide variety of situations. It covers twenty assignments in applied statistics, each one written by a leading authority in the fields of decision analysis, forecasting, multivariate analysis, the design and analysis of surveys, and the design and analysis of experiments. The assignments cover a wide range of applications in the management sciences, social sciences, industry, and medicine and provide practical experience in data collection and analysis using real life models.

Analysis and Decision in Regional Policy Ian Cullen, 1979 **Proceedings of the ... Euromicro Workshop on Advanced Mobile Robots**, 1997 What Research Tells the Coach about Soccer Thomas Reilly, 1979 Decision Theory and Multi-Agent Planning Giacomo Della Riccia, 2006-03-09. The work presents a modern unified view on decision support and planning by considering its basics like preferences, belief, possibility, and probability, as well as utilities. These features together are immanent for software agents to believe the user that the agents are intelligent.

Systems and Control Encyclopedia Supplementary Volume 1 M.G. Singh, 1987. A compendium of systems ideas, methods, and applications that emphasizes on the role of computers.

Unveiling the Magic of Words: A Report on "**Decision Theory And Incomplete Knowledge**"

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