

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

Hélène Fargier, Jérôme Lang
IRIT - Université Paul Sabatier
31062 Toulouse Cedex (France)

Thomas Schiex
INRA
31320 Castanet Cedex (France)

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

**JingTao Yao,Sheela Ramanna,Guoyin
Wang,Zbigniew Suraj**



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C. M. Cannon, Z. W. Kmietowicz, 1974 **Decision Theory and Incomplete Knowledge** Z. W. Kmietowicz, A. D.

Pearman, 1981 **Preferences and Decisions under Incomplete Knowledge** Janos Fodor, Bernard De Baets, Patrice Perny, 2000-05-16 Nowadays decision problems are pervaded with incomplete knowledge i.e. imprecision and/or uncertain information both in the problem description and in the preferential information. In this volume leading scientists in the field address various theoretical and practical aspects related to the handling of this incompleteness. The problems discussed are taken from multi-objective linear programming, rationality considerations in preference modelling, non-probabilistic utility theory, data fusion, group decision making and multicriteria decision aid. The book is oriented towards researchers, graduate and postgraduate students in decision analysis, fuzzy sets and fuzzy logic, and operations research, management science.

Information Processing and Management of Uncertainty in Knowledge-Based Systems. Theory and Foundations Jesús Medina, Manuel Ojeda-Aciego, José Luis Verdegay, David A. Pelta, Inma P. Cabrera, Bernadette Bouchon-Meunier, Ronald R. Yager, 2018-05-30 This three-volume set CCIS 853-855 constitutes the proceedings of the 17th International Conference on Information Processing and Management of Uncertainty in Knowledge-Based Systems (IPMU 2017) held in Madrid, Spain, in June 2018. The 193 revised full papers were carefully reviewed and selected from 383 submissions. The papers are organized in topical sections on: advances on explainable artificial intelligence, aggregation operators, fuzzy metrics and applications, belief function theory and its applications, current techniques to model process and describe time series, discrete models and computational intelligence, formal concept analysis and uncertainty, fuzzy implication functions, fuzzy logic and artificial intelligence problems, fuzzy mathematical analysis and applications, fuzzy methods in data mining and knowledge discovery, fuzzy transforms theory and applications to data analysis and image processing, imprecise probabilities, foundations and applications, mathematical fuzzy logic, mathematical morphology, measures of comparison and entropies for fuzzy sets and their extensions, new trends in data aggregation, pre-aggregation functions and generalized forms of monotonicity, rough and fuzzy similarity modelling, tools for soft computing for decision making in uncertainty, soft computing in information retrieval and sentiment analysis, tripartitions and uncertainty, decision making modeling and applications, logical methods in mining knowledge from big data, metaheuristics and machine learning, optimization models for modern analytics, uncertainty in medicine, uncertainty in Video Image Processing (UVIP). *Decision Theory With Imperfect Information* Aliev Rafiq Aziz, Huseynov Oleg H., 2014-08-08 Every day decision making in complex human-centric systems are characterized by imperfect decision-relevant information. The principal problems with the existing decision theories are that they do not have capability to deal with situations in which probabilities and events are imprecise. In this book we describe a new theory of decision making with imperfect information. The aim is to shift the foundation of decision analysis and

economic behavior from the realm bivalent logic to the realm fuzzy logic and Z restriction from external modeling of behavioral decisions to the framework of combined states This book will be helpful for professionals academics managers and graduate students in fuzzy logic decision sciences artificial intelligence mathematical economics and computational economics

Decision Theory, Incomplete Knowledge and Constrained Games Michael J. Ryan, University (Hull), University of Hull. Department of Economics and Commerce, 1991

The Science of Decision Making Pasquale De Marco, 2025-07-19 In a world awash with information and choices The Science of Decision Making emerges as a beacon of clarity guiding readers through the intricate maze of decision making processes that shape our lives Embark on an intellectual journey that unravels the art and science behind making choices empowering you with the tools and knowledge to navigate life's complexities with wisdom and discernment This comprehensive guide delves into the core principles of decision making illuminating the interplay between intuition and logic unveiling the common biases that cloud our judgment and providing strategies for overcoming decision making challenges With clarity and precision the book explores a multitude of decision making models ranging from the rational choice theory to behavioral economics equipping readers with a comprehensive understanding of the factors that drive human choices The Science of Decision Making ventures beyond theoretical frameworks exploring the practical application of decision making principles across diverse domains Discover how decisions are made in personal finance delving into financial goal setting budgeting investment strategies and the psychology of money management Uncover the intricacies of decision making in business and management examining strategic planning risk management and the art of leading and managing decision making teams The book navigates the complexities of decision making in public policy healthcare and environmental sustainability highlighting the unique challenges and considerations that arise in each of these domains Explore the role of decision making in governance public policy analysis and healthcare diagnosis and treatment Gain insights into the decision making processes that shape environmental conservation sustainable development and the impact of environmental decisions on society Throughout this intellectual odyssey The Science of Decision Making emphasizes the significance of critical thinking skills problem solving abilities and creative approaches to decision making The book underscores the power of collaboration and the invaluable lessons learned from decision making mistakes fostering a growth mindset that embraces continuous learning and improvement The Science of Decision Making is an indispensable guide for anyone seeking to make informed ethical and effective choices in their personal and professional lives With its interdisciplinary approach and accessible writing style this book empowers readers to navigate the complexities of decision making with confidence and discernment If you like this book write a review

Organization and Decision Theory Ira Horowitz, 2012-12-06 Ira Horowitz Depending upon one's perspective the need to choose among alternatives can be an unwelcome but unavoidable responsibility an exciting and challenging opportunity a run of the mill activity that one performs seemingly without thinking very much about it or

perhaps something in between Your most recent selections from a restaurant menu from a set of jobs or job candidates or from a rent or buy or sell or lease option are cases in point Oftentimes we are involved in group decision processes such as the choice of a president wherein one group member's unwelcome responsibility is another's exciting opportunity Many of us that voted in the presidential elections of both 1956 and 1984 irrespective of political affiliation experienced both emotions others just pulled the lever or punched the card without thinking very much about it Arriving at either an individual or a group decision can sometimes be a time consuming torturous and traumatic process that results in a long regretted choice that could have been reached right off the bat On other occasions the just let's get it over with and get out of here solution to a long festering problem can yield rewards that are reaped for many 1 ORGANIZATION AND DECISION THEORY 2 years to come One way or another however individuals and organizations somehow manage to get the decision making job done even if they don't quite understand and often question just how this was accomplished

Algorithmic Decision Theory Francesca Rossi, Alexis Tsoukias, 2009-10-13 This volume contains the papers presented at ADT 2009 the first International Conference on Algorithmic Decision Theory The conference was held in San Servolo a small island of the Venice lagoon during October 20-23 2009 The program of the conference included oral presentations posters invited talks and tutorials The conference received 65 submissions of which 39 papers were accepted 9 papers were posters The topics of these papers range from computational social choice preference modeling from uncertainty to preference learning from multi criteria decision making to game theory

Rough Set and Knowledge Technology JingTao Yao, Sheela Ramanna, Guoyin Wang, Zbigniew Suraj, 2011-09-21 This book constitutes the refereed proceedings of the 6th International Conference on Rough Sets and Knowledge Technology RSKT 2011 held in Banff Canada in September 2011 The 89 revised full papers presented together with 3 keynote lectures and 1 invited tutorial session were carefully reviewed and selected from 229 submissions The papers are organized in topical sections on attribute reduction and feature selection generalized rough set models machine learning with rough and hybrid techniques knowledge technology and intelligent systems and applications

Handbook of Research on Knowledge Management for Contemporary Business Environments Malheiro, Armando, Ribeiro, Fernanda, Leal Jamil, George, Rascao, Jose Pocas, Mealha, Oscar, 2018-05-25 Information is considered essential in every business model which is why staying abreast of the latest resources can help combat many challenges and aid businesses in creating a synthesis between people and information keeping up with evolving technologies and keeping data accurate and secure The Handbook of Research on Knowledge Management for Contemporary Business Environments is a critical scholarly publication that examines the management of knowledge resources in modern business contexts Including a wide range of topics such as information systems sustainable competitive advantage and knowledge sharing this publication is a vital reference source for managers academicians researchers and students seeking current research on strategies that are able to manage the information in more than one context for present and future generations

Knowledge, Data and Computer-Assisted

Decisions Martin Schader,Wolfgang A. Gaul,2012-12-06 Proceedings of the NATO Advanced Research Workshop on Data Expert Knowledge and Decisions held in Hamburg FRG September 3 5 1989 Random-Like Multiple Objective Decision Making Jiuping Xu,Liming Yao,2011-03-25 What are the random like phenomena that can be found everywhere in real life world When carrying out a random sampling survey on the traffic situation we often obtain some descriptive results such as approximately expedite a little crowded and so on therefore the average level should be regarded as the random fuzzy phenomenon which is one of the random like phenomena Decision makers usually need to make the decision for these problems with random like phenomena Which model should be constructed for them How should we handle these models to find the optimal strategy How can we apply these models to solve real life problems with random like phenomena In order to answer these questions this book provides an up to date methodology system 5MRP for random like multiple objective decision making which includes problem system with random like phenomena model system with random like coefficients research system with random like uncertain methods Some practical applications are also provided to illustrate the effectiveness of the proposed methodology system Researchers practitioners and students in systems science economics mathematics information engineering and MS OR will get a lot of useful references from this research monograph

Planning Based on Decision Theory Giacomo Della Riccia,Rudolf Kruse,Didier Dubois,Hans-J. Lenz,2014-05-04 Planning of actions based on decision theory is a hot topic for many disciplines Seemingly unlimited computing power networking integration and collaboration have meanwhile attracted the attention of fields like Machine Learning Operations Research Management Science and Computer Science Software agents of e commerce mediators of Information Retrieval Systems and Database based Information Systems are typical new application areas Until now planning methods were successfully applied in production logistics marketing finance management and used in robots software agents etc It is the special feature of the book that planning is embedded into decision theory and this will give the interested reader new perspectives to follow up

Encyclopedia of Decision Making and Decision Support Technologies Adam, Frederic,Humphreys, Patrick,2008-04-30 As effective organizational decision making is a major factor in a company s success a comprehensive account of current available research on the core concepts of the decision support agenda is in high demand by academicians and professionals Through 110 authoritative contributions by over 160 of the world s leading experts the Encyclopedia of Decision Making and Decision Support Technologies presents a critical mass of research on the most up to date research on human and computer support of managerial decision making including discussion on support of operational tactical and strategic decisions human vs computer system support structure individual and group decision making and multi criteria decision making **Behavioral Decision Theory** Kazuhisa Takemura,2021-09-29 This book is the second edition of Behavioral Decision Theory published in 2014 The main approach and structure of this book have been retained in the new edition However this second edition provides a fresh overview of the idea of behavioral decision theory and related research

findings such as theoretical and empirical discoveries of preference formation time discounting social interaction and social decision making The book covers a wide range from classical to relatively recent major studies concerning behavioral decision theory which in brief is a general term for 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

Decision Making in Complex Environments Jan Noyes, 2017-09-18 Many complex systems in civil and military operations are highly automated with the intention of supporting human performance in difficult cognitive tasks The complex systems can involve teams or individuals working on real time supervisory control command or information management tasks where a number of constraints must be satisfied *Decision Making in Complex Environments* addresses the role of the human the technology and the processes in complex socio technical and technological systems The aim of the book is to apply a multi disciplinary perspective to the examination of the human factors in complex decision making It contains more than 30 contributions on key subjects such as military human factors team decision making issues situation awareness and technology support In addition to the major application area of military human factors there are chapters on business medical governmental and aeronautical decision making The book provides a unique blend of expertise from psychology human factors industry commercial environments the military computer science organizational psychology and training that should be valuable to academics and practitioners alike

Intelligent Decision Technologies Junzo Watada, Toyohide Watanabe, Gloria Phillips-Wren, Robert J. Howlett, Lakhmi C Jain, 2012-05-20 The Intelligent Decision Technologies IDT International Conference encourages an interchange of research on intelligent systems and intelligent technologies that enhance or improve decision making The focus of IDT is interdisciplinary and includes research on all aspects of intelligent decision technologies from fundamental development to real applications IDT has the potential to expand their support of decision making in such areas as finance accounting marketing healthcare medical and diagnostic systems military decisions production and operation networks traffic management crisis response human machine interfaces financial and stock market monitoring and prediction and robotics Intelligent decision systems implement advances in intelligent agents fuzzy logic multi agent systems artificial neural

networks and genetic algorithms among others Emerging areas of active research include virtual decision environments social networking 3D human machine interfaces cognitive interfaces collaborative systems intelligent web mining e commerce e learning e business bioinformatics evolvable systems virtual humans and designer drugs This volume contains papers from the Fourth KES International Symposium on Intelligent Decision Technologies KES IDT 12 hosted by researchers in Nagoya University and other institutions in Japan This book contains chapters based on papers selected from a large number of submissions for consideration for the conference from the international community The volume represents the current leading thought in intelligent decision technologies

Collective Wisdom-Driven Three-Way Decision in Risk Management Decui Liang, Mingwei Wang, Zeshui Xu, 2024 Zusammenfassung This book delves deeply into the research progress on three way risk decision for risk management under complex social environment From the new perspective of collective wisdom it systematically explores three way group decision making methods and practical applications by considering group information fusion consensus reaching process group social network and group complex network This book intends to provide a reference for researchers practitioners and graduate students in the fields of risk management and decision analysis

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