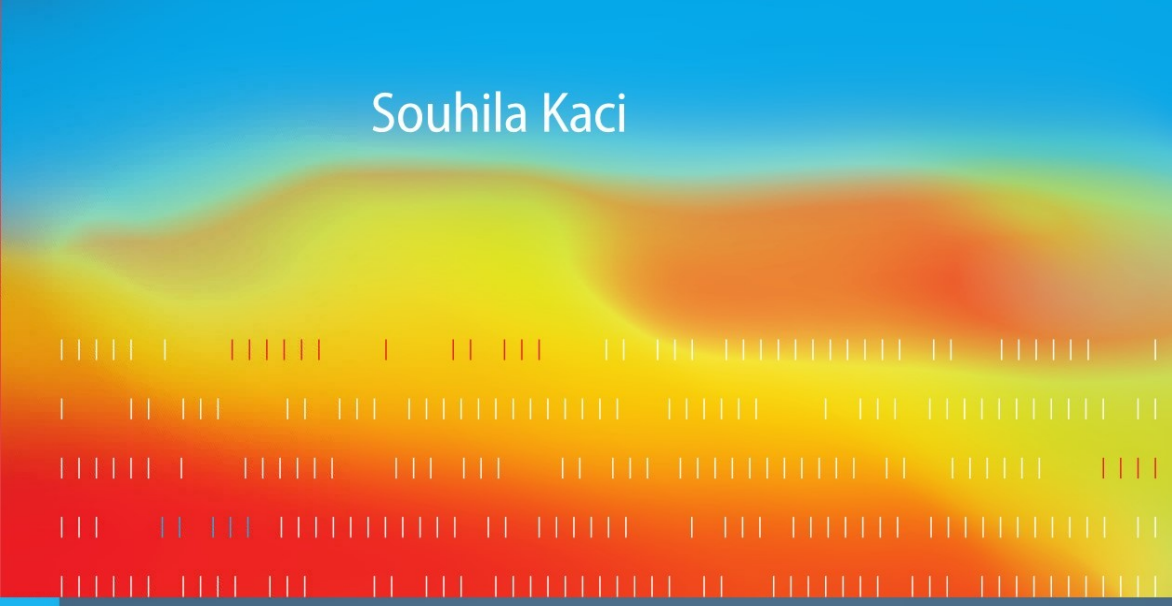
Souhila Kaci



Working with Preferences

Less Is More

Springer

Cognitive Technologies

Managing Editors: D. M. Gabbay J. Siekmann

For further volumes:
http://www.springer.com/series/5216

Souhila Kaci

Working with Preferences: Less Is More

Springer

Prof. Souhila Kaci
LIRMM (Laboratoire d'Informatique, de
Robotique et de Microélectronique de Montpellier)
161 rue ADA
F34392 Montpellier
Cedex 5
France
kaci@lirmm.fr

Cognitive Technologies ISSN 1611-2482
ISBN 978-3-642-17279-3 e-ISBN 978-3-642-17280-9
DOI 10.1007/978-3-642-17280-9
Springer Heidelberg Dordrecht London New York

Library of Congress Control Number: 2011929774

ACM Computing Classification: I.2, J.4, F.4

Cover design: KünkelLopka GmbH, Heidelberg

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

To my parents

Preface

Because preferences naturally arise and play an important role in many real-life decisions, they are the backbone of various fields. Preferences are fundamental in scientific research frameworks such as artificial intelligence, economics, and social choice theory, as well as applications, e.g., recommender systems, and e-commerce. Although preferences have been developed in diverse disciplines, their different usages share a common purpose, namely, to identify appealing choices from among those available.

In particular, preferences are a core and hot topic in artificial intelligence, for which we are witnessing plenty of work and dedicated international events. I have been involved with preferences for many years. My contributions to this topic were guided by two important questions I attempted to answer: *"How does one deal with users' preferences?"* and *"How can work on preferences in artificial intelligence be successfully exported to fields dealing with preferences?"* Each of these questions has motivated significant work. In particular, artificial intelligence researchers have extensively addressed the first question from representation issues when the number of choices is large. This led to a large number of different frameworks for preference representation. I contributed to this topic with new insights into preference representation. Nevertheless, I refrained from committing to any specific proposal (including mine). Instead, I studied, analyzed and compared the different frameworks and concluded that they are not competing but complementary. In fact, each has its merits but cannot adequately and/or naturally cope with all problems related to preference representation. Having studied different frameworks for preference representation allowed me to broaden my research contributions and address the second question. The purpose of this question is twofold. First, I aimed at understanding the usage of preferences in both artificial intelligence and other disciplines. Then, I aimed at highlighting the benefits of various successful preference representations developed in artificial intelligence and exporting them to other fields, allowing efficient handling of preferences. We promote the use of simple but satisfactory compact preference representation languages (less is more). This topic is of growing importance in the artificial intelligence community.

As I had always been keen on problems related to preferences, I moved for one year to a psychology lab (Cognition, Langues, Langage, Ergonomie, CLLE, Toulouse) as a researcher visitor. Preferences are not new topic in psychology. Different problems related to preferences have been identified and studied in this field. However, the relevance of the works in this field for artificial intelligence is largely unexplored. My collaboration with psychologists aims at exploring the connection between theoretical sciences and experimental sciences for preference handling in order to highlight the beneficial synergies among these fields.

Given that preferences have been extensively investigated from different perspectives, clearly a complete synthesis of this work does not fit in one book. On the other hand, one may wish to have an overview of these works. This book grew from an attempt to offer a coherent exposition of some problems related to preferences. The core part of this book is dedicated to preference representation and related problems. The second part is dedicated to the use of preference representation in various preference-based frameworks.

The book is reader-friendly. All concepts, definitions and results are explained in a simple way and illustrated with examples. The intended audience is students, novice researchers, and senior researchers in various fields, such as artificial intelligence, database management, operations research and psychology.

Lens, *Souhila Kaci*
October 2010

Acknowledgements

My work has benefited from discussions with many people from different research communities. I am not able to remember the names of all the people I should acknowledge (the list is too long). I would like to thank my collaborators and friends whose comments helped me improve this book. Many thanks go to Richard Booth, Rui da Silva Neves and Leon van der Torre.

I am enormously grateful to Youssef Hamadi for his support and encouragement to get this book through.

Special thanks go to my family for their unconditional support, encouragement and love.

Contents

Acronyms

List of abbreviations.

QCL	Qualitative Choice Logic
GAI	Generalized Additive Independence
GAI-net	Generalized Additive Independence Network
CPT	Conditional Preference Table
CP-net	Conditional Preference Network
CI-net	Conditional Importance Network
TCP-net	Conditional Preference Network with Tradeoffs
UCP-net	Conditional Preference Network with Utilities
CSP	Constraint Satisfaction Problem
SCSP	Soft Constraint Satisfaction Problem

List of symbols.

$\in$	membership
$\subseteq$	subset
$\subset$	proper subset
$\cap$	intersection
$\cup$	union
$\setminus$	difference
$\emptyset$	emptyset
$2^{\mathscr{A}}$	power set
$\times$	cartesian product
$\models$	satisfaction
$\neg$	negation
$\vee$	disjunction
$\hat{\times}$	ordered disjunction
$\wedge$	conjunction
$\forall$	universal quantifier
$\exists$	existential quantifier
$\top$	tautology

$\succeq$	at least as preferred as
$\succ$	strictly preferred to
$\sim$	incomparable with
$\approx$	as preferred as
min	minimal value
max	maximal value
$\geq$	greater than or equal
$>$	strictly greater
$\leq$	smaller than or equal
$<$	strictly smaller

Chapter 1
Introduction

What is a preference?

According to the dictionary, a preference is "(i) the act of preferring, (ii) the desire to have, do or choose one thing rather another, because you like it better, or because it is more convenient for you, (iii) a preferred choice: His preference is vanilla, not chocolate, (iv) a practical advantage given to one over others" (Collins Cobuild English Language dictionary, Dictionary.com).

Preferences are everywhere in our daily lives. They occur as soon as we are faced with a choice problem, e.g., "which ice cream flavor would you prefer?", "which investment funds would you choose?", etc. Among multiple choices, it is often necessary to identify one or more choices that are more appealing than others. Preference is inherently a multidisciplinary topic which brings together artificial intelligence researchers, philosophers, psychologists, economists, operations researchers, etc. In particular, preferences are becoming of greater interest in many areas in artificial intelligence, such as non-monotonic reasoning, multi-agent systems, constraint satisfaction, decision making, social choice theory and decision-theoretic planning.

The last few years were witness to different international events dedicated to preferences in artificial intelligence, which showed a growing interest in problems related to preferences in this framework:

- Workshop on Preferences in AI and CP: Symbolic Approaches, 2002 (with AAAI in Edmonton)
- Special issue on "Preferences in AI and CP", Computational Intelligence, Blackwell, 2004 (U. Junker, J. Delgrande, J. Doyle, F. Rossi, T. Schaub)
- Preferences: Specification, Inference, Applications, Dagstuhl seminars (2004)
- Multidisciplinary Workshop on Advances in Preference Handling (2005 with IJCAI in Edinburgh, 2006 with ECAI in Riva del Garda, 2007 with VLDB in Vi-

S. Kaci, *Working with Preferences: Less Is More*, Cognitive Technologies,
DOI 10.1007/978-3-642-17280-9_1, © Springer-Verlag Berlin Heidelberg 2011

enna, 2008 with AAAI in Chicago, 2010 with ECAI in Lisbon)

- Special issue on "Preferences and Soft Constraints", Journal of Heuristics, Springer, 2006 (S. Bistarelli, F. Rossi)

- Special issue on "Preference Handling for Artificial Intelligence", AI magazine, 2008 (J. Goldsmith, U. Junker)

- Special issue on "Representing, Learning, and Processing Preferences: Theoretical and Practical Challenges", Artificial Intelligence, Elsevier (C. Domshlak, E. Hüllermeier, S. Kaci, H. Prade)

Related problems

Research problems related to the study of preferences arise in their life cycle. We use in this book the generic term "user" to refer to an agent, an expert, etc.

When speaking about preferences, an obvious and natural question which arises is "what are users' preferences?", i.e. "where do preferences come from?". Preferences may be acquired through an interactive process with the user. This is called preference elicitation. They may also be acquired from data describing the user's behavior or her past preferences. This is called preference learning. Both frameworks are gathered under a generic terminology, namely, *preferences acquisition*. Once this is accomplished, the next step is the mathematical expression of preferences in terms of a preference relation over choices. In other words, this relation describes preferences between pairwise choices. The properties of such a relation are important. From among many questions, one may ask whether the relation is transitive, i.e., if the relation tells us that the choice c_1 is preferred to the choice c_2 and that the latter is preferred to the choice c_3, can we conclude that c_1 is preferred to c_3? Another question is about whether the relation is complete, i.e., is any choice comparable to any other choice? Constructing a preference relation and describing its properties is called *preferences modeling*. In most applications, preferences modeling calls for representation issues, which capture and manipulate the user's preferences described by a preference relation. The support of a preference relation is called a language, which we refer to as a preference representation language. This step is called *preference representation*. The last step in the preferences life cycle is *preferences reasoning*. This may involve, on the one hand, problems related to reasoning about preferences, e.g., preferences aggregation when we need to combine preferences of multiple agents, and preference revision when a new user's preferences must be added to her old preferences. On the other hand, preferences reasoning may involve problems related to reasoning with preferences, e.g., argumentation framework, decision theory, game theory, and database theory where preferences play an important role and need special attention.

To summarize, the preferences life cycle consists of four steps, namely, preferences acquisition, preferences modeling, preference representation and reasoning about and with preferences. Each step constitutes a major research topic.

Book content

Recent years have witnessed intensive work in each topic. This book aims at providing a coherent exposition of the above-cited problems, from preferences modeling and representation to reasoning with preferences.

Preference representation

Modeling users' preferences has long been tackled in decision theory. In this framework, a preference relation is represented by a numerical function which associates a utility value with each choice to express how satisfactory it is. However, it was early on recognized that the direct assessment of a preference relation is not the proper way to represent users' preferences. In fact, we generally have to deal with an exponential number of choices whose explicit enumeration and evaluation is time-consuming. Moreover, due to their cognitive limitation, it is not reasonable to expect that users are always able to compare all pairwise choices or evaluate how satisfactory each choice is.

Fortunately, choices we have to rank-order are not always holistic but are generally described by a set of attributes, e.g., cost, color, price, etc. On the other hand, in our daily lives, users more likely specify their preferences with respect to the attributes (or factors) they wish to consider. For example, a user planning a trip for her holiday may choose on the basis of destination, price and airline company. Thus she may prefer Venice to Barcelona and would prefer a cheap company. Lastly she may prefer travel with KLM to Barcelona and with Alitalia to Venice. The ultimate goal is to deal with such partial descriptions of preferences to find the most preferred trip (in terms of destination, price and airline company) or to compare two trips. This task is called preference representation. It is accomplished by compact preference representation languages which represent partial descriptions of preferences and rank-order the possible choices. Therefore, a preference relation is not explicitly exhibited but implicitly represented by a compact preference representation language. Preference representation has come to be an increasingly central framework in artificial intelligence. The challenge in developing a good compact preference representation language is in being faced with different conflicting aspects: it should (i) cope with sophisticated users' preferences, (ii) faithfully represent users' preferences in the sense that it rank-orders choices in a way as close as possible to users' specifications of preferences over choices if they were able to provide them, (iii) cope with possibly inconsistent preferences and (iv) offer attractive complexity

properties, i.e., the spatial cost of representing partial descriptions of preferences and the time cost of comparing pairwise choices or computing the best choices.

The last decade has seen a widespread number of compact preference representation languages aiming as best as possible to comply with the above-cited desiderata. Fundamentally these languages differ in the form of partial descriptions of preferences they support. In fact, users' preferences show up in different formats: comparative preference statements, e.g., "I like London more than Paris"; quantitative weighted preference statements, e.g., "I like Berlin with weight .7"; or qualitative weighted preference statements, e.g., "I really like Amsterdam". This leads to a first categorization of compact languages into weighted languages (qualitative or quantitative) and unweighted languages. Moreover, an analysis of comparative preference statements leads to a finer categorization. In fact, in some situations, users exhibit independency or dependency properties when expressing comparative preference statements. For example, a user may independently specify his preferences for the color of his pants and his jacket. On the other hand, his preference for the color of his shoes may depend on the color of his pants and his jacket. Independency and dependency are nice properties as they can be graphically shown, making explicit the relations between attributes. Therefore, unweighted languages are split into conditional logics and graphical languages.

The second fundamental difference is related to the way the languages rank-order the choices. Do they compare all possible choices or do they allow incomparabilities? Before we try to understand which comparisons are allowed by compact languages, this second difference calls for an essential question: How do languages compare choices? In fact, the answer to this question depends on our interpretation of preferences. Preferences can be viewed as hard constraints, in which case the user likes the choices which satisfy all her preferences and dislikes all the other choices. However, this behavior is wishful thinking since choices which satisfy all preferences may not exist when preferences are inconsistent, i.e., they cannot be fulfilled together. Moreover, even if preferences are consistent, choices which satisfy all of them may be not feasible. In such situations, a user is generally ready to accept less satisfactory choices such as those which better fulfill her preferences. In this case, preferences are viewed as soft constraints. Therefore, we move from a simple case of preferences being satisfied or not to a more graded issue. In other words, this means that some preferences are more important than others.

Let us now go back to the second fundamental difference between compact languages. In real life, users may not wish (or be able) to compare some choices, thus allowing ties or incomparabilities. They may also reject incomparability and wish to compare all possible choices. Compact languages reflect this idea. Some of them compare all possible choices, and others not.

The first part of this book is dedicated to preference representation and related problems. In Chapter 2 we present the necessary notation and background for the

mathematical encoding of preferences (preferences modeling). Chapter 3 constitutes an important part in the book. It offers a panoramic view of the well-known compact preference representation languages from each category we previously identified, namely, weighted languages, conditional logics and graphical languages.

Chapter 4 aims at explaining the behavior of some key languages in rank-ordering choices. As we previously said, given that preferences are considered as soft constraints, some preferences are more important than others. This importance is directly perceived in weighted languages, e.g., "I like Berlin with weight .7". In contrast, it is implicitly present in unweighted languages. For example, do the preference statements "prefer fish to meat", "if red wine is served, prefer meat to fish" and "if white wine is served, prefer cake to ice cream" have equal importance? It appears that "if red wine is served, prefer meat to fish" is more important than both "prefer fish to meat" and "if white wine is served, prefer cake to ice cream", which are in turn equally important. In Chapter 4 we consider some key unweighted languages and show their underpinning semantics with respect to the importance of preferences.

Chapter 5 approaches the preference representation framework from a different angle. While compact preference representation languages are mainly grounded in the interpretation of preferences in philosophy, we know relatively much less about preferences in psychology. Since preferences refer to subjective aspirations of the users, we believe that it is worth trying to understand preference representation from a cognitive psychology point of view. Preferences are not a new topic in psychology. Many works have focused on the study of preferences in human decision making and judgment. Chapter 5 concludes the first part of this book by providing some entry points to these studies. Surprisingly many well-known problems in artificial intelligence have been widely addressed in psychology, e.g., the construction of preferences and the transitivity of preferences, among many other problems.

Reasoning with preferences

Preference representation can be limited to an independent decision-aiding problem, in which case the purpose is to compute the best choices or to compare them. However the scope of preference representation is much wider than an isolated decision-aiding problem. Indeed, representing preferences and dealing with preference queries may be of interest in many fields of artificial intelligence, social choice theory, operations research and database management, to mention just a few. So far, preferences have been used in these fields in a very limited way, generally assuming that preferences over choices are explicitly available via a value function or a rank-ordering. It seems that researchers now realize the importance of revisiting the above fields and showing how they can profitably benefit from the use of compact preference representation languages. This is the focus of the second part