Vicenç Torra
Yasuo Narukawa
Sadaaki Miyamoto (Eds.)

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Modeling Decisions for Artificial Intelligence

Second International Conference, MDAI 2005
Tsukuba, Japan, July 2005
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Preface

This volume contains papers presented at the 2nd International Conference on Modeling Decisions for Artificial Intelligence (MDAI 2005), held in Tsukuba, Japan, July 25–27. This conference follows MDAI 2004 (held in Barcelona, Catalonia, Spain), the proceedings of which were also published in the LNAI series (Vol. 3131).

The aim of this conference was to provide a forum for researchers to discuss about theory and tools for modeling decisions, as well as applications that encompass decision-making processes and information fusion techniques. In this second edition, special focus was given to applications related to risk, security and safety.

The organizers received 118 papers, from 14 different countries, 40 of which are published in this volume. Each submission received at least two reviews from the Program Committee and a few external reviewers. We would like to express our gratitude to them for their work. The plenary talks presented at the conference are also included in this volume.

The conference was supported by the Department of Risk Engineering of the University of Tsukuba, the Japan Society for Fuzzy Theory and Intelligent Informatics (SOFT), the Catalan Association for Artificial Intelligence (ACIA), the European Society for Fuzzy Logic and Technology (EUSFLAT) and the Generalitat de Catalunya (AGAUR 2004XT 0004).

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April, 2005

Modeling Decisions for Artificial Intelligence – MDAI 2005

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Modeling Decisions for Artificial Intelligence: Theory, Tools and Applications

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Abstract. Aggregation operators, in particular, and information fusion techniques, in general are being used in several Artificial Intelligence systems for modeling decisions. In this paper we give a personal overview of current trends and challenges as well as describe our aims with respect to the MDAI conference series.

Keywords: Decision modeling, aggregation operators, information fusion, applications

1 Introduction

Methods for combining information (information fusion) have been used for different purposes for centuries. The election mechanisms (to select an alternative taking into account the preferences of different individuals) are a well known example. In fact, methods for this purpose were already proposed and studied [11] by R. Llull (S. XIII) and Cusanus (S. XV), and latter reconsidered by Condorcet and Borda (S. XVIII).

Current pervasive software systems have increased the importance of such techniques taking into account all the relevant information. Part of this information grows year by year [31] and is stored in a highly distributed environment. To further difficult the process, part of the information is *perishable* as becomes obsolete when the time passes (*e.g.*, sensory information in robots or traffic information in devices for route planning).

Several Artificial Intelligence-based applications embed aggregation operators and other information fusion tools to make such timely and appropriate decisions [26]. Existing applications include robotics where data from different sensors are fused, vision where image fusion is performed and machine learning with the so-called ensemble methods.

For all this, we can say that information fusion techniques are a basic element for decision making and that decision processes are increasingly situaded in dynamic environments.

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2 Establishing a Framework

In this section we review several issues concerning the use of information fusion tools in artificial intelligence applications.

2.1 Usage of Information Fusion and Aggregation Operators

Although the number of applications is rather large and fusion serves different purposes, most usages of aggregation and fusion methods can be classified according to two rough categories [33]: methods (i) to make (better) decisions and (ii) to have a better understanding of the application domain.

Decision making: In this case, the final goal is to make a decision. Then, the decision can be either selected from a set of alternatives (*alternative selection*) or built from several ones (*alternative construction*). Aggregation and fusion are applied in both cases but in a different way:

Alternative selection: Aggregation and fusion is typically used when there are several criteria for selecting each alternative. This corresponds to a multi-criteria decision problem. Software agents in an electronic auction would correspond to this situation, as the agent has to select a concrete alternative and this selection is done on the basis of several different criteria: the best price or the best quality.

This situation is modeled with a set of preferences or utility functions (one for each criteria) or using a single but multivalued preference. Then, to determine the best alternative, the preferences are aggregated. The alternative that gets the best score (in such aggregated utility or preference) is selected. As the score determines the final selection, the aggregation function used shapes the outcome.

Alternative construction: In this case, the alternative is constructed from a set of (partial) alternatives. Therefore, the method to build the alternative corresponds to the fusion process. Algorithms for *ensemble methods* can be studied from this perspective. Note that in ensemble methods for regression, several models are built first and each method corresponds to an alternative for deciding the outcome for a particular instance; then, all such outcomes are combined to construct the final outcome.

Improving the understanding of the application domain: The main motivation for using information fusion here is that the information supplied by a single source is limited with respect to the whole application domain (it is circumscribed to a subdomain) or not reliable enough (due to errors of the information source – either intentional or unintentional – or to the transmission chanel). Fusion is used to increase the area of application of the system and to increase its performance.

The use of aggregation operators and fusion helps the systems to improve their performance. Nevertheless, their use also causes difficulties as it is often

the case that information is not comparable and, in some cases, inconsistent. Therefore, systems have to embed simple fusion techniques in larger software tools so that the final outcome is consistent.

2.2 Integration, Fusion and Aggregation

In the previous sections we have used the terms "integration", "fusion" and "aggregation" as if they were synonyms. For the sake of clarity, we define them below. They are presented topdown. The following three terms are considered:

Information integration: This is the most general term that corresponds to the whole process of using information from several sources to accomplish a particular task. Similarly, we also have integration when the information is obtained at different time instants (even in the case that it is obtained from the same information source).

Information fusion: The integration of information requires particular techniques for combining data. Information fusion is the actual process of combining data into a single datum.

Aggregation operators: These operators (see *e.g.* [4, 41]) correspond to particular mathematical functions used for information fusion. We use this term when the functions that aggregate the information can be clearly identified in the whole system and their properties studied. In general, we consider that aggregation operators are mathematical functions that combine N values in a given domain D (*e.g.* N real numbers) and return a value also in this domain (*e.g.* another real number). Denoting these functions by $\mathbb{C}$ (from $\mathbb{C}onsensus$), aggregation operators are functions of the form:

$$\mathbb{C} : D^N \to D$$

From this point of view, it is clear that all aggregation operators are information fusion methods. However, only information fusion methods with a *straightforward* mathematical definition are considered here as aggregation operators. Therefore, not all information fusion methods are aggregation operators. In particular, methods with a complex operational definition (*e.g.* complex computer programs) are not considered in this paper as such. Naturally, the division between both terms is rather fuzzy.

Information fusion and aggregation operators heavily depend on the type of data representation (numerical, ordinal, nominal scales), kind of information they have to fuse (either redundant or complementary), etc. Accordingly, they can be studied from different perspectives.

3 Trends and Challenges: Theory, Tools and Applications

In this section we consider trends and challenges of information fusion focusing on aggregation operators. This section has been divided into three parts corresponding to theory, tools and applications.

3.1 Theory

Formal aspects of aggregation operators have been studied for a long time. Rellevant topics include the characterization of operators as well as representatation theorems. For example, results show that some operators can equivalently be expressed in terms of fuzzy integrals with respect to fuzzy measures[17, 24].

Results on the parameters of the operators and, more specifically, on fuzzy measures should also be considered as a present trend. In particular, current research focus on the definition of new families of fuzzy measures with reduced complexity (*i.e.*, requiring less than 2^N parameters where N is the number of sources) as well as characterizations of fuzzy measures. Distorted probabilities [25] and p-symmetric fuzzy measures [18] are examples of such new families.

Another topic for research on formal aspects is the definition of new operators or new applications. In this setting, we can find dynamic operators (dynamic in the sense that their behavior changes with respect to time). A particular type of them are standard aggregation operators with dynamic weights [36].

Finally, there are several techniques that have been used for modeling decisions and for which further research is needed. Rough sets and clustering techniques [19] are some of them. In the particular case of rough sets, rough measures and integrals have been defined [28]. Extensions of fuzzy multisets (bags) [20, 21, 38] might be also relevant to model situations in which several non-overlapping decisions are considered.

3.2 Tools

In a recent paper (see [34] for details), three research topics were distinguished concerning tools:

Parameter learning: As most aggregation operators are parametric, a crucial element for having a good performance is that parameters are correctly tuned. When the operator is fixed, this problem can be considered as an optimization one. Therefore, following the machine learning jargon, either supervised, unsupervised and reinforcement learning approaches can be applied.

Most research has been done using supervised approaches (see *e.g.* [1, 33]), although recently a few unsupervised approaches have also been used in conjunction with some fuzzy integrals (see *e.g.* [17] for details on fuzzy integrals). This is, methods have been defined for learning fuzzy measures from data. [14, 15, 29, 30] are a few examples of such results.

Function/operator selection: Selection of the operator is another important issue. At present much research has been devoted to the characterization of existing methods. Open issues include the development of algorithms and methodologies to determine (automatically) the suitable function for a given problem (see *e.g.* [2]).

Architecture determination: The topic of architecture determination encompasses two different aspects. On the one hand, we have the more general