Available online at www.sciencedirect.com
SCIENCE DIRECT®
Fuzzy Sets and Systems 156 (2005) 407–410
FUZZY sets and systems
www.elsevier.com/locate/fss

Aggregation operators and models

Vicenç Torra*

Institut d'Investigació en Intelligència Artificial-CSIC, Campus UAB, E-08193 Bellaterra, Catalonia, Spain

Available online 20 June 2005

Abstract

This paper gives an overview of the field of aggregation operators. Current research lines are described focusing on those related with the process of building real applications.

Keywords: Aggregation operators; Data modeling; Applications

1. Introduction

Aggregation operators, in particular, and data fusion methods, in general, have received a lot of attention in the last years. New methods have been developed and sound theoretical results have been obtained. Research results establish relationships between methods, describe their basic properties and define a roadmap for their use in practical applications. Such results are rooted in an old research trend on mechanisms to aggregate information. Ramon Llull, Nicolas di Cusa, Condorcet and Borda are some, to name a few, forerunners in this area [3]. Others such as Vitali, who defined the functional currently known as Choquet integral, in 1925, are not so known but also contributed to the development of the field. One may consider that current research follows the imprints of e.g. Cauchy, De Finetti, Aczél; and in the particular framework of fuzzy integrals Sugeno and Choquet.

The current theoretical interest to define a good roadmap for aggregation operators is tightly related with an increasing practical interest on using them for building applications. The amount of stored information is increasing day by day, and, thus, summarization mechanisms for reducing the burden of information as well as decision mechanisms to make timely decisions on the basis of such overwhelming data are

* Tel.: +34 93580 9570; fax: +34 93580 9661.
E-mail address: vtorra@iiia.csic.es.

0165-0114/$ - see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.fss.2005.05.037

needed. Aggregation operators are one of the basic bricks for building such systems. This causes that aggregation operators are currently in use in a large number of applications being very much different in nature. Aggregation operators are used in systems ranging from bioinformatics to information retrieval, from robotics to computer vision applications. Also, the information types that can be aggregated are large.

From a technical point of view, theoretical issues have reached in recent years a good level of maturity. For example, characterizations have been obtained for a large number of aggregation operators. See e.g. [5,2] for a good account on such results. Nevertheless, aggregation methods embedded in applications are still rather simple and do not exploit much of the most powerful operators. Instead, they usually use simple mechanisms (arithmetic or weighted mean, median and the like) and when more complex operators are used (as fuzzy integrals), their parameters are particularized so that the expressive power of the operator is radically diminished. In fact, this is the case of most practical applications of Choquet integrals that use particular classes of fuzzy measures that are rather *simple* from their expressive power point of view. For example, some of such applications use Sugeno λ-measures that are uniquely described using N values while arbitrary fuzzy measures require 2^N.

In this paper we outline some of the open research issues with respect to aggregation operators focusing on the requirements for their embedding in real applications. Although some theoretical issues are still open and they can be further developed, we focus here on those aspects that we think that are more directly related with the construction of applications.

2. Model building

When a new problem is encountered in which decision or summarization plays a role, the construction of a suitable model is not an easy task. This is so because several alternatives should be taken into account (e.g. operators, parameters). The modeling problems can be roughly classified at three different levels of abstraction. We review below such problems following a *top-down* description (from the most general problem to more specific ones).

Architecture construction: How aggregation operators and fusion mechanisms are integrated among themselves and with the system so that correct decisions and appropriate summaries are computed and used by the system to achieve its goals. For example, what is the appropriate information flow to integrate user preferences, knowledge-based systems' outcomes and search engine results to obtain a list of relevant web pages.

Function/operator selection: Once a generic architecture is built, the concrete fusion mechanisms have to be selected, e.g., which is the best aggregation operator to fuse lists of web pages.

Parameter learning: Aggregation operators are typically parametric (e.g., weights in the weighted mean and fuzzy measures in fuzzy integrals). Prior to the application of the model, parameters have to be fixed so that the system behaves in an *appropriate* way, e.g., which fuzzy measure should be used for combining ratings when we use a Choquet integral.

These three modeling problems introduce three different kinds of research topics. We review them below.

Parameter learning: In the last years, several methods for parameter determination have been developed. Approaches can be distinguished according to the available information. One case is when there is an expert participating in the modeling process. This would be the case of Saaty's Analytical Hierarchy