Smart Innovation, Systems and Technologies

Volume 87

The Smart Innovation, Systems and Technologies book series encompasses the topics of knowledge, intelligence, innovation and sustainability. The aim of the series is to make available a platform for the publication of books on all aspects of single and multi-disciplinary research on these themes in order to make the latest results available in a readily-accessible form. Volumes on interdisciplinary research combining two or more of these areas is particularly sought.

The series covers systems and paradigms that employ knowledge and intelligence in a broad sense. Its scope is systems having embedded knowledge and intelligence, which may be applied to the solution of world problems in industry, the environment and the community. It also focusses on the knowledge-transfer methodologies and innovation strategies employed to make this happen effectively. The combination of intelligent systems tools and a broad range of applications introduces a need for a synergy of disciplines from science, technology, business and the humanities. The series will include conference proceedings, edited collections, monographs, handbooks, reference books, and other relevant types of book in areas of science and technology where smart systems and technologies can offer innovative solutions.

High quality content is an essential feature for all book proposals accepted for the series. It is expected that editors of all accepted volumes will ensure that contributions are subjected to an appropriate level of reviewing process and adhere to KES quality principles.

More information about this series at http://www.springer.com/series/8767

Fábio Romeu de Carvalho
Jair Minoro Abe

A Paraconsistent Decision-Making Method

Springer

Fábio Romeu de Carvalho
Paulista University, UNIP
São Paulo
Brazil

Jair Minoro Abe
Paulista University, UNIP
São Paulo
Brazil

Additional material to this book can be downloaded from http://extras.springer.com.

ISSN 2190-3018 ISSN 2190-3026 (electronic)
Smart Innovation, Systems and Technologies
ISBN 978-3-319-74109-3 ISBN 978-3-319-74110-9 (eBook)
https://doi.org/10.1007/978-3-319-74110-9

Library of Congress Control Number: 2018933003

Printed on acid-free paper

This Springer imprint is published by the registered company Springer International Publishing AG part of Springer Nature
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Dedicated to Professor Newton
C. A. da Costa, teacher and friend.

Foreword

Nonclassical logic is a logic with some features which are different from those in classical logic. Consequently, nonclassical logics have been applied to applications for some areas, in particular, computer science and engineering. In fact, there are many logical systems classified as nonclassical logics.

In general, real systems face contradiction for many reasons. Classical logic cannot properly handle contradiction, and it is not regarded as an ideal system. Logics which are capable of dealing with contradiction are called paraconsistent logics. Now, the importance of paraconsistent logics is certainly recognized both in logic and computer science.

In fact, many different paraconsistent logics have been developed. One of the important paraconsistent logics was proposed by Newton da Costa in the 1950s. He is a leading person in the area. One of the authors of the present book, Jair Minoro, is da Costa's student and completed Ph.D. thesis under him on annotated logics in 1992.

Annotated logic was developed by Subrahmanian to provide a theoretical foundation for paraconsistent logic programming in 1987. Later, the logic has been studied by many including da Costa and Abe. The distinguished features of annotated logic are as follows: (1) it has a firm logical foundation, and (2) it is suitable for practical applications. On these grounds, annotated logic can be seen as an interesting paraconsistent logic.

In the 1990s, I also studied annotated logics by myself in connection with AI applications. I met Abe in 1997. Since then, I worked with him and wrote many papers. Recently, I also published a book *Introduction to Annotated Logics* with Abe and Kazumi Nakamatsu by Springer. We are now working on several books on annotated logics for applications.

The present book is concerned with applications of annotated logics to engineering. In Chap. 1, the authors say: "the object of this work is to present the reader with the principles of the annotated paraconsistent logics and their application in decision-making, mainly, in Production Engineering: the Paraconsistent Decision Method-PDM, which is based on the para-analyzer algorithm."

They provide the theoretical foundation for the PDM by using the paraconsistent annotated evidential logic Eτ, which is a version of annotated logics. Eτ seems to be appropriate for engineering applications since it captures several types of information including contradiction and incompleteness in real problems.

I can find several merits of the book by reading it. First, it is easy even for beginners to understand it. Namely, it starts with introductory chapters on theoretical aspects and goes on to chapters on engineering applications. Second, it is also regarded as a reference for experts. They can learn some aspects of annotated logics. Third, it covers many applications in some areas using annotated logic. Also, their approaches are carefully compared with others in the literature to defend their advantages. Finally, it includes useful appendix and references. They appear to be helpful for the readers.

I believe that the present book is significant in that it reveals the approach of annotated logic to engineering applications. The book also suggests many possibilities of annotated logics beyond engineering, which should be worked out.

I conclude that the readers will be able to understand the broad applicability of annotated logic.

Kawasaki, Japan
June 2017

Seiki Akama

Preface

At the dusk of the past century and at the dawn of this one, Computing in general (including the Information Systems, Artificial Intelligence, Robotics, and Automation, among others) goes through a real revolution, never seen before. The paradigm not only of knowledge but also of technology and its applications suffered radical changes.

Operational Research has been a very broad and inexhaustible subject. Hundreds of researchers all over the world have dedicated to this issue, which progresses daily. To have an idea of its dimension, there is a world conference—*European Conference on Operational Research, EURO,* which is annually held and, in July 2010, held its 24th edition, in Lisbon. In 2009, it was held in Bonn, Germany, where we were together with other 2,221 researchers from 72 countries.

Within Operational Research, the study of decision-making is inserted. A lot has been researched about this subject, several decision-making methods have been developed, but until today, none has managed to end the subject and, we believe, none will be able to do so. A fast Internet browsing may show how much is researched and how much is published about the so-called *Decision Support Systems, DSS.* They constitute a class of information systems (including, but not limited to computational systems), which support decision-making activities in the organizations and the businesses.

Moreover, it is in this area that we ventured, seeking to provide one more contribution to the scientific world, developing a new decision method substantiated on a logic which is alternative to the classical one, recently discovered, the paraconsistent annotated evidential logic. We named it Paraconsistent Decision-Making Method, PDM.

It is worth to highlight that it was a Brazilian logician; Newton C. A. da Costa is among the pioneers who developed the first paraconsistent systems in all logical levels in 1958. Others pioneers were the Polish logician J. Łukasiewicz and S. Jaśkowski, and the Russian logician N. A. Vasiliev.

Decision-Making with Paraconsistent Annotated Logic Tools

da Costa developed a family of paraconsistent logics, the C_n propositional systems, the corresponding predicate calculi, and higher order logic (in the form of set theory), containing in this way all the common logical levels. Regarding this theme, da Costa has lectured in all the countries of South and North America and some countries in Europe.

He received, among several distinctions, the Moinho Santista Award on Natural Sciences (1994), the Jabuti Award on Natural Sciences (1995), the "Nicolaus Copernicus" Scientific Merit Medal of the University of Torun, Poland (1998). He is a full member of the International Institute of Philosophy of Paris, the first Brazilian person to belong to this institution. He is also Emeritus Professor of Campinas State University.

We believe there is not a reference in the literature that gives the reader a proper comprehension of the themes related to this logic, which we have discussed in the several scientific meetings we have participated. With this work, we intend to provide a contribution in this sense, disseminating this new logic class, the paraconsistent logics, and showing how they may be utilized in decision-making, especially when the database we have is provided with inconsistencies and imprecisions.

Therefore, the object of this work is to present the reader with the principles of the annotated paraconsistent logics and their application in decision-making, mainly, in Production Engineering: the Paraconsistent Decision-Making Method—PDM, which is based on the para-analyzer algorithm. Besides that, a comparison of the PDM with the statistical method is made, as well as with a simplified version of the fuzzy decision method. Examples of practical applications are thoroughly developed and discussed, with numerical applications, tables, and charts.

The theoretical foundation for the PDM is the paraconsistent annotated evidential logic Eτ maximization and minimization rules. These rules are applied to the degrees of favorable evidence or degrees of belief (***a***) and the degrees of contrary evidence or degrees of disbelief (***b***), the compose the so-called annotation constants: $\mu = (\boldsymbol{a}; \boldsymbol{b})$. This application is performed using operators and may be done so in two different ways.

(**1**) Conducting the *maximization of the degrees of evidence* of a set of annotations, in order to seek the best favorable evidence (**highest** value of the degree of favorable evidence ***a)*** and the worst contrary evidence (**highest** value of the degree of contrary evidence ***b)***. This maximization is made by an Eτ logic operator, designated by **OR** (conjunction). For the case of a set of only two annotations, the application of this operator is as follows:

$$\textbf{OR}\ \{(\boldsymbol{a}_1; \boldsymbol{b}_1), (\boldsymbol{a}_2; \boldsymbol{b}_2)\} = (\max\ \{\boldsymbol{a}_1, \boldsymbol{a}_2\}; \max\ \{\boldsymbol{b}_1, \boldsymbol{b}_2\})$$

For the minimization, we do the opposite: we seek the worst favorable evidence (**lowest** value of the degree of favorable evidence ***a)*** and the best contrary evidence (**lowest** value of the degree of contrary evidence ***b***). The operator that executes it is designated by **AND** (disjunction).

$$\textbf{AND}\ \{(\boldsymbol{a}_1;\ \boldsymbol{b}_1),\ (\boldsymbol{a}_2;\ \boldsymbol{b}_2)\} = (\min\{\boldsymbol{a}_1,\ \boldsymbol{a}_2\};\ \min\{\boldsymbol{b}_1,\ \boldsymbol{b}_2\})$$

(**2**) Performing the *maximization (or the minimization) of the degree of certainty* (H = $a - b$) of the set of annotations, a degree that, in a certain way, translates how much the information contained in this set enable to infer for the veracity or the falsity of the premise.

The maximization of the degree of certainty (H) is obtained seeking the best favorable evidence **(highest** value of the degree of favorable evidence ***a)*** and the best contrary evidence **(lowest** value of the degree of contrary evidence ***b***). This maximization is made by an Eτ LOGIC OPERATOR, designated by **MAX and that, in this book, will be called maximizing.**

$$\textbf{MAX}\ \{(\boldsymbol{a}_1;\ \boldsymbol{b}_1),\ (\boldsymbol{a}_2;\ \boldsymbol{b}_2)\} = (\max\{\boldsymbol{a}_1,\ \boldsymbol{a}_2\};\ \min\{\boldsymbol{b}_1,\ \boldsymbol{b}_2\})$$

Analogously, minimization seeks the worst favorable evidence **(lowest** value of the degree of favorable evidence ***a*)** and the worst contrary evidence **(highest** value of the degree of contrary evidence ***b*)**. This minimization is made by the **MIN** operator that will be called **minimizing.**

$$\textbf{MIN}\ \{(\boldsymbol{a}_1;\ \boldsymbol{b}_1),\ (\boldsymbol{a}_2;\ \boldsymbol{b}_2\} = (\min\{\boldsymbol{a}_1,\ \boldsymbol{a}_2\};\ \max\{\boldsymbol{b}_1,\ \boldsymbol{b}_2\})$$

Therefore, we observe that there are two ways to apply the maximization and minimization rules of the logic Eτ. In some aspects, one has advantages over the other; in others, disadvantages. For example, the first way enables a better identification of the existent inconsistencies in the database, but on the other hand, the second one is more intuitive and leads to more predictable and coherent results.

In this work, we will opt for the second manner, that is, for the **MAX** and **MIN** operators. The decisions will be made based on the application of the so-called min-max rule, or optimistic decision rule, once it minimizes the best results.

For the execution of the operations demanded by the method, in Chap. 5, we developed a calculation program based on the Excel spreadsheet, which was named Calculation Program for the Paraconsistent Decision Method, CP of the PDM.

In Chap. 9, a discussion is established about two ways to interpret the maximization and minimization, enabling a comparison between them.

There are five appendices that accompany this book, with data and solutions for the several items that are presented and analyzed.

For each appendix, there are two versions: a blocked one (but not hidden), which leaves only the cells related to the data input of each analysis free for the reader to alter, although it shows the other ones, including the formulas; and a free one, which gives the reader the possibility to alter whatever they consider necessary.

This concern resulted from the possibility of a more distracted user altering the free spreadsheet and, then, not being able to recompose it. The spreadsheet in Appendix E is blocked and hidden, constituting an exception. These appendices are found on the website: http://extras.springer.com.

Appendix A brings the solution of what was developed in Chap. 5; Appendix B brings a generic solution for what was proposed in Chap. 5; Appendix C contains the databases utilized in the development of five paragraphs of Chap. 6 and the exercises of Chaps. 6 and 8; Appendix D brings the solutions for what was developed in the text of Chap. 6 and provides the guidance for the exercises proposed in this chapter; and finally, Appendix E presents the solution for a challenge (exercise) proposed in Chap. 9.

Even though the language of logic is developed with all the strictness the subject demands, the exhibition of the book is pervaded by language abuse. The attentive reader will perceive them and be able to overcome them as he/she becomes acquainted with the text.

São Paulo, Brazil

Fábio Romeu de Carvalho
Jair Minoro Abe

Acknowledgements

We would like to express our very great appreciation to Prof. Dr. João Carlos Di Genio, Rector of Paulista University—UNIP, São Paulo, Brazil, for providing us with a distinct support as researchers at UNIP over the past years.

Contents