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Luis Argüelles Méndez

A Practical Introduction to Fuzzy Logic using LISP



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To my wife Ana

To my mother Esperanza

Preface

The origins of this book are rooted back to the 1990s of the last century. In those times I was asked to prepare an introductory course on Fuzzy Logic for engineering students who were eager to take the fundamentals of the theory, especially from a practical approach. The students (already in their last year at the university) were certainly bored of theoretical issues and heavy mathematical treatises since they had suffered a hard curriculum at college. Additionally, some students had varying programming experience in C language, some others in Pascal and then some others simply had no programming experience at all. Simultaneously, the most available publications and books on the subject at that time were either at a popular science level or excessively theoretical, usually far from the practical approach course they were expecting.

The solution was to prepare readings from selected material on the subject while using a teaching vehicle specifically suited to the task. This vehicle was the Lisp programming language. In that seminal course students would learn both fuzzy logic theory and the minimum Lisp required to use FuzzyLisp, a set of Lisp functions that I designed from scratch in such a way that students could easily understand the theory and at the same time build simple fuzzy models.

More than 15 years later, the overall situation has not changed significantly. The quantity of information on the Internet is nowadays overwhelming, but requires time and dedication in order to filter and put into order the essential concepts of the theory. Excellent books are nowadays on the market on Fuzzy Logic, but they continue being located either at the academic side or at the popular science level. The mission of this book is to fill the gap between these two shores of complexity, always under a practical approach and using Lisp as a sort of computing gateway that will allow the reader to reach two destinations: To perfectly understand the basics of Fuzzy Logic and to design and develop from small to medium complexity models based on this powerful artificial intelligence paradigm. This book is neither the best book on Fuzzy Logic nor the best available book on Lisp. However, it tries to be the only book that offers the reader (I sincerely hope it) the perfect balance for getting the aforementioned mission accomplished. In the first four chapters the

reader will learn the required level of Lisp and then even more, using a dialect of this language, NewLisp, that can be freely downloaded from the Internet and runs in the mainstream computer operating systems as of 2015. From Chap. 5, the theory is gradually introduced, seizing the opportunity to elaborate every FuzzyLisp language function (the complete set of functions that make up the FuzzyLisp programming toolbox can be downloaded from the companion book's website: <http://www.fuzzylisp.com>). At a higher level of resolution, this book is based on the following structure:

Chapter 1 puts Lisp in context, explaining its advantages as a modern computer language and offering a historical perspective of its development from its inception back in the last fifties of the twentieth century until nowadays. Then the NewLisp implementation is introduced and immediately the reader finds the first dialogues with the language by means of using it as a powerful electronic calculator.

Chapter 2 deals with lists. Lisp derives in fact from the words LISt Processing, so lists are the building blocks of the language. The fundamental list management functions are introduced there and soon the reader finds as an example a simple practical model of queue for a highway toll station.

Chapter 3 is all about user-defined functions in Lisp and explains how to structure and organize functions, extending first the available set of list management functions and then showing how to incorporate conditional structures. Later some loop structures introduce the concept of iteration, a common paradigm to many other programming languages. Finally, recursion is shown in detail, at a level not usually shown in Lisp introductory books.

Chapter 4 can be seen almost as a Lisp celebration where all the material exposed in the previous chapters is assembled in order to show how to build real applications in Lisp. The first one is a simulation of a French roulette that aside from dealing with random numbers allows the user to bet and then lose or win. The second application is a simple but powerful collection of functions for CSV (comma separated values) database management. This approach of Lisp programming preludes the architecture of FuzzyLisp.

With Chap. 5 the book enters into the realm of fuzzy sets theory. It starts with a quick review of classic set theory and soon transits toward the foundations of fuzzy sets. The central pages of the chapter express the nuclear concepts and ideas of the theory. If the reader understands well this section then he or she will probably not have difficulties to digest the rest of the material in the book. For assisting the reader in its travel through the chapter, plenty of Lisp functions are introduced in order to test every new concept at the keyboard. Finally, and as a practical application, Life Illness Curves are presented, a new approach for interpreting human health evolution in medicine.

Chapter 6 introduces a number of additional material about the theory of fuzzy sets and includes also a big share of the Lisp functions that make up FuzzyLisp. The code of every FuzzyLisp function is discussed and exhaustively commented in those rare occasions where some tricky code is used. An important section is presented about fuzzy numbers, including the notion of intervals and interval arithmetic for introducing fuzzy numbers arithmetic and then fuzzy averaging,

together with a first view on defuzzification. After this, linguistic variables are introduced. The chapter ends with a practical application on fuzzy databases.

Chapter 7 deals with fuzzy logic. Since fuzzy logic is a special and powerful type of logic it deals also with propositions and logical inferences. The theory exposed in the chapter is dense but the abundance of Lisp examples helps the reader to understand every hidden corner in the way. Fuzzy hedges are introduced and Fuzzy Rule-Based Systems (FRBS) are presented in detail. As practical applications, an air-conditioner control model is developed in FuzzyLisp as well as an intelligent model for evaluating performance in regularity rallies, a modality of car racing.

The last chapter is entirely dedicated to practical applications of Fuzzy Logic using FuzzyLisp. These applications are exposed as “projects” that try to stimulate the creativity of the reader. Three applications are developed at an increased complexity level with respect to models from previous chapters. The first one merges simulation and fuzzy control, creating a simplified, yet intelligent model for landing the Apollo XI Lunar Module on the Moon. The second project deals with speech synthesis where double stars in astronomy are the excuse for elaborating on the required architecture for the project, but the theoretical aspects described in the chapter are of direct application in practically every field in science. The last section introduces Floating Singletons, an advanced modeling technique that shows its potentiality in an example model for getting an index of pulmonary chronic obstruction. The book is tail-complemented by two appendices: The first appendix shows the main differences between NewLisp and ANSI Common Lisp, while the second is a complete reference of the FuzzyLisp functions developed along this book.

The audience for this book covers readers not only from the field of computer science, but also those from the world of engineering and science. The focus is on undergraduate students and practicing professionals of technical or scientific branches of knowledge, including engineering, medicine, biology, geology, etc. It also can serve as a textbook for and introductory course on Fuzzy Logic. The book assumes basic tertiary mathematical knowledge from the intended reader. Any first-year student from college should be able to read it without special efforts. Needless to say, professionals in engineering and scientific fields will find it easy to follow. No previous programming knowledge is needed in any computer language since, as already said, it includes a gentle introduction to LISP programming.

Incidentally, the book can also be of huge interest to software developers. Certain FuzzyLisp functions can be understood as a bridge between FuzzyLisp and any other programming language. The text files produced by these functions can be loaded into any software project and then all the expert knowledge from the previously developed fuzzy models can be incorporated in those software projects. As an example, this opens the possibility for using FuzzyLisp as a software tool for developing intelligent apps for smartphones and other mobile devices.

Finally, from these pages I would like to seize the opportunity to thank the many persons who in some way have helped me to write this book, being well aware that it is impossible to mention them all, so I shall try to at least thank the people closest

to this work. First, I would like to show my most intimate gratitude to my wife Dr. M.D. Ana Fernández-Andres not only for always being there with her patience and support while writing the manuscript but also for her always useful advice in the medical examples used in this book. I wish also to express my deepest appreciation to Dr. Rudolf Seising for giving me the ultimate boost for starting this project when I shared with him my preliminary ideas of an introductory book on Fuzzy Logic using Lisp. On the other hand, I must express my deepest gratitude to Dr. Gracián Triviño for so many conversations while writing the chapters of this book. It is also impossible to forget the inspiration from the scientific sessions at the European Centre for Soft Computing from Prof. Michio Sugeno, and last, but not least, I would like to thank the inspiration from Prof. Enric Trillas. This book owes him a very special kind of push. Much more than he would ever have imagined. Also, I would like to thank Dr. Lutz Müller (the creator of NewLisp) for his kindness when confronted with technical questions concerning his Lisp implementation. An especial mention must be made also to Dr. Janusz Kacprzyk for accepting this book in his series *Studies in Fuzziness and Soft Computing*, and the Springer Verlag (Heidelberg), in particular to Dr. Leontina di Cecco and Mr. Holger Schaepe for their support and valuable comments while developing this work.

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