

Studies in Fuzziness and Soft Computing

Luis Magdalena
José Luis Verdegay
Francesc Esteva *Editors*

Enric Trillas: A Passion for Fuzzy Sets

A Collection of Recent Works on Fuzzy
Logic

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Studies in Fuzziness and Soft Computing

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Editors

Enric Trillas: A Passion for Fuzzy Sets

A Collection of Recent Works
on Fuzzy Logic

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Foreword

To say that it is a great pleasure to write a foreword to *Enric Trillas: A Passion for Fuzzy Sets* is an understatement. *Enric Trillas: A Passion for Fuzzy Sets* is a highly impressive collection of authoritative papers which deal with a wide variety of issues in the theory and applications of fuzzy logic, with emphasis on issues which fall within the realm of mathematics. My foreword is a personal tribute to my very special friend—Enric Trillas. Over the years, Enric has contributed in so many ways and so fundamentally to the advancement of fuzzy logic and its applications.

Enric is a member of a very small group of mathematicians who took a positive view of a fuzzy logic and contributed importantly to its development during its formative years. In the world of mathematics, the initial reaction to fuzzy set theory and fuzzy logic was, in larger measure, one of indifference or derision. Here is what a colleague of mine, Prof. William Kahan had to say about fuzzy logic in 1972. In a similar vein, my colleague, a brilliant computer scientist, William Kahan, wrote:

Fuzzy theory is wrong, wrong, and pernicious. I cannot think of any problem that could not be solved better by ordinary logic. What Zadeh is saying is the same sort of things ‘Technology got us into this mess and now it can’t get us out. Well, technology did not get us into this mess. Greed and weakness and ambivalence got us into this mess. What we need is more logical thinking, not less. The danger of fuzzy theory is that it will encourage the sort of imprecise thinking that has brought us so much trouble. (Kahan 1972).

Despite many comments in this spirit, with the passage of time fuzzy logic grew in visibility and importance. Today, there are over 360,000 papers with fuzzy in title (Google), with over 25,000 in mathematics (MathSciNet). On the applications side, there are over 240,000 patents (Google). These numbers speak for themselves. What is striking is that in almost all fields of science and engineering there are papers with fuzzy in title. The contents of *Enric Trillas: A Passion for Fuzzy Sets* are a reflection of the wide-ranging impact of fuzzy logic.

What is widely unrecognized is that underlying the wide-ranging impact of fuzzy logic, this is what I call FL-generalization. In my view, FL-generalization has a position of centrality in fuzzy logic. My tribute to Enric is a brief exposition of FL-generalization.

The concept of FL-generalization was introduced in my 2008 paper “[Is there a need for fuzzy logic?](#)” Information Sciences. The basic importance of FL-generalization has not been fully recognized as yet. For those who are not familiar with FL-generalization, a brief explanation is provided in the following.

In large measure, science—including mathematics—is based on the classical, Aristotelian, bivalent logic. Bivalent-logic-based science has achieved brilliant successes. But what is striking is that bivalent-logic-based science ignores a basic reality. In human cognition, almost all classes have unsharp (fuzzy) boundaries. Bivalent logic is not the right logic for dealing with such classes, nor is bivalent-logic-based probability theory. What is needed for this purpose is fuzzy set theory and, more broadly, fuzzy logic, FL. Informally, fuzzy logic is a system of reasoning and computation in which the objects of reasoning and computation are classes with unsharp (fuzzy) boundaries.

The point of departure in fuzzy set theory is a generalization of the concept of a set to the concept of a fuzzy set. A fuzzy set, A , in a space, U , is a graduated class of elements of U . Graduation involves association of each element, u , of U with its grade of membership in A . This very simple generalization has wide-ranging ramifications.

Let T be a bivalent-logic-based theory, formalism, algorithm, concept, etc. T is FL-generalized by adding to T the concept of a fuzzy set, along with associated concepts and techniques. The result of FL-generalization is fuzzy T . Examples. Fuzzy arithmetic, fuzzy linear programming, fuzzy control, fuzzy stability, fuzzy support vector machine, fuzzy group theory, fuzzy topology, fuzzy convex set, fuzzy back-propagation algorithm, fuzzy probability, etc. T may be viewed as a special case of fuzzy T . FL-generalization is a matter of degree, reflecting the extent to which sets in T are replaced by fuzzy sets. In the limit, FL-generalization of T involves a shift in the foundations of T from bivalent logic to fuzzy logic.

What is gained by FL-generalization? There are two principal rationales. First, FL-generalization opens the door to construction of better models of reality. There is a fundamental conflict between two realities. In the world of human cognition, almost all concepts are classes with unsharp (fuzzy) boundaries, that is, are a matter of degree. In the world of science, almost all definitions are bivalent, with no degrees allowed. Here are a few examples. In economics, the official definition of recession is bivalent. Specifically, economy is in a state of recession if the GDP declined in two successive quarters. Realistically, recession is not a bivalent concept—it is a matter of degree. The same applies to the concept of unemployment. Clearly, unemployment is not a bivalent concept, but it is defined as such. In probability theory, stationarity is defined as a bivalent concept. Realistically, stationarity is a matter of degree. In stability theory, stability is defined as a bivalent concept. Realistically, stability is a matter of degree, and so on, and on and on. FL-generalization of definitions, serves an important purpose—replacement of bivalent definitions with fuzzy-logic-based definitions which are much better models of reality.

The second rationale has a position of centrality in applications of fuzzy logic. Specifically, the second rationale involves an exploitation of tolerance for

imprecision through replacement of numbers with precisiated words. A word is precisiated by representing it as a label of a fuzzy set which has a specified membership function. A striking example of exploitation of a tolerance for imprecision is the problem of stabilization of an inverted pendulum. The traditional approach starts with formulation of differential equations of motion, followed by application of the machinery of stability theory. In the fuzzy logic-based approach, a small number of very simple fuzzy if-then rules, with precisiated words in the antecedents and consequents, are employed to describe the dynamics of the inverted pendulum. This is the essence of what is called the Fuzzy Logic Gambit. Fuzzy Logic Gambit is an essential ingredient of the formalism of Computing with Words (CWW). Basically, CWW may be viewed as a progression from the use of numbers to the use of precisiated words.

In summary, FL-generalization may be viewed as an important instrument of generalization in which the point of departure is replacement of the concept of a set with the concept of a fuzzy set. In large measure, scientific progress is driven by a quest for better models of reality. What I see in my crystal ball is the following. In the coming years, more and more theories, formalisms, algorithms and concepts will be FL-generalized. This is likely to be the case even in mathematics—a discipline in which the word “fuzzy” strikes a dissonant note. What should be recognized is that shifting foundations of a theory from bivalent logic to fuzzy logic need not involve a loss of rigour and precision. Example. Fuzzy topology is every bit as rigorous and precise as classical topology.

It is rather unusual to include in a foreword an exposition of a formalism. I chose to do so as a way of paying my tribute to an exceptional person—Enric Trillas and to draw attention to widely unrecognized—the centrality of FL-generalization in fuzzy logic and its applications. As was pointed out earlier, in one way or another almost all papers in *Enric Trillas: A Passion for Fuzzy Sets* employ FL-generalization implicitly or explicitly.

Enric Trillas: A Passion for Fuzzy Sets is an important contribution to the literature. There is much that is original, insightful and significant. The contributors, the editors and the publisher deserve our thanks and congratulations.

UC Berkeley, November 2014

Lotfi A. Zadeh

Preface

Reality does not always present itself in the form of classical propositions, of crisp knowledge that can be answered with a simple yes or no, but in many cases has shades; it may be vague or uncertain. To represent this vague or imprecise knowledge, Lotfi Zadeh devised fuzzy sets. In Spain, one of the paradoxes of life, the knowledge of who is the father of fuzzy research is not fuzzy, it is most certainly crisp.

Those who know the subject know that the father of fuzzy research in Spain is called Enric Trillas. This book is dedicated to him as a tribute by colleagues and students who have enjoyed his knowledge and teachings throughout his long and fruitful scientific career, without forgetting his organizational skills which are also of such great use for fuzzy research. The editors are a representation of his collaborators, who have gladly accepted the task of editing this tribute book to Enric in the year that he will celebrate his 75th birthday. Francesc Esteva was involved in the creation of the Barcelona group and was the first president of EUSFLAT. Luis Magdalena was the second president of EUSFLAT and is the current director of the European Centre for Soft Computing. José Luis Verdegay has been one of the pioneers of the Granada group and the first president of FLAT.

Enric's relationship with fuzzy sets came shortly after his thesis, which dealt with probabilistic metric spaces. Those were years of cultural vacuum, which reached their peak in the realms of scientific research. Enric not only discovered fuzzy sets in his readings in the search for new and inviting issues, but also managed to reach out to the father of fuzzy sets, Lotfi Zadeh, and establish a lasting relationship with him, which is still very much alive today. In parallel, he created a research team at the Department of the School of Architecture of the Technical University of Catalonia where he works, creating school. Its multidisciplinary seminar counts on the presence of foreign professors and the research carried out by Enric and his students is frequently at conferences and in publications throughout the world. The Barcelona group is well known and he knows all the pioneers. He created the *Stochastica* journal (one of the few noteworthy Spanish journals of those times in the mathematical review) and has organized national and international events, including the first IFSA World Congress in Mallorca in 1985.

Trillas achieved what was difficult at those times: he created a research group and had recognised international presence in the subject.

In his bid to boost research in Spain, Enric pushes the department to organize conferences of introduction to research, which had the side effect of opening the relationship with one of the groups currently most active on Fuzzy research in Spain: the Granada group, which at that time was beginning to break into the world of research.

It was not easy to put the wheels into motion and subsequently create the Granada group. Times were not the best for that task; there was no tradition of teamwork, the academia did not accept the “fuzzy” and publications in prestigious journals raised inexplicable misgivings among colleagues. But little by little, the group was consolidated through significant international support, reflected in numerous and ongoing visits to Granada by renowned, and unquestionable scientists. This was the case with M. Sugeno, E. Ruspini, H. Tanaka, E. Sánchez or T. Yamakawa. However, the real architect of the creation of the Granada group was Enric Trillas, who encouraged them, provided them with contacts and helped to participate in the first international meetings, such as was the case in the Fall International Seminar on Applied Logic (FISAL), a series of seminars in which Spanish researchers participated along with some foreign guests, allowing for fruitful discussions. The FISAL also served as a meeting point and place for other young Spanish scientists to present themselves, and who over time came to create their own research groups in Fuzzy.

In the mid-1980s Enric moved to Madrid to chair the CSIC, a position from which he promoted research in Spain. Despite this task being very demanding on his time he continued his research on Fuzzy and remains the driving force behind many research groups in Fuzzy in Spanish universities. Precisely in the 1990s when he had completed his stage at the CSIC and was president of the National Institute for Aerospace Technology (INTA), Enric started two transcendental projects for the Spanish fuzzy community. The first, the ORBE (Experimental Fuzzy Computer) project that involves virtually all the Spanish groups researching into Fuzzy Sets to build the first computer based on fuzzy logic. The ORBE project had continuity with various research sub-projects that addressed different applications: in the automotive sector, in expert systems, in developing software, etc. In parallel, on the other hand, Enric drives the organization of the First Spanish Conference on Technologies and Fuzzy Logic (which later became known by the acronym ESTyLF) and proposes the creation of FLAT (the Spanish Association of Fuzzy Logic and Technology), to group together the Spanish researchers in the field. This first congress was held in Granada in 1991, and has since continued to be held every year in different research centres which have groups researching in this field. The list is very long and includes most Spanish universities.

After this, and with the same drive as always, Enric accepted the responsibility for leading the Spanish scientific research strategy, acting as Secretary General of the National Plan for Scientific Research and Technology, within which he created the Joint Science, Technology and Industry Programme (PACTI) affording scope to the area of Intelligent Technologies, which thus officially emerge into the

research field for the first time in Europe, opening important perspectives for research in Fuzzy Sets and Systems not only in Spain but throughout Europe.

Enric left his responsibilities in research institutions in the mid-1990s and returned to the university. From his post at the Technical University of Madrid (UPM) he created a research group and resumed his activity of directing theses, giving conferences and boosting Fuzzy research groups throughout Spain.

In this context, Enric promotes the creation of EUSFLAT (the European Association for Fuzzy Logic and Technology) whose first presidents were Francesc Esteva, one of Enric's collaborators from the outset in the School of Architecture, and Luis Magdalena, collaborator to Enric at UPM. This drives the corresponding congress, held biennially, thus enabling to maintain the ESTYLF congresses in the years with no EUSFLAT Congress. We stress this fact since such congresses reflect a characteristic of Fuzzy research groups in Spain (which probably has a lot to do with the mark of Enric) which is none other than to keep the spirit that in ESTYLF congresses all the researchers of the area are involved. New researchers have the opportunity to explain their first research and veterans can know what the different groups are working on. Everything is always carried out in an atmosphere of deep scientific rigour, not without collaboration and constructive discussions. First-time participants never cease to be surprised at how the most seasoned of veterans are actively involved in discussions of the work of the novices, criticising when necessary, but always from a constructive perspective that strengthens relationships.

With this new era came new ideas and Enric, together with Lotfi Zadeh, launched the idea of creating a European Centre for Soft Computing. With his habitual tenacity and after different attempts, he gained the necessary funding. In late 2005 the European Centre for Soft Computing was created in Mieres, with Lotfi Zadeh as president of the Scientific Committee and Luis Magdalena as its director. Enric moved to work at the centre, from where he today continues his research work in fuzzy sets.

Enric has never been a supporter of gifts, honours or accolades other than those derived from scientific work. His passion has always been research in Fuzzy Sets, and the editors of this book, respecting his tastes, but admiring that calling and wanting to show the gratitude of so many colleagues, disciples and friends who have worked with him over the years, believe that preparing this tribute in the form of a book of contributions, will serve to keep his passion alive.

The participants in the book are not by random. Among the hundreds of colleagues who might have contributed to it, the editors had to select those who are gathered here, limiting ourselves to only inviting co-authors of papers and doctoral students or collaborators in research projects with Enric. Special mention should, obviously, be made to the case of Lotfi Zadeh, who from the very beginning expressed his enthusiasm for actively participating in this tribute.

In this context, the book is structured into five parts, in the manner of fuzzy cluster, dealing with virtually all the subjects that Enric has studied at one time or another: preorders, connectives, implications, actual applications,.... From the very outset the editors wanted to avoid a thematic classification of the papers to be found in this book so as to evoke, with the final order that we propose, the variety,

multiplicity and richness of the themes addressed by Enric to date, demonstrating the magnitude of his scientific work.

Finally, the three editors wish to show our gratitude to Janusz Kacprzyk for all the assistance given to us in editing this book. Likewise, we must express our highest consideration to all the authors participating in the book for their enthusiasm, understanding and patience with all the many requests we have made in the search for the best publishing results. And of course we have to express our admiration for Lotfi Zadeh, passionate promoter of this tribute to his friend Enric, for having got around all the obstacles that have appeared during the preparation of the book, with the affection, encouragement and freshness only conceivable by those who know him personally.

The editors, as one voice, wish to express our scientific and personal appreciation to Enric, who is our teacher, and we do so in representation of so many of his collaborators who share the same opinion. This book is nothing more than the result of a temporal coincidence that, wanting to pay a tribute, in no case do we want this to be interpreted as a full stop, but as a point and to continue because, as Enric himself would say, now we have to keep working and we still have many things to do together.

Luis Magdalena
José Luis Verdegay
Francesc Esteva

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