



Mathware & Soft Computing

*The magazine of the European Society
for Fuzzy Logic and Technology*

**Scientific research is a matter of
dedicated work, peace of mind and
good luck- D. Dubois and H. Prade**

**Didier's groundhog day-
I. Couso and S. Destercke**

**Ten steps to a whole new engineer and a whole
new engineering education- D. Goldberg**

**Swarm Intelligence research at IRIDIA,
Université Libre de Bruxelles- M. Dorigo**

**Alan Turing and Bayesian statistics-
P. Larrañaga and C. Bielza**

**Computing With Words (CWW): role of fuzzy,
probability and measurement concepts, and
operations- B. Kovalerchuk et al.**



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Message from the Editor-in-Chief (December 2012)

HUMBERTO BUSTINCE



It is my pleasure to present this new issue of the Mathware&Soft Computing online magazine. Especially since, with it, we complete the first year of life of our common project. A project that has been possible thanks to the collaboration of all of you. So, congratulations!, since this is your success as well as ours.

Being only one year old, our magazine has to keep growing. And to do so, this issue arrives with important novelties. The first one is linked to the promotion of the scientific activity of our society, which is the *raison d'être* of this magazine. So from now, the Mathware&Soft Computing pages will be open to the submission of contributions which have been presented to any conference or workshop either supported by EUSFLAT or which is linked to EUSFLAT in some way. These contributions will be submitted to a peer-review process before publication, and we hope that in this way we can help to spread researchers' work to the whole community. For instance, we can already announce that in forthcoming issues some selected works of the recent Brazilian Conference in Fuzzy Logic will appear.

The second novelty is the creation of a series of reports on panels of different conferences related to Soft Computing. We encourage organizers of such panels to submit their contents to our magazine.

I would also like to thank all those who have made possible this new issue. Specially Didier Dubois and Henri Prade, for the interview that opens the issue, but al-

so Inés Couso and Sébastien Destercke, Dave Goldberg, , Marco Dorigo, Pedro Larrañaga and Thierry Denoeux for their contributions, without forgetting Gleb Beliakov, Bernadette Bouchon-Meunier, Janusz Kacprzyk, Boris Kovalerchuk, Vladik Kreinovich and Jerry M. Mendel. All of them have made great contributions under the pressure of time. And, of course, many thanks to all of you who have contributed to the conference reports, news and calls.

This new issue opens with an interview between Didier Dubois and Henri Prade, in which they talk about their origins, scientific career and visions of fuzzy logic and science. Related to this is the work by Inés Couso and Sébastien Destercke a their funny day in the life of Didier Dubois.

As our magazine is interested in educational problems, we include in this issue an interesting discussion by Dave Goldberg on engineering education. We also follow our series on CajAstur Mamdani prize winners with a text of Marco Dorigo on his research on swarm intelligence.

This year is the centennial of the birth of Alan Turing, one of the fathers of Artificial Intelligence. To celebrate such important date, Pedro Larrañaga and Concha Bielza write an overview on the relation between Turing and Bayesian statistics.

A second report, by Gleb Beliakov, Bernadette Bouchon-Meunier, Janusz Kacprzyk, Boris Kovalerchuk, Vladik Kreinovich and Jerry M. Mendel, presents the results of the Panel on Computing with Words at WCCI 2012. Thierry Denoeux gives a presentation of the International Journal of Approximate Reasoning. Finally, the minutes of the EUSFLAT 2012 assembly are published. And, of course, news, reports and conference calls complete the issue.

We count on your collaboration for the next issue that will appear on June, 2013. Note that the deadline for submitting your contributions is May, 1st.

Enjoy our magazine!

Humberto Bustince
Editor-in-chief

The Mathware&Soft Computing Magazine opens its pages to the submission of contributions which have been presented to any conference or workshop either part of EUSFLAT or supported by EUSFLAT in some way. These contributions will be submitted to a peer-review process before publication. Please contact the editor-in-chief, Humberto Bustince, through the e-mail: bustince@unavarra.es

Message from the President (December 2012)

JAVIER MONTERO



Dear EUSFLAT member,

Let me first remind you all that the EUSFLAT by-laws were modified in our last General Assembly, held in Catania (July 11, 2012). In this way we have relaxed some undesired tension with the traditional ruling of our Society. You will find somewhere in this *Mathware & Soft Computing Magazine* issue the report presented by the EUSFLAT board at this General Assembly, where among other things, our colleague Didier Dubois was acknowledged with the first EUSFLAT Scientific Excellence Award.

EUSFLAT plays a leading role within the fuzzy and soft computing community. Today we are almost 300 EUSFLAT members that, for only 40 euro (20 euro for students), have been able to get relevant fee discounts in more than 6 international conferences during 2012, a free subscription to the *International Journal of Computational Intelligence Systems*, and access to this *EUSFLAT Magazine* that brings the possibility of spreading our activities, offers attractive interviews with key researchers in the field, and publishes selected state-of-the-art reports. In addition, our students have the possibility of obtaining student travel grants, the Best Student Paper award at the EUSFLAT conference, and the EUSFLAT Best Ph.D. Thesis award. Above all these arguments, EUSFLAT allows to share a collaborative framework that should open interesting possibilities for our activities, and should be used to spread the impact of our research (particularly by

means of this *EUSFLAT Magazine*, that now reaches to all fuzzy associations within IFSA). Since the EUSFLAT Working Groups should play a key role here, each EUSFLAT Working Group has been recently asked to increase their visibility by editing a book on Atlantis Press, to be distributed by Springer: it would be great if we can show in few years a reference collection of EUSFLAT Working Group edited books, where other researchers besides EUSFLAT members can of course participate (if interested, please contact EUSFLAT Working Group coordinators). Moreover, EUSFLAT has formalized a collaborative network with 5 scientific societies and 30 conferences that are directly linked to EUSFLAT interests. Please help us to invite your colleagues to join the EUSFLAT project.

Let me remind also that IFSA has made a call for the IFSA Outstanding Application Award, as already announced in *Fuzzy Sets and Systems*, see <http://dx.doi.org/10.1016/j.fss.2012.10.007>. And if you are organizing a conference within the EUSFLAT framework, you can consider applying for some support to IFSA (and to EUSFLAT, within our Student Grant Programme).

It will be very nice if we can meet at IFSA 2013 conference, to be held in Edmonton, Canada (June 24-28, 2013), see <http://www.ualberta.ca/~reformat/ifsa2013/index.html>.

But we certainly cannot miss the next EUSFLAT meeting, to be held in Milan, Italy (September, 11-13, 2013), see <http://www.ir.disco.unimib.it/eusflat2013/>. Please help us to distribute the EUSFLAT 2013 call, and consider joining any of the special sessions being organized by our colleagues. Or propose another special session to local organizers, if you consider some interesting topic is not yet properly covered.

Moreover, please take into account that a new President and EUSFLAT board should be elected in Milan, during our annual General Assembly. Call for candidatures will be properly announced by May or June 2013, three months prior to our Assembly.

Looking forward to meet you either at Edmonton or Milan,

Javier Montero
President of EUSFLAT

INTERVIEW

Scientific research is a matter of dedicated work, peace of mind, and good luck

Didier Dubois and Henri Prade



D. Dubois and H. Prade, in Marseille, Jul. 19-21, 1983, IFAC Symp. on Fuzzy Information, Knowledge Representation and Decision Analysis; photo by L. A. Zadeh.

Some questions by Humberto Bustince (HB) to Didier Dubois (DD) and Henri Prade (HP).

HB. Let's start by the very beginning. What are your origins? How did you meet?

DD. We both get our engineering degrees in aeronautics in 1975 from the Ecole Nationale Supérieure de l'Aéronautique et de l'Espace, a French "Grande Ecole" (usually known in France as "Sup'Aéro").

HP. Sup'Aéro, originally in Paris, had moved in Toulouse in the late sixties, because of the development of the aeronautics and the space industry there. It is why we came to Toulouse, coming from the north of France (Lille) for Didier, and from the west (Poitiers) in my case. We thus met in September 1972, at the beginning of the first school year.

DD. Just after our engineer diploma, we both prepared a Doctoral thesis in Engineering for two years (the usual duration at that time for a French PhD thesis) at the Department of Automatic Control of the "Centre d'Etude de Recherche de Toulouse" (CERT-DERA) in France, a research center close to Sup'Aéro. The topic of my thesis was the optimization of bus transportation networks.

HP. My thesis was dealing with the real time management of scheduling problems. Although we have different PhD advisors, we were working in the same office, having thus many opportunities for discussions. Transportation networks and scheduling were two active areas in operations research in those years.

We both get our engineering degrees in aeronautics in 1975 from the Ecole Nationale Supérieure de l'Aéronautique et de l'Espace

HB. And you arrived at fuzzy logic...How did it happen?

DD. As far as I remember, we encountered the words "fuzzy sets" for the first time in a research note surveying future directions of interest by a French professor, Lucas Pun, from Bordeaux, working in production engineering. As a matter of fact, he has a paper, we saw later, in the early collection of fuzzy set papers "Fuzzy Automata and Decision Processes" edited in 1977 by M. M. Gupta, G. N. Saridis, and B. R. Gaines. His note advocated the relevance of the general idea of using fuzzy sets in our research areas, without providing any details.

HP. Some time later, in June 1976 (we had already been working on our thesis for nine months), a friend of us mentioned the arrival, at the Sup'Aéro library, of three volumes dealing with a strange thing called “sous-ensemble flou” (the French counterpart for “fuzzy sets”). He explained us that it had something to do with a generalized set theory with graded membership. Actually, it was the treatise written by Arnold Kaufmann, “Introduction à la Théorie des Sous-Ensembles Flous à l’usage des ingénieurs”, the first volume of which appeared in English translation in 1975. Our curiosity was immediately aroused, because we soon realized that it might be connected to multiple-valued logic, a topic for which I had an older personal interest and curiosity. So, it’s a bit by chance that we came across fuzzy sets.

A friend of us mentioned the arrival, at the Sup'Aéro library, of three volumes dealing with a strange thing called “sous-ensemble flou” (the French counterpart for “fuzzy sets”)

DD. Very rapidly, we realized the close relation between fuzzy sets and min/max-based multiple-valued logic, and were impressed by the large range of potential applications advocated by Kaufmann. We got excited by the new idea, and we asked our respective PhD advisors the permission to devote one month of our PhD time to a bibliographical study in order to figure out whether fuzzy sets had any potential for the respective topics of our theses. We got their green light immediately without any problem (as we expected) since they were open-minded. Kaufmann was at the time a highly regarded name as the author of many books having introduced in France new topics in engineering. He was famous at least in the engineering circles to which our advisors belonged. But, it might have been quite a different situation, had we prepared our theses directly in the French university world where fuzzy sets were really considered as a controversial topic (to say the least) at that time. Research benefits from freedom and absence of dogmatism.

We asked our respective PhD advisors the permission to devote one month of our PhD time to a bibliographical study in order to figure out whether fuzzy sets had any potential for the respective topics of our theses

HP. The result of this first (fuzzy) month of bibliographical search was a (handwritten !) CERT-DERA technical report with an unorthodox title :“Le flou, kouacksek-sa?”, where “kouacksek-sa” is an onomatopoeia, a phonetic rendering of a funny distorted French counterpart of “what is this?”. Following the advice of our supervisors, we were bold enough to send this report to professor Kaufmann himself. To our surprise, he quickly replied in a very encouraging letter. But, it is only a bit later that we finally discovered fuzzy numbers in an article by Ramesh Jain. We were immediately convinced that fuzzy numbers were the kind of notion that would be very useful for modeling ill-known task duration times or transportation times in

our problems. Yet at that time, no practical computation method with fuzzy intervals had been published.

DD. After some joint research, we were lucky enough to discover a parametric representation of fuzzy numbers (the so-called L-R representation, now quite popular). We could then perform arithmetic operations on fuzzy numbers, as well as “horizontal” max and min operations, by simple computations on the parameters, thus extending interval arithmetics. We were also lucky enough to meet several key people that in some way or other influenced our future works at that time. First, in december 1976, we heard that a fuzzy set researcher, Michio Sugeno, was a visiting scholar in another neighboring laboratory on the same campus. Thus, we had the privilege to discuss very early with Michio Sugeno, who gave us a copy of his landmark PhD dissertation on fuzzy integrals. It was also the opportunity to meet a young CNRS researcher from the same laboratory where Sugeno was staying, Gérard Banon, interested in fuzzy measures and Shafer’s belief functions, whose work would be the departure point of our chapter on this topic in our 1980 book “Fuzzy Sets and Systems: Theory and Applications”.

We were also lucky enough to meet several key people that in some way or other influenced our future works at that time: Michio Sugeno, Gérard Banon, Elie Sanchez, Kaufmann, King-Sun Fu, Zadeh ...

HP. A bit later we also had the chance to meet Elie Sanchez, back from Berkeley, who gave us a copy of his remarkable PhD thesis on fuzzy relation equations, and revealed us the existence of Zadeh’s proposal for a possibility theory. These lucky encounters clearly contributed to enrich our view of the field, while we were completing our PhD dissertations that we finally defended in October 1977. We had successfully applied for post-doctoral fellowships so as to pursue our works in the US. Just before our departure, Kaufmann strongly suggested us to take this opportunity and write a book on fuzzy sets. It was an unexpected advice given by a very unusual, generous and experienced man to 25 year old researchers! In fact, we decided to take this advice seriously.

DD. Then Henri and I went to the U.S., supported by one-year scholarships, with one idea in mind: to write that book. Thus, in November 1977, I arrived Purdue University, in the group headed by Prof. King-Sun Fu, a leading figure in pattern recognition in that time, who had already done some remarkable work on fuzzy automata, but also on the axiomatics of fuzzy set connectives in relation to decision analysis. Prof. Fu encouraged us continuously during this period, even reading the manuscript of the future book and making some suggestions, and he was then instrumental for recommending our work and having it accepted in the prestigious “Mathematics in Science and Engineering” series edited by Richard Bellman at Academic Press.

HP. On my side, I was a visiting scholar at the Stanford Artificial Intelligence Laboratory, one of the very few leading research places in AI in those days, for getting acquainted with this new area. At that time, nobody there

was interested in fuzzy sets, but it gave me the opportunity to learn a lot about AI and to meet people. On the other hand, Stanford was only one hour by car from Berkeley University and the Electronics Research Laboratory at Evans Hall, where Prof. Zadeh's seminar was taking place. So after a while, I was able to attend the seminar and very glad to meet Prof. Zadeh for the first time. He welcomed me in a very friendly way, and was immediately interested in our work on fuzzy numbers that I was reporting to him. This year was the occasion of traveling around in the USA for working with Didier. I stayed in Purdue for about three months for the joint writing the book, and Didier had previously visited me in California for several weeks so as to prepare the tentative table of contents of the future book. As Zadeh wrote it later in the foreword to the book, he "was rather skeptical" on the possibility of "writing an up-to-date research monograph on fuzzy sets and systems", when we presented this tentative table of contents to him in April 1978.

HB: This is really a mixture of luck, dedicacy and hard work... And you have been at the very core of fuzzy logic since then, so I have to ask: Which is your vision of fuzzy logic in France and Europe?

Soft computing favors black box systems, while the core of AI is more oriented towards the building of systems capable of reasoning and explaining the conclusions they obtain

DD: Fuzzy logic is 47 years old. It means that in 2012, it already has a quite long history. The period that lasted until the late seventies was characterized by the great hopes of a few people and the disparaging attitude of many others. In the eighties, more tools and results were added to the theory, making it more respectable. Then in the late eighties came the fuzzy boom in Japan, after the pioneering works in fuzzy automatic control made in Western Europe by Abe Mamdani and his immediate followers. The nineties were the realm of fuzzy rule-based systems and more generally of neuro-fuzzy and soft computing applications. Meanwhile, and quite independently many other areas had been developing such as fuzzy topology and fuzzy analysis, fuzzy aggregation operations, fuzzy relations, possibility theory, approximate reasoning, fuzzy operations research, fuzzy clustering and image processing, fuzzy databases and information retrieval. The last decade has seen the continuation of this diversification and specialization process, with a broader acceptance of fuzzy logic in general.

The situation may quite differ from a country to another, and from a continent to another. For instance, if we consider North America, the number of researchers interested in fuzzy logic seems to be smaller than in Europe

HP: Indeed, since 2000, in Europe, we have in particular witnessed the increased development of the research on aggregation operations, the growing interest of researchers in mathematical multiple-valued logics for fuzzy sets,

as well as the move of fuzzy control researchers closer to non-linear control theory. This shows the maturity of these developments, but we have also to acknowledge that research is more scattered, which results in the fact that only few people nowadays have a complete view of the basics of fuzzy set and possibility theories. Moreover, the situation may quite differ from a country to another, and from a continent to another. For instance, if we consider North America, the number of researchers interested in fuzzy logic seems to be smaller than in Europe, and the main topic of interest in the the last decade over there is apparently the study and the application of type 2 fuzzy sets.

Our efforts have always been towards clarifying the significance of basic notions, and developing unified views

HB: And what about the present? How do you see fuzzy logic nowadays? Or, to go one step ahead, what do you think of nowadays research in soft computing and artificial intelligence?

DD: The impact of fuzzy logic in AI is real but remains limited. AI itself is a vast domain divided in many subareas, where different knowledge representation schemes are favored. Moreover, researchers oriented towards logic-based settings usually understand little of probabilistic or other uncertainty models, and the converse is true as well. Then, logicians and Bayesian probabilists, who dominate AI, still largely ignore fuzzy logic and possibility theory-based methods, even if developments in knowledge representation, reasoning or learning using such methods are regularly accepted in AI conferences and journals. As for Soft Computing, I never was convinced this is a genuine research area : in the narrow sense it denotes the joint use of three techniques and it is natural to use their synergies as they complement one another. But it is too narrow to make a full-fledged area, let alone a new direction. In the wide sense, I find it hard to figure out what could Soft Computing be. To oppose it to Artificial Intelligence looks very ... artificial, as was unwarranted the hostility of Artificial Intelligence towards fuzzy-rule based systems in the early years of fuzzy control.

HP: Soft computing and artificial intelligence have quite distinct agendas. Soft computing favors black box systems, while the core of AI has a deeper concern in knowledge representation. It is more oriented towards the building of systems capable of reasoning and explaining the conclusions they obtain. In the former approach, fuzzy rule-based systems are mainly viewed as universal approximators, while in the other perspective they are expected to be genuine knowledge representation devices. Zadeh's approach to approximate reasoning, as presented in the early eighties, based on combination and projection is more in line with logic-based Artificial intelligence than with neurofuzzy systems.

HB: You have talked about different influences in your career. But, on the other hand, research in general and yours in particular has also influence both in the scientific community and in the real world. How do you see this influence?



Didier Dubois

He is a Research Advisor at IRIT, the Computer Science Department of Paul Sabatier University in Toulouse, France and belongs to the French National Centre for Scientific Research (CNRS). He holds a

Doctorate in Engineering from ENSAE, Toulouse (1977), a Doctorat d'Etat from Grenoble University (1983) and an Honorary Doctorate from the Faculté Polytechnique de Mons, Belgium (1997). He is the co-author, with Henri Prade, of two books on fuzzy sets and possibility theory, and 15 edited volumes on uncertain reasoning and fuzzy sets. Also with Henri Prade, he coordinated the HANDBOOK of FUZZY SETS series published by Kluwer (7 volumes, 1998-2000, 2 of which he co-edited). He has contributed about 200 technical journal papers on uncertainty theories and applications.

Didier Dubois is an Advisory Editor of the IEEE Transactions on Fuzzy Systems. He is a member of the Editorial Board of several technical journals, such as the International Journal on Approximate Reasoning, General Systems, and Information Sciences among others. Since January 1, 1999, he has been co-Editor-in-Chief of Fuzzy Sets and Systems. He is a former president of the International Fuzzy Systems Association (1995-1997).

In 2002 he received the Pioneer Award of the IEEE Neural Network Society, and the 2012 Scientific Excellence Award from EUSFLAT.

His topics of interest range from Artificial Intelligence to Operations Research and Decision Sciences, with emphasis on the modelling, representation and processing of imprecise and uncertain information in reasoning, risk analysis and decision tasks.

DD. This is a very difficult question. We can explain what we have tried to achieve, and which views we are defending. Our efforts have always been towards clarifying the significance of basic notions, and developing unified views. For instance, from the beginning we have insisted on the difference between degrees of truth and degrees of uncertainty, or between fuzzy sets and possibility distributions (the former being an abstract notion, the latter capturing epistemic issues), on the respective roles of probability theory and possibility theory in the modeling of different types of uncertainty (due to variability vs. due to lack of information). We do not see the different uncertainty theories as competitors but rather as being complementary. We distinguish between qualitative possibility theory which provides a general setting for reasoning and making decisions under incomplete information, and quantitative possibility theory, which is a special case, yet remarkable, of imprecise probability systems (since then possibility measures approximate families of probability measures).

HP. On the qualitative side, we have developed possibilistic logic for 25 years (and we are currently enriching it in a generalized form that is much more expressive), as a general tool that may be used for default reasoning, reasoning under inconsistency, belief revision, information fusion, preference modeling, or even for argumentation. This approach is shared by a number of researchers in AI even if sometimes under a different terminology (like kappa-functions for instance). We have also emphasized the bipolar nature of possibility theory which enables us to represent positive information (what is possible for sure) and negative information (what is impossible) in a distinct manner.

In the future we can expect a migration of fuzzy set concepts and tools to cross-fertilize other disciplines

HB: And the future? Where do you think soft computing goes towards?

DD. As we have not taken part to research on neuro-fuzzy methods or on meta-heuristics such as genetic algorithms, we are misplaced for answering this question. If we consider fuzzy logic more specifically, it is not clear that there is much left to find on the basic foundations and concepts. There has been tremendous progress made on aggregation operations, fuzzy relations, fuzzy numbers, fuzzy measures, possibility theory and many-valued logics in the past twenty years. The algebraic background of fuzzy logic is well-understood. In the future we can expect a migration of fuzzy set concepts and tools to cross-fertilize other disciplines. For instance in fuzzy control, it is clear that the Takagi-Sugeno architecture is now in the tool-box of non-linear control engineering. Papers in this area make contribution to control theory and practice, not to fuzzy sets. Soft computing sounds like the absorption of fuzzy rule-based interpolation techniques and the like into the field of numerical non-linear modeling, more than a new paradigm that makes Artificial Intelligence obsolete.

HP. Another recent example of cross-fertilization is the recent extension of formal concept analysis using fuzzy logic and its algebraic apparatus, as well as possibility theory. It also has relation to rough sets, an important notion for the granulation of universes of discourse, which has already given birth to mutual enrichments with fuzzy sets for a long time. We may as well expect that the rich qualitative modeling setting offered by possibility theory gains more recognition in AI, decision theory, and even databases. Generally speaking, the number of published papers related in a way or another on fuzzy sets is quite stable and even still slightly increasing. This should lead to a strengthening of the existing subareas of interest for a while.

We could never have written our 1980 book, let alone publish it, if our working conditions at the time had been those of young researchers as of today

HB: And just to finish, a more philosophical question. How do you understand science in a broad sense? And

taking into account the present situation, what about the science policy?

DD. It is important to keep in mind that what may appear simple, straightforward, or even obvious later on, has not always been so, that apparently easy steps may take time to be made as soon as they are devoted to new directions, and that the path towards new conceptual and methodological advances is a long chaotic route with difficulties, but also rich in joys and encounters. This specificity of research is poorly understood by state agencies that to-date highly privilege application-oriented research, forgetting that ideas and tools that are really new are only discovered thanks to a blend of dedicated work and chance, which takes time, and is prevented by forcing researchers to constantly look for funds or justify of their excellence via debatable evaluation procedures. We could never have written our 1980 book, let alone publish it, if our working conditions at the time had been those of young researchers as of to-day. We were given a one-year scholarship to freely follow our intuitions.

HP. The research world has indeed witnessed important changes in the last decade. First, too often only short-term application-oriented research is supported, while long-term basic research is neglected. Moreover project proposals are reviewed on the basis of their announced results, while it will be wiser to evaluate them once finished, and to give more financial support to all those who obtained interesting results in previous projects. At the same time, there is an increasing pressure for taking into account the ranking (done by who and how?) or impact factors of journals where to publish. Thus, people are eager to format their paper and choose their topics so as to publish in top-ranked journals or conferences, rather than being primarily motivated by the advancement of knowledge. We are not sure that the forthcoming period will be as favorable for the younger generation as the one we have experienced over more than 3 decades, for the sound development of basic research (including its impact on practical problems).

HB: Thank you very much.



Henri Prade

He was born in Mulhouse in 1953. He is “Directeur de Recherche” at C.N.R.S. (France), and works at IRIT (Institut de Recherche en Informatique de Toulouse). He received a Doctor-Engineer

degree from Ecole Nationale Supérieure de l’Aéronautique et de l’Espace, in Toulouse (1977), his “Doctorat d’Etat” (1982) and the “Habilitation à Diriger des Recherches” (1986) both from Paul Sabatier University in Toulouse.

He is the co-author, with Didier Dubois, of two monographs on fuzzy sets and possibility theory published by Academic Press (1980) and Plenum Press (1988) respectively. He has contributed a great number of technical papers (including about 200 journal papers) and has co-edited several books including the seven volumes of the “Handbooks of Fuzzy Sets Series” (Kluwer, 1998-2000) with Didier Dubois.

He is a member of the editorial board or of the advisory board of several international journals including Fuzzy Sets and Systems, IEEE Transactions on Fuzzy Systems, the Inter. J. of Approximate Reasoning, the Inter. J. of Intelligent Systems, the J. of Intelligent Information Systems, Fundamenta Informaticae, the Int. J. of Uncertainty, Fuzziness and Knowledge-Based Systems, the Transactions on Rough Sets, and Information Sciences. In 2002 he received the Pioneer Award of the IEEE Neural Network Society. He is an IFSA Fellow and an ECCAI Fellow. His current research interests are in uncertainty and preference modeling, non-classical logics, approximate, plausible, and analogical reasoning with applications to artificial intelligence and information systems.

REPORT

Didier's groundhog day

Some of Didier Dubois scientific contributions summarized in the events of a usual workday

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Photo of Didier.



Didier seen by his children.

A weekday in Didier's life can seem pretty repetitive. However, each of these days see him playing with new ideas, talking with new people, reading new stuffs, connecting ideas and people (among which are the authors)... he even saves time to read, go to the movie and the theatre, and enjoy singing Renaissance songs every Tuesday night. He also finds time to enjoy his family, although probably not quite enough.



7:00 To be or not to be fuzzy?

Didier wakes up in a fuzzy world made of blurry shapes. He can barely recognize the black keys from the white on the piano, and Geneviève has the appearance of a ghost. Slowly emerging from a well-earned sleep, he reaches for his glasses. As his thoughts get sharper, so does the world around him as he puts his glasses on. He shortly ponders about the existence of fuzzy entities before going for breakfast.

One of the qualities of Didier, as a scientist, is that he always wants to have a clear understanding about the meaning of things while not discarding any view point. This leads him to repeatedly ask the question (either to himself or to conference speakers) "how can I (could we) interpret it for it to make sense?" rather than thinking "this does not make sense".

This will to make sense of things and to clarify some position is probably at the roots of his research concerning the meaning of fuzzy sets. One of his most celebrated papers, "The three semantics of fuzzy sets" [47], clarifies the different meaning of fuzzy sets and how they should be interpreted. Namely, he associates to the fuzzy sets three different semantics: similarity, preference and ill-known quantity, this latest semantic leading to possibility theory.

This trend of research has continued with the development of fuzzy sets composed of membership and non-membership functions [54], and more recently with the question of differentiating the ontic from the epistemic view of fuzzy sets.

Didier gave a plenary talk entitled "Do fuzzy data exist?" at IPMU 2010, in Dortmund (Germany). Coming from the coauthor of one of the first books on fuzzy sets [43] and the Co-Editor in Chief of the journal Fuzzy Sets and Systems, this title was clearly provocative. Actually, he deliberately reminded the audience to the famous statement "Probability does not exist" written by Bruno de Finetti in capital letters in the prologue of his famous book [20]. During that talk, Didier made clear the difference between the *conjunctive* and *disjunctive* interpretations of sets: while a conjunctive set represents a collection of elements forming composite objects, and provides precise information of an objective entity, a disjunctive set represents incomplete information about a quantity x taking value in the universe of discourse. An element e inside a disjunctive set E is a possible candidate for x , while elements outside E are considered impossible. Analogously, one can distinguish between the *ontic* and *epistemic* interpretations of fuzzy sets [54]. According to [31], ontic fuzzy sets represent objects originally construed as sets

but for which a fuzzy representation is more expressive due to gradual boundaries. Degrees of membership evaluate to what extent components participate to the global entity. Contrarily, epistemic memberships represent possibility degrees. A possibility distribution is supposedly attached to an ill-known element x . Namely $\pi(e) > 0$ expresses that e is a possible value of x , all the more plausible as $\pi(e)$ is greater.

In accordance with Didier's thesis, the concept of fuzzy set is just a formal notion that refers to a function taking values on the unit interval, and does not account for any impreciseness or vagueness *per se*. It is the scientist using fuzzy sets who has to clarify the meaning of membership values in each specific problem.



7:10 What comes first?

Thoughts already full of what awaits him today, Didier is not aware that he is actually spreading the butter after the jam on his piece of bread. Unfortunately, Geneviève is busy and cannot tell him that he got the wrong order. Luckily, in this case the order does not matter much.

Didier scientific career started with operational research and scheduling problems [24]. These problems already included many of the fields Didier would explore later on, including decision making and uncertainty modelling. Although he quickly focused on various other topics, operational research and scheduling problems are topics to which he comes back the time of some collaborations [36, 38, 33].

His most recent work on the topic include exploring some computational aspects of using intervals as well as fuzzy and gradual numbers in PERT problems and activity networks [39, 57, 34].



8:00 The ultimate decision maker

Time to go to work, but how? Should I take the car or the bike? is thinking Didier. I like the bike better than the car, and some exercise would do me good. On the other hand, it is getting cold and it has been raining a lot in the last few days. And even if weather forecast predicts a sunny day, relying on it is sometimes similar to relying on politician promises: it can be very disappointing. He is still wondering when the radio announces a debate about rain forest preservation, wakening Didier's ecological consciousness. The bike it will be, then.

Geneviève (after kissing him goodbye).- Remember to take the car. You have to pick the other Geneviève on the way home, before the choir rehearsal, because she has her leg broken.

Didier.- Oh, yes, it's true! OK, I will. Bye!

Decision making is another field in which Didier has made some contribution. The problem of decision making is to pick or to select, among different actions a_i , the one(s) that is (are) optimal. This means that a preference relation (in general a partial order), reflecting the decision-maker behaviour, has to build between the different alternatives. In decision problems under uncertainty, we do not know what is the state x of the world among a set of possible states \mathcal{X} , while in multicriteria decision problems, an alternative a_i is described by many features a_i^1, \dots, a_i^n . In practice, it is quite common to build the preference relation by using some numerical representation: in decision problems under uncertainty, the benefit of picking a_i when x is the state of the world is then described by the numerical utility $u_i(x)$; in multicriteria decision problems, a classical solution is to construct a numerical utility function $u(a_i)$ built from the values a_i^1, \dots, a_i^n that fits the decision maker (expressed) preferences as best as possible.

However, it may happen that the origin and meaning of numbers are questionable, as well as their need to solve the decision problem. One of Didier scientific obsession is to forget about those numbers and to go for a qualitative setting when possible. Building upon this idea, he developed with some colleagues a qualitative decision theory based on possibility theory [55, 35]. In particular, they have shown that possibility decision theory follows the tradition of Savage view of decision theory [59], since it satisfies all its axioms except for the one enforcing numerical representation of preferences [37]. This trend of reasoning has also led him to study more closely qualitative aggregation functions, and in particular the Sugeno integral [42] as well as the links between quantitative and qualitative approaches [41]. He presented his recent advances on such links at the MDAI 2010 conference [27], discussing among other things the close relationship between Sugeno integral and belief/plausibility functions [32]. He has also discussed the role of fuzzy sets in decision making, providing a critical overview of the state-of-the-art and pointing out the potential of qualitative evaluation methods in a very recent paper [29] based on a plenary talk given at the Eurofuse Workshop 09 (Pamplona, Spain, 2009).

Outside exploring the qualitative side of decision-making, Didier has also contributed to the problem of ranking numerical values pervaded with uncertainty, one of his first contributions on the topic being the very well known paper [44], where the authors propose four comparison indices in order to rank pairs of fuzzy numbers within the Possibility Theory setting. He went back recently to this subject, analyzing existing ranking methods and proposing new ones under two different viewpoints of fuzzy sets, namely possibility distributions and intervals of gradual numbers [2]. He has also studied the connection

between probability orderings and rankings of intervals and their impact together on different definitions of preference relations in Imprecise Probabilities [18]. Methods for ranking fuzzy random variables can be also seen as joint extensions of intervals' and random variables' comparisons. Under this viewpoint, different extensions for the notion of stochastic dominance have been proposed in [1].



8:30 Which one to trust?

Didier puts his office keys on the table and turns on the computer. As almost every morning, he assigns some papers submitted to FSS to reviewers and area editors, before checking the completed reviews. Among them, those of Paper FSS-D-012-12345 are conflicting: reviewer #1 recommends the rejection due to lack of originality, but Didier has a vague knowledge of the paper content and has some doubts about this claim; reviewer #2 wants to accept the paper but has provided only a short review as (s)he has been very busy lately; finally reviewer #3 recommends a minor revision. Didier knows too much about aggregation to just take the average 'major revision', meaning he will have to invite another reviewer or to check the paper himself.

How to build knowledge representation in presence of multiple sources of information or how to modify our beliefs with the arrival of new information is another question addressed by Didier in his work.

In particular, he makes a difference between generic information that describes background and general knowledge about the world on one hand, and contingent or singular information on the other hand that describes some evidence concerning the current situation. He then makes a distinction between the act of *focusing*, where a new singular piece of information is used to interrogate the generic initial information and draw inference from it about the current situation, and the act of *revising* where the two pieces of information have the same genericity levels (both are either generic or singular) and the initial information must be modified accordingly to the new one. In probability theory, both problems are treated by Bayes conditioning, that is the conditional measure $P(\cdot|B)$ can be read as interrogating the generic information P when all we know about the current situation is that we are in B , or as a minimal modification of information P into P' when we learn that $P'(B) = 1$. However, focusing and revising take different shapes once one consider other frameworks. Didier explored both cases in quantitative [46] and in qualitative/logical [26, 14] settings, also (partially) bridging the gap between the two [58].

He also makes a distinction between the problem of information fusion, where one must combine items of information (of same genericity level) provided by several sources and the problem of revision [58]. Roughly speaking, an essential difference between information fusion and revision is that in the former problem all pieces of information are considered as being of equal importance, while in the latter problem the new item of information is often considered as more important and should be kept intact (only refining it with the initial information). He presented some ideas along this line in his talk at the last ECSQARU conference [28]. Some of his works on the topic of information fusion investigate, among other things, the combination of logical bases [9] or the relation between combination operators of different uncertainty theories [56, 21].



9:30 - 12:30 Do I know that I know?

Again, FSS has required more time than planned. However, one of the paper title reminded him of a discussion he had with A. Dock¹ in a conference last week. This also connects with some paper from RG dating from the mid-fifties, that he must have somewhere in his office. After fifteen minutes of search, he finally finds it and starts reading it. He jots down some notes to clarify a bit the connection that is definitely there. He will probably put them in LaTeX form and send it to A. Dock to have his opinion. He does not know it yet, but it is the start of another paper.

Didier's interests also cover the relations and interactions between logic and uncertainty representations, with a particular focus on possibilistic logic [48]. In particular, possibilistic logic has proved to be a theoretically and practically adequate answer to deal with issues such as non-monotonic reasoning [11, 13] and or inconsistency handling in logical bases [12, 52].

This trend work has also led him to study non-classical logics such as epistemic logic, many-valued logics or modal logics [15, 4] and their links with uncertainty theories, focusing in part on the notions of ignorance and contradictions [30].



12:30 - 14:00 Where are my keys?

Henri asks if Didier wants to go to lunch. Leila and Florence are already waiting in the Hall, and he cannot

¹To preserve anonymity, names have been changed.

find his keys. Where did he put them again? Quickly checking around, he cannot see them. This morning, he has only left his office to go to the printer and Luis office, so the keys must be in one of these places. Luis office is very unlikely, and a quick check around the printer rules out this possibility.

In the meanwhile, Henri picks up the paper by RG from Didier's table to have a look, curious about Didier's current readings. Here they are, under RG's paper!

Following his interest on modeling imprecise/incomplete information, Didier arrived at Imprecise Probabilities Theory from Possibility Theory. As he and Henri state in [53]:

“Quantitative possibility theory is the simplest framework for statistical reasoning with imprecise probabilities. As such it has close connections with random set theory and confidence intervals, and can provide a tool for uncertainty propagation with limited statistical or subjective information.”

According to [5], a possibility measure can be used either to model imprecise knowledge about a deterministic or a random value x_0 . Both meanings fit into the epistemic interpretation of a fuzzy set, whose membership function is assumed to represent a possibility distribution, π , inducing a possibility measure, Π . In the first case, the possibility distribution, π , represents a nested family of confidence sets, $\{\pi_\alpha\}_{\alpha \in (0,1]}$, each one containing the unknown value x_0 with a probability not lower than $1 - \alpha$. It is checked in [19] and [40] that the family of probability measures satisfying the constraints

$$P(\pi_\alpha) \geq 1 - \alpha, \forall \alpha \in (0, 1]$$

is in fact the set of probability measures dominated by the possibility measure associated to π . In the second case, the possibility measure Π is seen as an upper probability dominating the probability measure ruling the behavior of the random value: the expert provides “disjunctive” information about the probability measure associated to such random value, by means of the family of probability measures dominated by the possibility measure, one of those is the true underlying probability measure.

In [5] and [16], both epistemic meanings of fuzzy sets are separately considered in order to interpret the information provided by a fuzzy random variable. A fuzzy random variable (also referred to as “random fuzzy set”), $\tilde{X} : \Omega \rightarrow \mathbb{R}$, connects each outcome, ω , of a random experiment to a fuzzy set on the real line, $\tilde{X}(\omega)$. When the image $\tilde{X}(\omega)$ is viewed as the representation of the expert's ill-knowledge of an otherwise deterministic value $x(\omega)$, the fuzzy random variable can be viewed as the representation of an ill-observed random variable $x_0 : \Omega \rightarrow \mathbb{R}$. Alternatively, when each image $\tilde{X}(\omega)$ is viewed under the second epistemic interpretation above mentioned, the fuzzy random variable is interpreted as a family of conditional possibility measures of the form Π_ω , each one of them

representing the partial knowledge about the probability measure ruling the random object $x(\omega)$. Both epistemic interpretations of fuzzy random variables, along with the ontic interpretation are reviewed in [16]. In that paper, it is pointed out that each different interpretation of a fuzzy random variable leads to different extensions of classical notions in Probability Theory, with special attention paid to the concept of variance. In fact, the idea of adapting the most appropriate technique to each specific problem underlies most contributions of Didier. The same formal notion, such as the notions of (fuzzy) set and random (fuzzy) set above mentioned, can arise in quite different situations. The techniques developed in each particular situation strongly depend on the particular interpretation of each formal tool. This idea is again illustrated in [31]. As the author states, different interpretations of random (fuzzy) sets impact on computations carried out with this model. This idea is exemplified throughout the notions of conditioning and variance. Also different generalizations of classical regression techniques are reviewed under the light of the different interpretations of random fuzzy sets.

Another maxim of Didier is the idea of exploiting, when feasible, all the available information, without artificially adding non-verified hypothesis or unavailable information. He has also contributed to clarify the difference between random variability and imprecision. With these ideas in mind, he has explored different mathematical models to represent each or both facets of uncertainty, like probability intervals, random sets, generalized p-boxes, commonotonic and general clouds, generalized rough sets, etc. (see, for instance, [6, 7, 8, 17, 23, 22, 25]).



16:00 Should I stay or should I go?

Didier receives an email from I. Wantu, who invites him to give a plenary talk in a forthcoming conference in July. A simple check of his schedule shows him that he has accepted two invitations and has planned to attend another conference in July, so it will be a busy month. Should he accept the invitation or not? On one side, I. Wantu work is very interesting and the invitation was very kind. Also, this conference topic promises to be interesting. On the other side, Didier sometimes feels like an ever travelling parrot always repeating the same things, and he desperately seeks some time to investigate new topics. Also, it is not certain that Geneviève would appreciate the destination or would come with him. Leaving the question open, he will weight the pros and cons and decide afterwards.

Another aspect of information that interests Didier is the notion of bipolarity [50]. Generally speaking, bipolarity in information processing refers to the existence of both a positive and a negative side in the information. One can recognize at least three types of bipolarity [3],

usually based on the notion of bipolar scales. A first type, called *Symmetric univariate* bipolarity, involves only one scale containing a neutral element. This is the case in probability theory, where $P(A) = 0$ and $P(A) = 1$ are the extreme situations, $P(A) = 1/2$ being the neutral element and in multi-criteria decision-making. A second type, often termed *Symmetric bivariate* bipolarity, concerns cases where negative and positive aspects of information each have their own scales, but are related through some duality relation. This is the case with possibility measures and necessity measures, as the two measures are related ($\Pi(A) = 1 - N(A^c)$) but models different aspects of the information.

The two first types of bipolarities are therefore already present in classical probabilistic or possibilistic representations, and are therefore implicitly treated within them. The third kind of bipolarity, called *asymmetric*, is concerned with cases where negative and positive information are poorly or not related with each other. This is the case where positive information asserts existence of possible worlds, for example through observation or preferred attributes, and where negative information rule out possible worlds, for example through the means of expert opinion (stating impossible values) or of rejected solutions.

In possibility theory, handling *asymmetric* bipolarity requires to add a so-called *guaranteed* possibility distribution δ to the classical possibility distribution π , with the inequality $\delta \leq \pi$ expressing a coherence requirement between positive and negative information [51]. Such bipolar representations can then be used to handle preferences in a multi-criteria decision framework [10] or to represent uncertain knowledge about a quantity [49, 23], using different processing tools. As the pair (δ, π) is formally equivalent to interval-valued fuzzy sets and related models, such a view of possibility theory also provide these latter models with clear new semantics.



19:00 Time to go home

The telephone rings. This must be Geneviève phoning to tell me I am late, thinks Didier as he checks the time on his computer screen. Indeed, this is Geneviève, who also recalls him that he has to pick up the other Geneviève, because of the Choir rehearsal. It could be that they will be a little late tonight.

Most of the works mentioned in this paper had for origins the application of possibility theory [45] to a particular field or topic. Possibility theory can thus be seen as the root of Didier's work, however these roots have spread in many different directions, producing new roots of their own and sometimes getting very far from their origins. An important part of these roots are also strongly intertwined

and not as separated as the different parts of this paper may suggest.

Indeed, the notions of conditioning, revision, information fusion, bipolarity, inconsistency, uncertainty, etc. either in a qualitative or quantitative setting are all strongly linked and form a wide picture. This review tries (and we hope succeeds) to give a glimpse of Didier's efforts to complete this wide picture. It is of course limited, as is our knowledge of his work. The length devoted to each topic reflects this limited knowledge rather than the importance of Didier's contributions concerning those topics. The references we provide show that, while some topics such as scheduling or ranking were very early addressed by Didier and remained topics of interest in further years, other topics such as bipolarity have only been recently addressed in his work.

A word from the authors

We would like to mention that Didier's scientific qualities go along with human qualities and a personality that make his company very pleasant. This certainly also explains why so many people want to work with him. We would also thank the EUSFLAT magazine editors for giving us the opportunity to write this paper. The content of this paper is, of course, the sole responsibility of its authors.

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References

- [1] Farid Aiche and Didier Dubois. An Extension of Stochastic Dominance to Fuzzy Random Variables, volume 6178 of Lecture Notes in Computer Science, pages 159–168. Springer, 2010.
- [2] Farid Aiche and Didier Dubois. Possibility and Gradual Number Approaches to Ranking Methods for Random Fuzzy Intervals, volume 299 of Communications in Computer and Information Science, pages 9–18. Springer, 2012.
- [3] Leila Amgoud, Claudette Cayrol, Marie-Christine Lagasque-Schiex, and P. Livet. On bipolarity in argumentation frameworks. *Int. J. Intell. Syst.*, 23(10):1062–1093, 2008.
- [4] Mohua Banerjee and Didier Dubois. A simple modal logic for reasoning about revealed beliefs. In *ECSQARU*, pages 805–816, 2009.
- [5] Cédric Baudrit, Inés Couso, and Didier Dubois. Joint propagation of probability and possibility in risk analysis: Towards a formal framework. *Int. J. Approx. Reasoning*, 45:82–105, 2007.
- [6] Cédric Baudrit and Didier Dubois. Practical representations of incomplete probabilistic knowledge. *Computational Statistics and Data Analysis*, 51(1):86–108, 2006.

- [7] Cédric Baudrit, Didier Dubois, and Dominique Guyonnet. Joint propagation and exploitation of probabilistic and possibilistic information in risk assessment. *IEEE T. Fuzzy Systems*, 14(5):593–608, 2006.
- [8] Cédric Baudrit, Didier Dubois, and Nathalie Perrot. Representing parametric probabilistic models tainted with imprecision. *Fuzzy Sets and Systems*, 159(15):1913–1928, 2008.
- [9] Salem Benferhat, Didier Dubois, Souhila Kaci, and Henri Prade. Possibilistic merging and distance-based fusion of propositional information. *Ann. Math. Artif. Intell.*, 34(1-3):217–252, 2002.
- [10] Salem Benferhat, Didier Dubois, Souhila Kaci, and Henri Prade. Bipolar possibility theory in preference modeling: Representation, fusion and optimal solutions. *Information Fusion*, 7(1):135–150, 2006.
- [11] Salem Benferhat, Didier Dubois, and Henri Prade. Nonmonotonic reasoning, conditional objects and possibility theory. *Artif. Intell.*, 92(1-2):259–276, 1997.
- [12] Salem Benferhat, Didier Dubois, and Henri Prade. Some syntactic approaches to the handling of inconsistent knowledge bases: A comparative study part 1: The flat case. *Studia Logica*, 58(1):17–45, 1997.
- [13] Salem Benferhat, Didier Dubois, Henri Prade, and Régis Sabbadin. Exception-tolerant reasoning and decision under uncertainty using qualitative possibility theory. *KI*, 15(3):9–15, 2001.
- [14] Salem Benferhat, Didier Dubois, Henri Prade, and Mary-Anne Williams. A framework for iterated belief revision using possibilistic counterparts to Jeffrey’s rule. *Fundam. Inform.*, 99(2):147–168, 2010.
- [15] Davide Ciucci and Didier Dubois. Relationships between connectives in three-valued logics. In *IPMU*, pages 633–642, 2012.
- [16] Inés Couso and Didier Dubois. On the variability of concept of variance for fuzzy random variables. *IEEE T. Fuzzy Systems*, 17(5):1070–1080, 2009.
- [17] Inés Couso and Didier Dubois. Rough sets, coverings and incomplete information. *Fundam. Inform.*, 108(3-4):223–247, 2011.
- [18] Inés Couso and Didier Dubois. An Imprecise Probability Approach to Joint Extensions of Stochastic and Interval Orderings, volume 299 of *Communications in Computer and Information Science*, pages 388–399. Springer, 2012.
- [19] Inés Couso, Susana Montes, and Pedro Gil. The necessity of the strong α -cuts of a fuzzy set. *Int. J. Unc. Fuzz. Knowl. Based Syst.*, 9(2):249–262, 2001.
- [20] Bruno de Finetti. *Theory of probability*, volume 1-2. Wiley, NY, 1974. Translation of 1970 book.
- [21] Sébastien Destercke and Didier Dubois. Idempotent conjunctive combination of belief functions: Extending the minimum rule of possibility theory. *Inf. Sci.*, 181(18):3925–3945, 2011.
- [22] Sébastien Destercke, Didier Dubois, and Eric Chojnacki. Unifying practical uncertainty representations. i: Generalized p-boxes. *Int. J. Approx. Reasoning*, 49(3):649–663, 2008.
- [23] Sébastien Destercke, Didier Dubois, and Eric Chojnacki. Unifying practical uncertainty representations. ii: Clouds. *Int. J. Approx. Reasoning*, 49(3):664–677, 2008.
- [24] Didier Dubois. Quelques outils méthodologiques pour la conception de réseaux de transport. PhD thesis, Ecole Nationale Supérieure de l’Aéronautique et de l’Espace, 1977.
- [25] Didier Dubois. Possibility theory and statistical reasoning. *Computational Statistics and Data Analysis*, 51(1):47–69, 2006.
- [26] Didier Dubois. Three scenarios for the revision of epistemic states. *J. Log. Comput.*, 18(5):721–738, 2008.
- [27] Didier Dubois. Relationships between qualitative and quantitative scales for aggregation operations: The example of Sugeno integrals. In *MDAI*, pages 1–2, 2010.
- [28] Didier Dubois. Information fusion and revision in qualitative and quantitative settings - steps towards a unified framework. In *ECSQARU*, pages 1–18, 2011.
- [29] Didier Dubois. The role of fuzzy sets in decision sciences: Old techniques and new directions. *Fuzzy Sets and Systems*, 184(1):3–28, 2011.
- [30] Didier Dubois. Reasoning about ignorance and contradiction: many-valued logics versus epistemic logic. *Soft Comput.*, 16(11):1817–1831, 2012.
- [31] Didier Dubois. *Statistical Reasoning with Set-Valued Information: Ontic vs. Epistemic Views*, volume 285 of *Studies in Fuzziness and Soft Computing*, pages 119–136. Springer, 2013.
- [32] Didier Dubois and Hélène Fargier. Making discrete Sugeno integrals more discriminant. *Int. J. Approx. Reasoning*, 50(6):880–898, 2009.
- [33] Didier Dubois, Hélène Fargier, and Philippe Fortemps. Fuzzy scheduling: Modelling flexible constraints vs. coping with incomplete knowledge. *European Journal of Operational Research*, 147(2):231–252, 2003.
- [34] Didier Dubois, Hélène Fargier, and Jérômes Fortin. Computational methods for determining the latest starting times and floats of tasks in interval-valued activity networks. *Journal of Intelligent Manufacturing*, 16:407–421, 2005.

- [35] Didier Dubois, Hélène Fargier, and Patrice Perny. Qualitative decision theory with preference relations and comparative uncertainty: An axiomatic approach. *Artif. Intell.*, 148(1-2):219–260, 2003.
- [36] Didier Dubois, Hélène Fargier, and Henri Prade. Possibility theory in constraint satisfaction problems: Handling priority, preference and uncertainty. *Appl. Intell.*, 6(4):287–309, 1996.
- [37] Didier Dubois, Hélène Fargier, Henri Prade, and Patrice Perny. Qualitative decision theory: from savage's axioms to nonmonotonic reasoning. *J. ACM*, 49(4):455–495, 2002.
- [38] Didier Dubois and Philippe Fortemps. Computing improved optimal solutions to max-min flexible constraint satisfaction problems. *European Journal of Operational Research*, 118(1):95–126, 1999.
- [39] Didier Dubois, Jérôme Fortin, and Pawel Zielinski. Interval PERT and its fuzzy extension. In Cengiz Kahraman and Mesut Yavuz, editors, *Production engineering and management under fuzziness*, chapter 9, pages 171–199. Springer, 2010.
- [40] Didier Dubois, Laurent Foulloy, and Henri Prade Gilles Mauris. Probability–possibility transformations, triangular fuzzy sets, and probabilistic inequalities. *Reliable Comput.*, 10:273–297, 2004.
- [41] Didier Dubois, Michel Grabisch, François Modave, and Henri Prade. Relating decision under uncertainty and multicriteria decision making models. *Int. J. Intell. Syst.*, 15(10):967–979, 2000.
- [42] Didier Dubois, Jean-Luc Marichal, Henri Prade, Marc Roubens, and Régis Sabbadin. The use of the discrete Sugeno integral in decision-making: A survey. *International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems*, 9(5):539–561, 2001.
- [43] Didier Dubois and Henri Prade. *Fuzzy Sets and Systems: Theory and Applications*, volume 144 of *Mathematics in Science and Engineering*. Academic Press, Inc., 1980.
- [44] Didier Dubois and Henri Prade. Ranking fuzzy numbers in the setting of possibility theory. *Inf. Sci.*, 30(3):183–224, 1983.
- [45] Didier Dubois and Henri Prade. *Possibility Theory: An Approach to Computerized Processing of Uncertainty*. Plenum Press, 1988.
- [46] Didier Dubois and Henri Prade. Focusing vs. belief revision: A fundamental distinction when dealing with generic knowledge. In *ECSQARU-FAPR*, pages 96–107, 1997.
- [47] Didier Dubois and Henri Prade. The three semantics of fuzzy sets. *Fuzzy Sets and Systems*, 90(2):141 – 150, 1997.
- [48] Didier Dubois and Henri Prade. Possibilistic logic: a retrospective and prospective view. *Fuzzy Sets and Systems*, 144(1):3–23, 2004.
- [49] Didier Dubois and Henri Prade. Interval-valued fuzzy sets, possibility theory and imprecise probability. In *EUSFLAT Conf.*, pages 314–319, 2005.
- [50] Didier Dubois and Henri Prade. An introduction to bipolar representations of information and preference. *Int. J. Intell. Syst.*, 23(8):866–877, 2008.
- [51] Didier Dubois and Henri Prade. An overview of the asymmetric bipolar representation of positive and negative information in possibility theory. *Fuzzy Sets and Systems*, 160(10):1355–1366, 2009.
- [52] Didier Dubois and Henri Prade. Handling various forms of inconsistency in possibilistic logic. In *DEXA Workshops*, pages 327–331, 2011.
- [53] Didier Dubois and Henri Prade. Possibility theory and its applications: Where do we stand? *Mathware and Soft Computing Magazine*, 18(1):18–31, 2011.
- [54] Didier Dubois and Henri Prade. Gradualness, uncertainty and bipolarity: Making sense of fuzzy sets. *Fuzzy Sets and Systems*, 192:3–24, 2012.
- [55] Didier Dubois, Henri Prade, and Régis Sabbadin. Decision-theoretic foundations of qualitative possibility theory. *European Journal of Operational Research*, 128(3):459–478, 2001.
- [56] Didier Dubois and Ronald R. Yager. Fuzzy set connectives as combinations of belief structures. *Inf. Sci.*, 66(3):245–276, 1992.
- [57] Jérôme Fortin, Hélène Fargier, and Didier Dubois. Gradual numbers and their application to fuzzy interval analysis. *IEEE Transactions on Fuzzy Systems*, 16(2):388–402, 2008.
- [58] Jianbing Ma, Weiru Liu, Didier Dubois, and Henri Prade. Bridging Jeffrey's rule, agm revision and dempster conditioning in the theory of evidence. *International Journal on Artificial Intelligence Tools*, 20(4):691–720, 2011.
- [59] Leonard J. Savage. *Foundations of Statistics*. Wiley, NY, 1954.

REPORT

Ten steps to a whole new engineer and a whole new engineering education

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Note to readers of Mathware & Soft Computing Magazine

Many of the Readers of *Mathware & Soft Computing Magazine* may remember my work in genetic algorithms and evolutionary computation. From 1980 until about 2007 or so, I devoted my research energies to understanding and applying evolutionary computation, publishing *Genetic Algorithms in Search, Optimization, and Machine Learning* (Addison-Wesley, 1989) and *Design of Innovation* (Kluwer, 2002) and many research papers. Around 2007 or so, my attention turned to the global problem of the transformation of engineering (and computer science) education.

I switched gears because I was increasingly alarmed at the ways in which work in engineering had changed and the ways in which educating engineers had not. This led to the founding of a university incubator for programmatic change (www.ifoundry.illinois.edu), a partnership between a very small innovative school and a very large traditional one (www.ifoundry.illinois.edu/oip), resigning my tenure (in December 2010), training as a leadership coach (<http://bit.ly/VP2aNR>), the founding of a higher change, training, and coaching firm (www.threejoy.com), and the creation of a movement for the transformation of engineering education worldwide (www.bigbeacon.org).

Although I miss my research and colleagues in soft computing, studying complex systems, in particular evolutionary systems, informs these efforts to transform higher ed. A career spent watching where populations of actors end up as shaped by both the fitness landscape and the action of innovation operators, has helped shape the approach adopted for shaping the evolution of educational systems.

I think educators, students, and researchers who read this magazine should be especially interested in educational reforms that make way for new approaches and new thinking, and I invite you to join the many students, educators, engineers, and employers around the world who are taking up the ideas of the Big Beacon (www.bigbeacon.org).

Introduction

We live in a technological time. With nearly 7 billion people on the planet (and counting), we depend upon technology in almost every aspect of our lives. Billions are clothed, healed, fed, transported, connected, entertained, and employed through increasingly complex products, processes, and systems. And while technology is one sense the gift that enables life for billions, it's unintended consequences cause environmental and sustainability problems that are increasingly a concern.

As such, engineers and engineering are increasingly necessary to sustain and improve our way of life. Unfortunately, engineering is increasingly not the career path of choice for many who would otherwise make terrific engineers, and even if it were, the kinds of engineers being turned out by colleges and universities around the globe are too narrowly technical to address the complex and integrated nature of the opportunities and challenges of our times.

Big Beacon (www.bigbeacon.org) is a global movement to transform engineering and engineering education, to make engineering an attractive career path to young people and to help educate the kind of engineers that our world needs. The Big Beacon Manifesto (www.bigbeacon.org) calls for (1) a *whole new engineer* appropriate to our times, (2) a *whole new engineering education* to educate the engineers we need, and (3) steps of *educational* rewire or effective educational change or transformation that will bring about the necessary change.

The following are ten steps necessary to bring a new generation of whole new engineers into the world:

Step 1: Become aware how engineering and engineering education got stuck.

To create a whole new engineer, we need to understand the historical consensus, sociological factors, and conceptual ingredients of the cold war engineer. After World War 2, there was a belief among engineering academics that physics won the war, and the curriculum was stripped of practical subjects and injected with a heavy dosage math, science, and engineering science. These decisions were made in large part to tap into the growing status of science, and they went against the distinctive philosophical nature of engineering as a practical discipline.

Step 2: Recognize ways the world has changed.

Since World War 2 there have been three missed revolutions that have changed the world in ways that call for a significantly different kind of engineer: the quality revolution, the entrepreneurial revolution, and the information technology revolution have change the way we make things, the way we make institutions, and the way we make connections. These revolutions were “missed” in the sense that they were embraced by organizations that face competition in the marketplace and largely missed by those that don’t, including universities. Friedman, Florida, and Pink highlight these changes in their sayings that “the world is flat,” that “we live in a creative era with a rising creative class,” and that we need a “whole new (creative) mind.” As a result the engineer of the cold war, a *category enhancer*, is being replaced by the engineer of the 21st

century, a *category creator*. Unfortunately, engineering schools are continuing to turn out engineers appropriate to earlier times.

Step 3: Understand why reform efforts haven't worked.

Many efforts have been mounted to fix the engineering curriculum, and they have largely focused on content, curriculum, and pedagogy. These *bright shiny objects* of reform are attractive, because they seem to offer a fairly direct way to bring about change, but they largely haven't worked. Content and pedagogy change can be brought about classroom by classroom, but the efforts end up being isolated and don't diffuse or spread quickly. Curriculum change could be more transformative, but it ends being a political process with a stable equilibrium in the status quo. The twin sentiments that "Transformation is great," but "Don't change my course" is something of an academic NIMBY problem ("not in my back yard") in which people generally favor change, as long as it doesn't require personal change or commitment. Thereafter, the political process of logrolling ensures that curriculum change goes nowhere fast.

Step 4: Use a change approach that combines emotional, conceptual, and organizational factors.

In industry, change processes use a combination of heart, mind, and restructuring, and change eventually takes place. In academic life, universities date back to the Middle Ages, and they received their last organizational upgrade when German universities invented the modern research department in the 19th century. To overcome this inertia, best practices such as those described by the Heath brothers or John Kotter must be brought to bear in ways that activate passions among all stakeholders, especially students. The educational system currently assumes that all of the key change variables are rational, but effective change practices recognize that the key variables are emotional, cultural, and institutional.

Step 5: Trust students before they trust themselves.

An unexamined assumption of the way we educate students (not just in engineering) is that they are fundamentally incompetent and unable to learn without the disciplinary expertise and learning guidance of the teacher. Although not intended as such, this message creates a continuing dependency on expertise and guidance that is inconsistent with the ideal of lifelong learning. Programs that trust in students and help them take action, fail, and learn on their own teach students that they are resourceful, creative, and whole human beings and capable of taking initiative whenever it serves them. The result is a more courageous, self-confident practitioner right out of the box.

Step 6: Instill the keystone habits of noticing, listening, and questioning (NLQ).

If we think of education as an iceberg, much of the effort of traditional education is *above the waterline*. We

teach and master concepts, facts, and figures, essentially *mastery of the already mastered*. Education in a world of change is largely about factors *below the waterline*, the ability to notice, inquire, reflect, and learn. Explicit experiential training in noticing, listening, and open-ended questioning transforms schools by (1) giving teachers the tools they need to become aware of the perception, needs, and untapped potential of students, and (2) give students the tools they need to become aware of their own stories and purpose, and to guide their own learning in productive directions of their own choosing. NLQ is not the whole story, but the current system becomes more amenable to the needed changes as more students and faculty members practice NLQ.

Step 7: Promote cultural change through intentional shifts in language and story.

The current culture of engineering and engineering education is held in place through certain unnoticed stories and language. The need for "rigorous" courses and the disdain for "soft" subjects are preserved by the very words we use. To change the culture in ways that promote the values of the whole new engineer requires the creation of sticky language and stories that compete against the status quo. "Soft" subjects become the "missing basics" and the "fundamentals" become a "math-science death march" as part of an essentially cultural process that leads to effective and sustainable change. Successful exemplars of change such as Olin College (www.olin.edu) are as much about culture shift as curriculum or content shift.

Step 8: Create new institutional forms to promote innovation, community, and connection.

The current educational system is a collection of individual teachers and students acting largely as individuals in a world of teamwork and collaboration. New programmatic incubators such as the iFoundry model (www.ifoundry.illinois.edu) connect dots across the organization to permit pilot innovation and experimentation. New and revitalized forms of student organizations connect students to their school experience from the very first day, thereby connecting them socially to a supporting culture and community. Faculty members connect to students and each other in ways that promote lifelong faculty development in ways that bring greater meaning and leadership capability to their teaching and scholarship. These forms help knit together a less parochial and more interdisciplinary organization.

Step 9: Practice and teach entrepreneurship in thought and action.

Entrepreneurship has a different kind of action logic from the usual planning practices of routine organizations and business. In routine settings, we plan by setting goals, predicting how to achieve them, and then arranging a reasonably sure sequence of tasks to achieve exactly the predetermined goals. In entrepreneurial settings, our ability to predict is much less certain, so both the goals and ability to predict outcomes for tasks is much less predictable. As such, entrepreneurs must be *present* to what

happens in the moment and then must be much less *attached* to the goals they started with. Instead, given the high uncertainty and high variability in outcome, the entrepreneurial actor must immediately learn from what just happened and in real-time formulate a response to those outcomes and possible next states. This kind of behavior has been studied in successful entrepreneurs and has been called *effectuation* by Sarasvathy. In a world of change and uncertainty, it is fundamental that young engineers be taught these processes in addition to those of *causal thinking* or planning. Moreover, the processes of changing our educational systems must themselves become more effectual and entrepreneurial and less dependent on more rigid action logics, if they are to be successful and bring about more effective reforms.

Step 10: Band all stakeholders together coordinate effective action and collaboratively disrupt the status quo.

To date, education reform has largely been a school-by-school or even classroom-by-classroom attempt to bring about local change, and oftentimes schools or departments carefully guard their innovations as giving their unit a competitive advantage. Unfortunately, the real competi-

tor here is not the university down the road. The real competitor is an educational system and cultural forces that preserve a 60-year old engineering curriculum that is demoralizing prospective engineers while or even before they come to school. Even when change efforts aren't viewed in this competitive way, schools have had difficulty coordinating, diffusing, and sustaining the results throughout their own institutions and to others. To bring about the necessary changes it is important for likeminded stakeholders, whether students, educators, employers, or practicing engineers, to come together and unite to bring about the needed changes. Studies of innovation suggest that radical innovations take place outside of the organizations that are wedded to earlier innovations, and that *disruptive innovator* takes over from the earlier innovator after the radical innovation has shown its superiority in the marketplace. In the Big Beacon the movement creates a global virtual organization, a *disruptive innovator*, that transforms the organizations wedded to the status quo.

These steps are not easy ones, but increasing numbers of students, faculty, engineers, and their employers are coming together to help ensure that we have the kinds of engineers our world needs now and in the future. Find out what you can do to join in this global movement to shine a light on needed change at www.bigbeacon.org.



Dave Goldberg, President and founder of Big Beacon (www.bigbeacon.org) is an educational entrepreneur and leadership coach, trainer, and consultant devoted to the global transformation of engineering education. Prior to founding Big Beacon, he was the Jerry S. Dobrovolsky Distinguished Professor in Entrepreneurial Engineering at the University of Illinois at Urbana-Champaign, where he was known for his path-breaking research in genetic algorithms and evolutionary computation, for his role in co-founding ShareThis, Inc (www.sharethis.com), as well as his work as co-founder and co-director of the Illinois Foundry for Innovation in Engineering Education (iFoundry). Author of *The Entrepreneurial Engineer and Genetic Algorithms in Search, Optimization, and Machine Learning* among other books, Dave holds BSE, MSE, and PhD degrees in Civil Engineering from the University of Michigan and a Certificate in Leadership Coaching from Georgetown University. Dave also serves as President and founder of ThreeJoyAssociates, Inc (www.threejoy.com), a consulting, coaching, and training firm for smooth change in higher education.

REPORT

Swarm Intelligence research at IRIDIA, Université Libre de Bruxelles

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Swarm intelligence deals with natural and artificial systems composed of many individuals that coordinate using decentralized control and self-organization [1, 2, 5]. The main focus of swarm intelligence research is on the collective behaviour that results from local interactions of individuals with each other and with their environment. There are many examples of natural systems that are studied in swarm intelligence research: ant and termite colonies, fish schools, bird flocks, animal herds and even human crowds. There are also a number of human artefacts that are studied: swarms of robots, computer programs that tackle difficult problems in optimization and in data analysis. IRIDIA, the artificial intelligence laboratory at the Université Libre de Bruxelles, is known world-wide for its work in swarm intelligence. In particular, in the last 20 years my research group has been focusing on swarm optimization and on swarm robotics.



Fig.1 A swarm of s-bots.

Swarm optimization

The two best-known swarm intelligence techniques for the solution of optimization problems are ant colony optimization (ACO) and particle swarm optimization (PSO).²

Ant colony optimization

(www.aco-metaheuristic.org)

The main contribution of my research group has been in ant colony optimization, a population-based metaheuristic that can be used to find approximate solutions to NP-hard problems [9, 8, 6, 4]. In ACO, a set of software agents called artificial ants search for good solutions to a

given optimization problem. To apply ACO, the optimization problem is transformed into the problem of finding the best path on a weighted graph. The artificial ants incrementally build solutions by moving on the graph. The solution construction process is stochastic and is biased by artificial pheromones, that is, numerical parameters associated with graph components (either nodes or edges) whose values are modified at runtime by the artificial ants. ACO has been applied to a large number of NP-hard problems, often obtaining state-of-the-art performance—an overview can be found in [11]. ACO has also been applied to network routing problems in a number of different situations: from standard packet-switched networks offering a best-effort service [3], to highly dynamic mobile ad hoc network [12]. More recently, ACO has been extended to tackle continuous and mixed variable optimization problems, with very encouraging results [18, 14].

Particle swarm optimization

My group has also contributed to particle swarm optimization research [13, 10]. In particular, we have proposed a novel high-performing PSO algorithm called Frankenstein's PSO [15], and the use of incremental learning techniques within PSO [16].



Fig.2 A swarm-bot made of four s-bots attached to each other can pass over a trough that is too large for a single s-bot.

Swarm robotics

Swarm robotics is embodied swarm intelligence. In other words, it is an approach to the control of groups of robots with a focus on systems that are composed of a large number of autonomous robots that cooperate to perform tasks that are beyond the capabilities of a single

²Research in swarm optimisation has been partially funded by the French Community of Belgium via the “Meta-X” ARC project, by the European Commission via the Marie Curie programme, and by the European Research Council via the Advanced Grant “E-SWARM; Engineering Swarm Intelligence Systems”.

robot. Additionally, the robots' sensing and communication capabilities are local and the robots' actions are neither directed by a centralised controller nor based on any global knowledge. In this field, I have coordinated two European projects: Swarm-bots and Swarmanoid.³



Fig.3 The object search and retrieval scenario.

Swarm-bots (www.swarm-bots.org)

The main objective of the Swarm-bots project⁴ was to study a novel approach to the design and implementation of self-organising and self-assembling artefacts. One of the main achievements of the project was the design, construction and control of 35 s-bots (Fig.1), autonomous robots capable of grasping each other using a gripper and to communicate using sound and colour. By grasping each other, s-bots form bigger connected structures that we call swarm-bots. A swarm-bot can perform tasks that a single s-bot cannot. An example is given in (Fig.2).



Fig.4 An eye-bot.

These robots have been used to run a number of experiments in which the robots were given tasks that were beyond their individual capabilities, but that could be performed via cooperation. An example scenario we considered was the search and retrieval of an object. The object was too heavy to be transported by a single robot and therefore the s-bots needed to find strategies to physically cooperate. Additionally, the object was placed in

a large environment so that, given their limited sensing capabilities, the s-bots also needed to cooperate both to find the object and to find an appropriate path to the goal location. An illustration of the experimental environment is shown in Figure 3. The interested reader can find detailed descriptions of the results of these experiments in [17].



Fig.5 A foot-bot.

Swarmanoid⁵ (<http://www.swarmanoid.org>)

The main scientific objective of this research project⁶ was the design, implementation and control of a novel distributed robotic system composed of three types of robots called eye-bots, foot-bots and hand-bots. The name of each robot type is reminiscent of their principal respective robot functionality. Eye-bots (Fig.4) are flying robots equipped with a camera and whose main functions are to search the environment and to guide foot-bots towards a goal location. Foot-bots (Fig.5) are robots that can move on the ground and transport objects or other robots. Finally, hand-bots (Fig.6) are robots that can manipulate objects and climb structures, but cannot move on the ground: they are transported by foot-bots (Fig.7). Collectively, these robots form a swarmanoid. Over the course of

³These two project were funded by the Future and Emerging Technologies programme of the European Commission; in addition to IRIDIA, coordinator of the project, participants in the projects were EPFL, Lausanne, Switzerland; IDSIA, Lugano, Switzerland; and ICST, CNR, Rome, Italy.

⁴The project lasted 3.5 years: from October 1, 2001, to March 31, 2005.

⁵The neologism "swarmanoid" is the contraction of the terms "swarm" and "humanoid". The idea behind it is that a swarmanoid is a robotic system composed of a swarm of robots that perform tasks that are usually performed by humanoid robots.

⁶The project lasted 4 years: from October 1, 2006, to September 30, 2010.

the project we built a swarmanoid composed of about 60 autonomous robots of the three above-mentioned types.



Fig.6 A hand-bot.

In a large scale experiment, we deployed the swarmanoid to search for and retrieve a book that was placed on a shelf at the end of a corridor in a standard office environment. To do so, constituent robots of the swarmanoid had to cooperate both logically and physically. The eye-bots' main mission was to search for the book and, once found, to indicate to the foot-bots the path to reach it. Foot-bots were charged with transporting hand-bots to the shelf. Once there, hand-bots climbed the shelf and grasped the book. They were then carried, together with the book, to the start location. A video of the experiment, fully described in [7], won the AAAI 2011 Best AI Video Award and can be seen at www.aaaivideos.org/2011/swarmanoid_the_movie/.

Current and future research

I believe that, in the future, swarm intelligence will be an important tool for engineers interested in solving certain classes of complex problems. However, our current understanding of how to use swarms of artificial agents largely relies on rules of thumb and intuition based on the experience of individual researchers. This is not sufficient for us to design swarm intelligence systems at the level of complexity required by many real-world applications, or to accurately predict the behavior of the systems we design. For these reasons, the main goal of ongoing research in my lab⁷ is the development of a rigorous engineering methodology for the design and implementation of artificial swarm intelligence systems. This same goal is also being pursued by another European project, ASCENS: Autonomic service-component ensembles, where we are trying to adapt software engineering methods so that they can be used in the design and implementation of swarm robotics systems.

Acknowledgements

Tens of PhD students and many colleagues have given significant contributions to the research presented in this short article. I wish to collectively thank them all. I also wish to explicitly express my most sincere gratitude to Dr. Mauro Birattari and to Dr. Thomas Stützle, the two

senior researchers in my group that more than anyone else have contributed in the last 15 years to the success of our lab.

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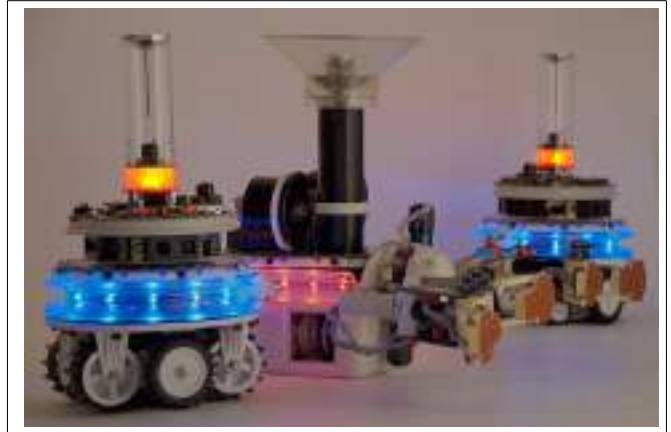


Fig.7 Two foot-bots are approaching a hand-bot that they will then transport.

References

- [1] Bonabeau, E., Dorigo, M., and Theraulaz, G. (1999). *Swarm Intelligence: From Natural to Artificial Systems*. Oxford University Press, New York.
- [2] Bonabeau, E., Dorigo, M., and Theraulaz, G. (2000). Inspiration for optimization from social insect behavior. *Nature*, 406:39–42.
- [3] Di Caro, G. A. and Dorigo, M. (1998). AntNet: Distributed stigmergetic control for communications networks. *Journal of Artificial Intelligence Research*, 9:317–365.
- [4] Dorigo, M. (2007). Ant Colony Optimization. *Scholarpedia*, 2(3):1461.
- [5] Dorigo, M. and Birattari, M. (2007). Swarm intelligence. *Scholarpedia*, 2(9):1462.
- [6] Dorigo, M., Di Caro, G. A., and Gambardella, L. M. (1999). Ant algorithms for discrete optimization. *Artificial Life*, 5(2):137–172.
- [7] Dorigo, M., Floreano, D., Gambardella, L. M., Mondada, F., Nolfi, S., Baaboura, T., Birattari, M., Bonani, M., Brambilla, M., Brutschy, A., Burnier, D., Campo, A., Christensen, A. L., Decugnière, A., Di Caro, G., Ducatelle, F., Ferrante, E., Förster, A., Guzzi, J., Longchamp, V., Magnenat, S., Martinez Gonzales, J., Matthews, N., Montes de Oca, M., O'Grady, R., Pinciroli, C., Pini, G., Rétoznaz, P., Roberts, J., Sperati, V., Stirling, T., Stranieri, A., Stützle, T., Trianni, V., Tuci, E.,

⁷This research is funded by the European Research Council via the ERC Advanced Grant “E-SWARM; Engineering Swarm Intelligence Systems”.

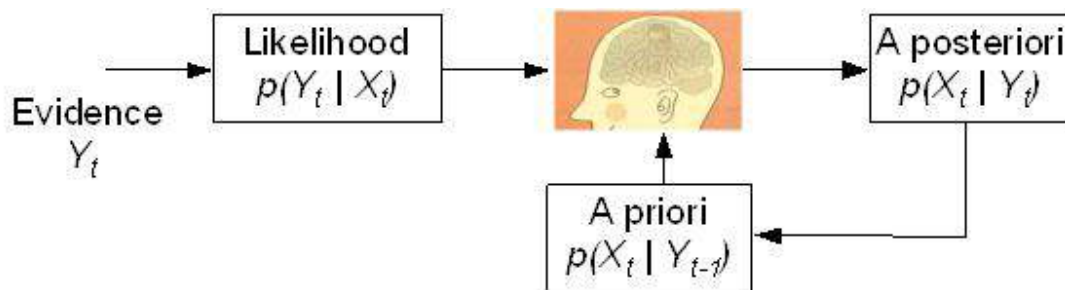
- Turgut, A. E., and Vaussard, F. (2013). Swarmanoid: a novel concept for the study of heterogeneous robotic swarms. *IEEE Robotics & Automation Magazine*. In press.
- [8] Dorigo, M. and Gambardella, L. M. (1997). Ant Colony System: A cooperative learning approach to the traveling salesman problem. *IEEE Transactions on Evolutionary Computation*, 1(1):53–66.
- [9] Dorigo, M., Maniezzo, V., and Coloni, A. (1996). Ant System: Optimization by a colony of cooperating agents. *IEEE Transactions on Systems, Man, and Cybernetics – Part B*, 26(1):29–41.
- [10] Dorigo, M., Montes de Oca, M. A., and Engelbrecht, A. P. (2008). Particle swarm optimization. *Scholarpedia*, 3(11):1486.
- [11] Dorigo, M. and Stützle, T. (2004). *Ant Colony Optimization*. MIT Press, Cambridge, MA.
- [12] Ducatelle, F., Caro, G. D., and Gambardella, L. (2010). Principles and applications of swarm intelligence for adaptive routing in telecommunications networks. *Swarm Intelligence*, 4(3):173–198.
- [13] Kennedy, J. and Eberhart, R. (1995). Particle swarm optimization. In *Proceedings of the 1995 IEEE International Conference on Neural Networks*, volume 4, pages 1942–1948. IEEE Press, Piscataway, NJ.
- [14] Liao, T., Montes de Oca, M. A., Aydin, D., Stützle, T., and Dorigo, M. (2011). An incremental ant colony algorithm with local search for continuous optimization. In *Proceedings of the Genetic and Evolutionary Computation Conference (GECCO-2011)*, pages 125–132. ACM press, New York.
- [15] Montes de Oca, M. A., Stützle, T., Birattari, M., and Dorigo, M. (2009). Frankenstein’s PSO: A composite particle swarm optimization algorithm. *IEEE Transactions on Evolutionary Computation*, 13(5):1120–1132.
- [16] Montes de Oca, M. A., Stützle, T., Van den Enden, K., and Dorigo, M. (2011). Incremental social learning in particle swarms. *IEEE Transactions on Systems, Man, and Cybernetics – Part B*, 41(2):368–384.
- [17] Nouyan, S., Groß, R., Bonani, M., Mondada, F., and Dorigo, M. (2009). Teamwork in self-organized robot colonies. *IEEE Transactions on Evolutionary Computation*, 13(4):695–711.
- [18] Socha, K. and Dorigo, M. (2008). Ant colony optimization for continuous domains. *European Journal of Operational Research*, 185(3):1155–1173.

REPORT

Alan Turing and Bayesian statistics

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Most of the notes, articles and comments published and academic events held during 2012 to mark the centenary of Alan Turing's birth focus on his pioneering research, circumscribed largely to the Turing machine and its relationship to the "decision problem" (*Entscheidungsproblem*) set forth by David Hilbert. This note, however, explains a less well-known facet of his work, his contribution to Bayesian statistics.



Unlike frequentist statistics based on the idea of quantifying the probability of an event based on the relative frequency of its occurrence, Bayesian statistics is inspired by the notion that probability represents the degree of belief that we have in the event in question. The Bayesian approach, named after Bayes' theorem, explains how each person revises his or her belief in an event after receiving new information. In other words, we decide whether the new evidence that we gather supports the original hypothesis or, contrariwise, favours a new alternative hypothesis. According to this sequential hypothesis testing schema, the view that the observer personally takes of previous experience can count as much as the evidence received in support of a hypothesis. This was considered overly subjective and unscientific in Turing's time, although, in actual fact, the British and American governments did use it to solve top-secret problems. Fortunately, the outstanding success of this Bayesian approach in solving countless real-world problems (McGrayne, 2011) has served to prove that it can outperform the frequentist approach. The

North American presidential elections (Garicano, 2012), where Nate Silver was able to correctly predict the winning party in each and every one of the 50 states, are a recent case in point. As a result, some Internet forums consider that it was Reverend Bayes, not Obama, that came out of the elections victorious.

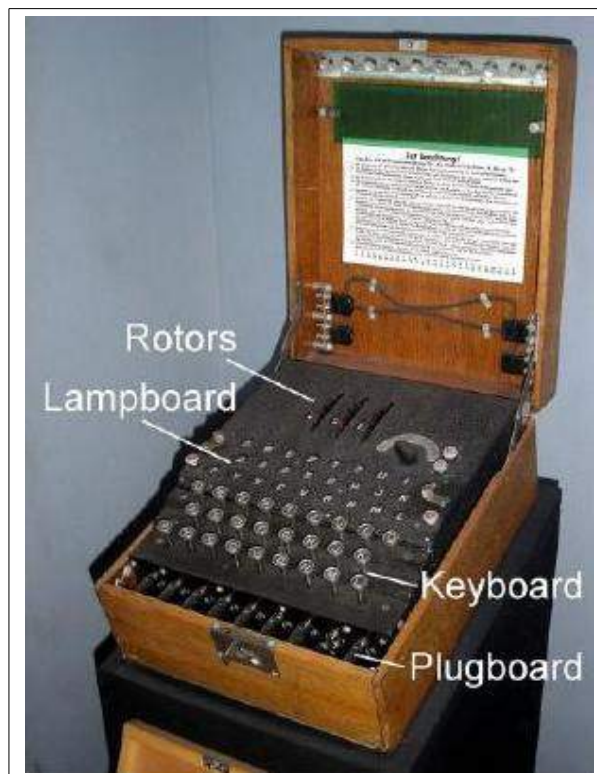
The contributions that Turing made to Bayesian statistics were related to the Banburismus algorithm. Banburismus was a process applied during World War II to break coded messages sent by the German Navy using the Enigma machine. These messages were of capital importance to the British population, whose provisioning was critically dependent on the survival of the Allied naval convoys.

In an article published in *Biometrika* (Good, 1979), the famous Bayesian statistician, Irwing J. Good, who worked as Turing's assistant at Bletchley Park in the early 1940s, explained Turing's methodological contributions to Bayesian theory, including what is known as *weight of evidence* and the introduction of a hypothesis test based on likelihood ratios used to contrast null and alternative hypotheses. Thanks to Banburismus-related documents recently declassified by the American government, we know that this algorithm is based on the hypothesis test designed by Turing.



The Enigma machine was composed of a keyboard, a lampboard and several rotors. To encode a message, the rotors were first placed in the starting position, the message was then written, and the coded message was output on the lampboard. Decoding the coded message was a symmetric process: the rotors had simply to be placed in

the initial position, the coded message keyed in, and the decoded message appeared on the lampboard. The initial positions were distributed to machine users, first monthly and more often as the war advanced.



The rotors were used to substitute any letter of the alphabet for A. Thus, for example, if the letter A was substituted by F, then the letter B was G and so on. The rotor starting point could be any letter of the alphabet. This gives an idea of the combinatorial explosion caused by the computation of all the possible ciphering combinations.

As ciphered messages were received, the belief in the hypothetical starting position of the machine was updated according to the Bayesian reasoning schema. When the weight of evidence in favour of a particular starting position of the Enigma machine was big enough, that is, statistically significant according to the likelihood ratio, this starting position was considered probable. All the probable positions were tested exhaustively using the received messages. As a result of these tests, Turing and his team managed to break and decipher the code.

Information on expressions that occurred frequently in messages, like *Heil Hitler* or even daily weather reports, was added to the process. The interception of a message that Hitler sent to Rommel in 1944 led to this methodology's biggest success. Its decoding ultimately led to the Normandy landings. This scientific breakthrough is estimated to have shortened World War II by two years.

In short, apart from his academic achievements in the field of computational theory, Alan Turing can also be considered as the architect of the rebirth of modern Bayesianism.

References

- [1] Luis Garicano (2012). This is Mathematics, stupid. El País, 13 November 2012, in Spanish.
- [2] Irwing J. Good (1979). Studies in the history of probability and statistics. XXXVII A. M. Turing's statistical work in the World War II. Biometrika, 66, 2, 393-396.
- [3] Sharon B. McGrayne (2011). The Theory that Would Not Die: How Bayes' Rule Cracked the Enigma Code, Hunted Down Russian Submarines, and Emerged Triumphant from Two Centuries of Controversy. Yale University Press.

JOURNAL HIGHLIGHTS

International Journal of Approximate Reasoning



The **International Journal of Approximate Reasoning** was founded in 1987. The journal title was explained as follows by its founding Editor-in-Chief, Jim Bezdek, in the editorial of the inaugural issue: “According to Webster’s, *reasoning* is “the drawing of inferences or conclusions from known or assumed facts”. The term *approximate* indicates the presence of uncertainty. (...) Thus, *approximate reasoning* might be literally taken as the drawing of inferences or conclusions from known and unknown, or at least partially known facts. IJAR will contain articles about this process”.

Twenty five years later, this initial description of the journal’s scope remains entirely valid and up-to-date. As now emphasized by the subtitle “Uncertainty in Intelligent Systems”, IJAR is intended to serve as a forum for the treatment of all aspects of uncertainty (including randomness, imprecision, incompleteness, contradiction, vagueness, etc.) in Artificial and Computational Intelligence. It covers both the foundations of uncertainty theories and the design of intelligent systems with uncertain reasoning capabilities for scientific and engineering applications. It publishes high-quality research papers describing theoretical developments or innovative applications, as well as review articles on topics of general interest.

Scope

The editorial policy of IJAR has always been to reflect the diversity of approaches to uncertainty without being tied to any specific formalism. In particular, the journal welcomes articles on probabilistic reasoning and Bayesian networks, imprecise probabilities, random sets, belief functions (Dempster-Shafer theory), possibility theory, rough sets, decision theory, non-additive measures and integrals, qualitative reasoning about uncertainty, comparative probability orderings, game-theoretic probability, default rea-

soning, nonstandard logics, argumentation systems, inconsistency tolerant reasoning, elicitation techniques, philosophical foundations and psychological models of uncertain reasoning, etc. Domains of application for uncertain reasoning systems include, but are not limited to, risk analysis and assessment, information retrieval and database design, information fusion, machine learning, data and web mining, computer vision, image and signal processing, intelligent data analysis, statistics, multi-agent systems, etc.

To cover such a broad spectrum, the field has been divided into five areas, each covered by an area editor. These areas are:

- Soft computing, hybrid systems. Area editor: Oscar Cordón
- Fuzzy sets and Possibility theory. Area editor: Inés Couso
- Probabilistic reasoning. Area editor: Thomas Dyhre Nielsen
- Rough sets. Area editor: Yiyu Yao
- Imprecise probabilities. Area editor: Marco Zaffalon.

Organization

Since this article appears in the magazine of the European Society for Fuzzy Logic and Technology, it seems relevant to clarify the position of IJAR with respect to Fuzzy Sets (as opposed, in particular, to more specialized journals in this field such as *Fuzzy Sets and Systems*). Fuzzy Sets are considered to be in the scope of IJAR as long as they serve the general purpose of modeling uncertain reasoning. This criterion excludes papers on fuzzy control as well as fuzzy mathematics (fuzzification of algebraic structures, fuzzy topology, fuzzy differential equations, etc.). In contrast, the study of fuzzy sets viewed as possibility distributions is fully in the scope of IJAR, as Possibility Theory was actually introduced to relate fuzzy sets to uncertainty theories. In any case, the meaning of fuzzy sets and their extensions should always be made explicit. In particular, new variants of fuzzy sets (such as type-2, intuitionistic, hesitant, vague, soft, etc.) should only be introduced with strong motivation and clear interpretation. Papers describing fuzzy approaches to decision making can be considered for publication as long as they have a solid theoretical foundation, they emphasize the uncertainty dimension and they are proved to bring significant advantages over state-of-the-art methods.

Interesting data

- IJAR receives around 250 to 300 submissions each year and the rejection rate is around 75 %. Out-of-scope papers or submissions with very weak scientific content are rejected within a few days, while most submissions go through a full review process.
- The Editorial Board is striving to provide authors with timely reviews while maintaining a high quality of evaluation. The average time between submission and first decision is around two months, while the average time between submission and final acceptance is around 40 weeks.

- In 2011, IJAR had an impact factor of 1.948 and ranked 27 out of 111 journals in the Artificial Intelligence area.

As the complexity of our world is increasing, uncertainty and risk management can be expected to become issues of growing importance in the coming years. The *International Journal of Approximate Reasoning* will continue to play its role as one of the world's leading journals where original, groundbreaking research results on uncertainty are presented and discussed.

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SCIENTIFIC REPORT

Computing With Words (CWW): role of fuzzy, probability and measurement concepts, and operations

Gleb Beliakov, Bernadette Bouchon-Meunier, Janusz Kacprzyk, Boris Kovalerchuk, Vladik Kreinovich and Jerry Mendel



(Left) Brisbane Convention and Exhibition Centre.

(Right) A moment during posters presentation at WCCI 2012.

The goal of this panel at IEEE World Computational Intelligence Congress in Brisbane, Australia was to discuss the fundamental concepts that underline a new area of computing with words initiated by L. Zadeh. The panel was held on June 10 with six panelists: Gleb Beliakov (Deakin University, Australia), Bernadette

Bouchon Meunier (University of Paris, France), Janusz Kacprzyk (Polish Academy of Sciences, Poland), Boris Kovalerchuk (moderator, Central Washington University, USA), Vladik Kreinovich (moderator, University of Texas, USA), and Jerry Mendel (University of Southern California, USA).



Participants of CWW Panel at WCCI 2012: F.l.t.r Jerry Mendel, Bernadette Bouchon-Meunier, Boris Kovalerchuk, Vladik Kreinovich, Gleb Beliakov and Janusz Kacprzyk.

Overview of the Panel at WCCI-2012

Boris Kovalerchuk

The topic of the panel was inspired by Zadeh's test tasks [10] for computing with words (CWW). According to Zadeh, the standard probability theory presented in textbooks offers no solutions for these tasks. Below several of these test tasks are listed:

- Probably John is tall. What is the probability that John is short?
- Most Swedes are tall. Most Swedes are blond. Tom is Swede. What is the probability that Tom is short? What is the probability that a Swede picked at random is tall and blond? What fraction of Swedes is tall and blond?
- Usually it takes Robert about an hour to get home from work. Usually Robert leaves office at about 5 pm. What is the probability that Robert is home at 6:15 pm?
- A box contains about 20 balls of various sizes. A few are small and several are large. What is the probability that a ball drawn at random is neither large nor small?
- Most young men are healthy; Robert is young. What can be said about Robert's health?
- Most young men are healthy; it is likely that Robert is young. What can be said about Robert's health?
- Slimness is attractive; Cindy is slim. What can be said about Cindy's attractiveness?
- Usually travel time from Berkeley to Palo Alto is about 1 h and usually travel time from Palo Alto to San Jose is about 25 min. How long will it take to drive from Berkeley to San Jose?
- X is a normally distributed random variable with a small mean and a small variance. Y is much larger than X . What is the probability that Y is neither small nor large?
- Consider a perception-valued times series $T = \{t_1, t_2, t_3, \dots\}$ in which the t_i 's are perceptions of, say temperature, e.g., warm, very warm, cold, ... Assume that the t_i 's range over a set of linguistic values, A_1, A_2, \dots, A_n , with probabilities P_1, \dots, P_n . What is the average value of T ?
- I am checking in at San Francisco airport. I ask the ticket agent "What are the chances that my flight will be delayed?" The ticket agent tells me, "Usually most flights leave on time." What does his statement tell me about the probability that my flight will be delayed?

The expected answers are not numbers, but *linguistic descriptions of fuzzy perceptions of probabilities*, e.g., not very high, quite unlikely, about 0.8, etc. This is the area of PTP (perception-based probability theory). Zadeh proposed a *restriction/constraint based approach* to these tasks in line with PTP and fuzzy logic. This panel continued several recent related discussions. The discussion at Berkeley Initiative on Soft Computing (BISC) started with a "naïve" question from a student: "What is the difference between fuzzy and probability?" Previous round table was organized by B. Bouchon-Meunier at the World Conference on Soft Computing in 2011 in San Francisco with invited panelists Zadeh, Widrow, Bouchon-Meunier, Kacprzyk, Kovalerchuk, and Perlovsky. At WCCI 2012 a "warm up" tutorial for this round table "Fuzzy Logic, Probability, and Measurement: Similarities and Differences in Computing with Words" was delivered by B. Kovalerchuk [7]

CWW challenges

To fill in deficiencies of the standard Probability Theory (PT), Zadeh proposed a Generalized Theory of Uncertainty (GTU). He also stated that he has not attempted to construct an axiomatic approach to GTU, believing that "it will be very hard, perhaps impossible, to do it". To support this statement Zadeh referenced his **Impossibility Principle**: "The closer you get to reality, the more difficult it becomes to reconcile the quest for relevance and applicability with the quest for rigor and precision."

One of the goals of this panel was to explore if the situation is indeed hopeless. See question Q3 of the panel below. The *optimistic* view is that high scientific rigor is compatible with the high uncertainty of the CWW tasks. The *pessimistic* view is that they are not compatible and only highly heuristic methods can and should be developed to be useful. Note that rigor and precision are not the same.

A rigorous solution is, in general, not necessarily precise. We can know that John is taller than Peter without knowing their precise heights. In particular in my panel presentation and in several of our papers it was shown that scientific rigor, relevance, and applicability are reachable when Zadeh's linguistic variables, membership functions and probabilities combined in what we call a linguistic context space (e.g., [3,6]). That creates a rigorous base for the combination of fuzzy logic and probability concepts.

It is critical to have rigor to call CWW a scientific domain. The representative measurement theory originally developed in mathematical psychology is very relevant to these challenges in CWW [8]. Our ability to assign 0.8 to "John is tall" and 0.7 to "Peter is short" does not imply that we also able to assign a number to a combined statement "John is tall and Peter is short". Such human "measurement" abilities decrease with increase of complexity of the statements when we add more And and Or

parts to the statements. Both the theory of subjective probabilities and the fuzzy logic have made brave attempts, suggesting how to compute such numbers for complex statements to mimic human reasoning (descriptive and/or normative). CWW test tasks only start, but not finish with assigning 0.8 for simple statements such as “John is tall”. We need a justification of operations with numbers for simple statements that humans are able to produce. The panel questions Q1, Q2, and Q5 are to discuss this issue.

Example of CWW challenges

A knowledge base contains a statement: “Old or almost old people are quite wise.” What is the probability that John, 59 is quite wise? What is the fuzzy membership function value that John, 59 is quite wise?

Let membership values be $\mu(\text{old}, 59) = 0.45$, and $\mu(\text{almost old}, 59) = 0.55$. These numbers are close to values from the frequency-based experiment [1]. Then $\mu(\text{old OR almost old}, 59) = \max(0.45, 0.55) = 0.55$ using the fuzzy logic max operator for OR. In essence, 0.55 means a refusal to judge how wise John is. This shows a limitation of the standard max operation of the fuzzy logic. Alternatively, let conditional probabilities be $P(\text{old}/59) = 0.45$ and $P(\text{almost old}/59) = 0.55$, then $P(\text{old OR almost old}/59) = P(\text{old}/59) + P(\text{almost old}/59) = 0.45 + 0.55 = 1$.

This is a certain answer that John, 59 is quite wise. Which of two answers fits better to our common sense reasoning? If we vote, I think that $\mu(\text{old or almost old}, 59) = \max(0.45, 0.55) = 0.55$ will not win over $P(\text{old OR almost old}/59) = 1$. The answer $P(\text{old OR almost old}/59) = 1$ is based on the **probability space** with two **linguistic labels** as elementary events {old, almost old} with probabilities that satisfy Kolmogorov’s axioms. Note that here linguistic labels are not equal to uncertain real world concepts. Labels do not overlap (mutual exclusion), but uncertain real world concepts overlap. This idea was developed as **Exactly Complete Linguistic Context Space** [3,4,6] and was discussed in my presentation. The panel question Q4 is about applicability of different techniques to CWW in comparison with very successful fuzzy control.

Panel Questions

- Q1 What are individual and joint areas for Fuzzy Logic (FL) and Probability Theory (PT) from the viewpoint of measurements that is obtaining initial uncertain values?
- Q2 How to select and justify the reasoning rules and operations? What is the justification to use the fuzzy logic operations when membership values are obtained by using a probabilistic technique such as frequencies or random sets?
- Q3 Would you prefer a technique that provides a solution in a few minutes using a few very uncertain inputs, but with high uncertainty and low scientific rigor? Or would you prefer a technique that required months or years of data collection and model

building, but will provide a more rigorous solution? Examples?

- Q4 Why do we have the major applications of the fuzzy linguistic variables and computing with words (CWW) in fuzzy control not in the Natural Language Communications (NLC) that had originally motivated CWW?
- Q5 What is an appropriate way of obtaining fuzzy Membership Function (MF) values? If it will be a subjective human judgment, how would you distinguish it from subjective probabilities?

The panelists agreed to pick up all or some of these questions and possibly modify them or talk about other challenges of the panel topic that the questions do not cover.

Gleb Beliakov concentrated on how to define membership functions of fuzzy sets. He had been reviewing approaches based on the measurement theory, statistical processing of empirical data, and purely pragmatic definitions that favor computational simplicity. Then he considered this issue from the perspective of aggregation operators, i.e., how can we interpret membership values that result from performing operations on fuzzy sets.

Bernadette Bouchon-Meunier focused on the well-known antagonism between probabilities and fuzzy sets to manage uncertainty inherent to complex problems. She proposed to analyze the uncertainties from the levels of uncertainty, numericity, intrinsicity and subjectivity. This analysis continues to the discussion of the combination of several sources of uncertainty, the choice of an uncertainty modeling technique and its influence on the rigor or determinism of the obtained solution in relation to the Computing with Words.

Janusz Kacprzyk emphasized that the panel has responded to a real and urgent need of our entire community involved in the research in broadly perceived uncertainty. Then he discussed new opportunities in CWW based on fuzzy logic, noting that their acceptance is for the time being far from what we might desire. He linked CWW with information/knowledge intensive tasks stating the benefits of CWW for solving these tasks. These tasks deal with inherently human specific features like intuition, sentiment, judgment, and affect. These characteristics of the tasks are connected to concepts that concern CWW reasoning: (1) usuality, (2) probability, possibility or certainty, (3) obligation or necessity, (4) ability, and (5) inclination.

Vladik Kreinovich started with the origin and motivation for CWW. He stated that CWW is a way to expand the availability of the best expert knowledge and increase its usage. The origin of the challenge to select an operation with fuzzy sets was then discussed. This included the motivation behind using T-norms and T-conorms, as well as choosing between these norms. Then he provided arguments on advantages of using intervals to build realistic MF values and reflected on Zadeh’s vision of processing words directly, without the need to use numbers as an intermediate step.

Jerry Mendel emphasized the importance of measurements in CWW and viewed them as random with proba-

bility and statistics used to preprocess the measurements and to build membership functions (MF). On obtaining fuzzy MF values he argued for simple and intuitive questions that do not ask subjects to produce directly the MF values. On justifying the CWW reasoning rules, Jerry proposed creating test cases with confirmed answers. On the justification of using fuzzy logic operations, when MF values are produced by a probabilistic technique, he discussed a convergence to probabilities. In question Q5, Jerry outlined new opportunities for getting data quickly from the Internet.

References

- [1] Hall, L.O., Szabo, S., and A. Kandel: On the Derivation of Memberships for Fuzzy Sets in Expert Systems, *Information Sciences*, vol. 40, 1986, pp. 39-52.
- [2] Kovalerchuk, B., and V. Talianski: Comparison of Empirical and Computed Values of Fuzzy Conjunction, *Fuzzy Sets and Systems*, vol. 46, 1992, pp. 49-53.
- [3] Kovalerchuk, B.: Context Spaces as Necessary Frames for Correct Approximate Reasoning, *International Journal of General Systems*, vol. 25 (1), 1996, pp. 61-80.
- [4] Kovalerchuk, B. and E. Vityaev: *Data Mining in Finance: Advances in Relational and Hybrid Methods* (chapter 7 on fuzzy systems), Boston: Kluwer, 2000.
- [5] Kovalerchuk, B.: BISC-group posts, 2010-2012, <http://mybisc.blogspot.com/>
- [6] Kovalerchuk, B., Quest for Rigorous Combining Probabilistic and Fuzzy Logic Approaches for Computing with Words, In: R. Seising, E. Trillas, C. Moraga, S. Termini (eds.): *On Fuzziness. A Homage to Lotfi A. Zadeh*, *Studies in Fuzziness and Soft Computing* Vol. 216, Springer 2012. (In print)
- [7] Kovalerchuk, B., Fuzzy Logic, Probability, and Measurement: Similarities and Differences in Computing with Words. Tutorial, Proc. IEEE WCCI-2012, <http://www.cwu.edu/~borisk/pub/tutorialKovalerchuk5CWW.pdf>
- [8] Krantz, D., R. D. Luce, P. Suppes, and A. Tversky. *Foundations of Measurement*, Vol. I-3: New York: Academic Press, 1971-1990, Reprinted by Dover, 2007, New York.
- [9] Thole, U., Zimmermann, H.-J. and P. Zysno: On the Suitability of Minimum and Product Operations for the Intersection of Fuzzy Sets, *Fuzzy Sets and Systems* vol. 2, 1979, pp. 173-186.
- [10] Zadeh L.A.: *Computing with Words - Principal Concepts and Ideas*. *Studies in Fuzziness and Soft Computing* 277, Springer 2012.



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Aggregation of membership values

The question of how to define membership functions of fuzzy sets has been around for at least four decades. Approaches include those based on measurement theory [1], statistical processing of empirical data [2], and purely pragmatic definitions that favour computational simplicity. I will look at this issue from the perspective of aggregation operators, and focus not on the input memberships but the outputs: how can we interpret membership values that result from performing operations on fuzzy sets.

The relation of aggregation operators to membership functions is direct: we usually need to combine degrees of membership into one value, the membership of an object in the combined fuzzy set, like “a tall and heavy person” (note the correlation). The standard combinations of fuzzy sets are the union, intersection and complement, and aggregation operators are used to compute the resulting membership values from the membership values in the fuzzy sets being combined.

Zadeh has defined the union and intersection of fuzzy sets using maximum and minimum operations [3], although he has also suggested the product as an alternative. While Bellman and Giertz [4] have shown that max and min operators is the only choice consistent with the standard set theoretic axioms, it soon became clear that they are too rigid to model human decision making. Zimmermann and Zysno [5] analysed human responses to the questions involving fuzzy sets intersection and found that a convex combination of max and min (so called gamma-operator) fits the empirical data much better. At the same time, the families of triangular norms and conorms have been introduced to fuzzy set theory from the area of statistical metric spaces. Nowadays it is customary to use t-norms for intersection and t-conorms for union of fuzzy sets, and the standard negation for the complement.

The ways the membership degrees are combined has a direct impact on the interpretation of memberships. The product t-norm, for instance, allows one to combine membership degrees seen as probabilities of independent events, and the resulting value can be interpreted as the probability of the combined event. That is, if we see $\mu_a(x)$ as the probability that a random variable X takes value x , and $\mu_b(y)$ is the probability that Y takes value y , then $\mu_a(x) * \mu_b(y)$ is the probability that $X = x$ and $Y = y$, if

the random variables are independent. The class of copulas (not all of which are t-norms, but associative copulas are indeed t-norms) allows one to model dependencies (the famous Sklar theorem states that a multivariate cumulative distribution function can be represented as a copula of its marginals). The minimum operator is also a copula which models dependence of comonotonic random variables. Another famous copula (yet only in the bivariate case), is the Lukasiewicz t-norm which models dependence of countermonotonic random variables.

Once we depart from the concept of copulas, the probabilistic interpretation of the combined membership degree no longer holds. Not only t-norms distinct from copulas are widely used, but other types of aggregation, such as the gamma-operator, seem to model human judgements better than copulas [5,6,7].

Among other types of aggregation operators, I will mention uninorms, means, ordered weighted averaging (OWA), and fuzzy integrals. Uninorms are interesting in that they allow one to model bipolar aggregation, where memberships below a threshold, called the neutral element, are aggregated by a t-norm, membership above the threshold are aggregated by a t-conorm, and otherwise they are averaged. This way “positive” and “negative” pieces of information are combined. Early expert systems such as MYCIN and PROSPECTOR relied on the uninorms to combine the inputs.

Means, including weighted arithmetic, geometric, power and quasiarithmetic means are also very popular. Typically the means offer compensation: small membership degrees in some sets are compensated by large membership degrees in the others. For instance, Zimmermann and Zysno data [5] are best modelled precisely using averaging operators [6]. There are studies by M. Grabisch, G. Beliakov and others on fitting another type of averaging functions, the discrete Choquet integral, to empirical data in more than two variables that suggest averaging fits the data well.

In popular OWA operators, the memberships are ordered according to their values, and weighted averaging is applied to the ordered memberships. Fuzzy integrals such as Choquet and Sugeno integrals model not only the importance of the inputs or their magnitude, but impor-

tance of subsets of inputs and their interactions. In this way redundant inputs produce lower combined value than the independent inputs. Finally, penalty-based averaging [7] produces such a combined value that minimises a penalty for inputs disagreement. With such a spectrum of aggregation operators, some of which are more successful in fitting empirical data than the others, it becomes very hard to interpret the membership values in the combinations of fuzzy sets. In fact, in some studies it was proposed to use interpolatory type aggregation operators, built exclusively by fitting empirical data [8]. While this is very pragmatic from the point of view of an application, it raises the questions of not only how to interpret the output membership values, but whether it can be or should be done at all.

In fuzzy logic one attempts to reproduce $\mu(A \text{ and } B)$ starting from $\mu(A)$ and $\mu(B)$. In the case of probabilities it would be the marginal probabilities $P(A)$ and $P(B)$. Specifically, if we have n marginal probabilities and want to produce n -D probability distribution, we must use a copula. The implication is that if we average probabilities by something else, like OWA, the result is not a probability anymore. It does not mean it cannot be related to probability in some way, but it is not a probability of an event itself. In other words, we lose this probabilistic interpretation after such an aggregation. What is the interpretation status of the result of such averaging/aggregating $P(A)$ and $P(B)$, $f(P(A), P(B))$? As we already discussed, it is not a probability in a strict sense, but there is a possibility to develop its interpretation as a degrees of evidence/likelihood instead.

It appears that in the complexity of an aggregation process one loses the initial interpretation of the inputs. Does it really matter? In an earlier work we presented an argument for looking at the membership degrees through the lens of similarity to the ideal [9]. In this framework, the actual aggregation procedure would not matter, as the result can still be interpreted as similarity to the “combined” ideal, where similarity is one minus a distance in some pseudometric.

Finally, the dependence of the membership values on the context is very important. For example the term “tall person” is interpreted differently in a kindergarten and in the general population. An approach based on pseudodistances, defined through the frequencies of appearances of

objects with certain attributes, such as height, in a fixed context was presented in [10].

References

- [1] Norwich, A.M. and I.B. Turksen, A model for the measurement of membership and the consequences of its empirical implementation. *Fuzzy Sets and Systems*, 1984. 12: p. 1-25.
- [2] Hisdal, E., Logical structures for representation of knowledge and uncertainty. 1998, New York: Physica-Verlag.
- [3] Zadeh, L., Fuzzy sets. *Information and Control*, 1965. 8: p. 338-353.
- [4] Bellman, R.E. and M. Giertz, On the analytic formalism of the theory of fuzzy sets. *Inform. Sci.*, 1973. 5: p. 149-156.
- [5] Zimmermann, H.-J. and P. Zysno, Latent connectives in human decision making. *Fuzzy Sets and Systems*, 1980. 4: p. 37-51.
- [6] Beliakov, G., How to build aggregation operators from data? *Int. J. Intelligent Systems*, 2003. 18: p. 903-923.
- [7] O. Cordon, F. Herrera, A. Peregrin, Applicability of the fuzzy operators in the design of fuzzy logic controllers. *Fuzzy Sets and Systems*, 1997, 86: p.15-41.
- [8] Calvo, T. and G. Beliakov, Aggregation functions based on penalties. *Fuzzy Sets and Systems*, 2010. 161: p. 1420-1436.
- [9] Beliakov, G., T. Calvo, and J. Lazaro, Pointwise construction of Lipschitz aggregation operators with specific properties. *Int. J. of Uncertainty, Fuzziness and Knowledge-Based Systems*, 2007. 15: p. 193-223.
- [10] Beliakov, G., Definition of general aggregation operators through similarity relations. *Fuzzy Sets and Systems*, 2000. 114(3): p. 437-453.
- [11] Beliakov, G., *Fuzzy Sets and Membership Functions Based on Probabilities*. Information Sciences, 1996. 91(1-2): p. 95-111.



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We focus on the well-known antagonism between probabilities and fuzzy sets to manage uncertainty inherent to complex problems. There is no need to say that both of these methodologies are useful and help to handle some aspects of imperfect knowledge. To clarify the difference between them, it should be noted that fuzzy sets are useful to represent imprecise information, which itself generates uncertainty. Probabilities directly provide a representation of certain types of uncertainty. Fuzzy sets and probabilities can clearly coexist in the same environment and work together to cope with system complexity. They should not be opposed to each other, since they do not correspond to the same aspects of uncertainty.

In the sequel, we will first propose to analyse uncertainties from two different angles, the first one associated with levels of uncertainty, the second one with three dimensions, namely numericity, intrinsicity and subjectivity, and we review the question of measurement in different cases. We then answer a few questions about the combination of several sources of uncertainty, the choice of an uncertainty modeling technique and its influence on the rigor or determinism of the obtained solution. We conclude by a focus on the capability of the Computing with Words paradigm to integrate several uncertainty modeling techniques

A first approach to the analysis of uncertainties and the choice of a modeling technique to cope with them consists in saying that there exist several *levels of uncertainty*. The first level refers to the structural doubt about the state of a phenomenon, for instance “the stock price will probably increase today” or “it may rain tomorrow”. The uncertainty is then “primary”. Probabilities are among the good candidates to manage such uncertainties.

The second level of uncertainty corresponds to a doubt resulting from imprecision, approximation, or incomplete knowledge. For instance, “Peter is approximately 24 years old” is based on imprecise information and entails an uncertainty about the fact that Peter is 24 years old or not. The imprecision is “primary” and the uncertainty is its consequence. Fuzzy set theory is an interesting solution to cope with imprecisions or approximations, and possibility theory is a natural way to manage uncertainties generated

by imprecisions or approximations, but not the only one.

The third level of uncertainty corresponds to a doubt due to a subjective appreciation or a judgment. For instance, “I don’t believe that Peter will come tomorrow” or “I am not sure that the stock price will strongly increase”. The appreciation is a cause of uncertainty which can be added to an uncertainty of the first or second level, as a kind of meta-uncertainty. There exist several solutions to deal with such uncertainties, for instance using a possibilistic framework or modal logics.

Identifying the levels of uncertainty is nevertheless not sufficient to differentiate probabilistic from fuzzy contributions to the management of uncertainty. Another important prism to use is the *nature of uncertainty*, which lies on several dimensions.

For the sake of simplicity, we propose to only consider three dimensions, as illustrated in Figure 1. The first dimension refers to the distinction between numerical and symbolic data. The second dimension corresponds to the intrinsicity of uncertain information: it is considered as intrinsic when it is attached to a real world phenomenon, and extrinsic when it is due to the process of observation itself. The third dimension indicates the gradual degree of subjectivity, from an objective measurement to a subjective evaluation.

The three dimensions take part in the choice of an appropriate method to be used to manage uncertainty, which is generally not unique. We give some examples of manifestations of uncertainty and possible methods to manage it.

(i) It seems clear that *numerical intrinsic* uncertainty must be dealt with by means of probabilities, be they *objective* and managed by classic frequentist probabilities (1), or *subjective* and handled by means of De Finetti’s subjective probabilities for instance (2). More details about the measurement of probabilities, for example through statistics or bets, can be found in the literature.

(ii) Examples of *objective symbolic intrinsic* uncertainty can be associated with imprecise descriptions of variables managed through fuzzy sets in the case of objective and measured data (3). For instance, in a medical application, spots on a mammogram are described as “elongated”

or “round” and uncertainty stems from the imprecise description, since “round” is only a linguistic approximation of the mathematical characterization “circular”. In such a case, membership functions are obtained in an automatic (machine learning-based) process from measurements of various criteria such as convexity or elongation, performed during the image processing. A *subjective intrinsic symbolic* uncertainty can be identified in felt probabilities (such as “highly probable”), which can be represented by fuzzy values (4), whose membership functions can be obtained by means of a psychometrics approach, through interviews, questionnaires or the use of scales.

(iii) In the case of an *objective* cause, *numerical extrinsic* uncertainty is for instance present in sensor imprecision or in estimations (5), and several tools can be used to deal with it, such as interval analysis, fuzzy sets or confidence intervals. Measurement is then performed from physical or technical data regarding the sensor errors. An example of *numerical extrinsic uncertainty* which is *subjective* is identified in web-based information quality (6), and it can for instance be managed by means of possibility theory or evidence theory.

(iv) A *symbolic extrinsic* source of uncertainty is related to the difficulty to characterize a given complex phenomenon, solved by means of linguistic expressions. On the one hand, an example of objective uncertainty is associated with imprecise values due to the impossibility to obtain precise values (7), in a case such as the evaluation of a distance by the observer (“the school is far from the house”). This kind of information is easy to represent through fuzzy sets with membership functions determined with the help of psychometrics methods. On the other hand, the *symbolic extrinsic* uncertainty will be *subjective*, for instance, in the case where the observer expresses a doubt on the validity of data (of the form “I believe that...” or another one), and modal logic is one of the candidates to cope with it (8).

The combination of several sources or manifestations of uncertainty must be achieved according to the chosen type of representation and to the specific constraints of the problem. The range of available aggregation tools is wide and a careful analysis will lead to the selection of one of them. There is obviously no reason to use fuzzy logic type operations when it is necessary to cope with probability-like uncertainties or, on the contrary, to choose probabilistic rules when fuzzy sets are involved.

In real-world applications, the uncertainty modeling technique must be chosen on the basis of the purpose of the built system and the available data and expertise. We can distinguish cases where the outcomes must be precise and the system deterministic, from cases where preserving some uncertainty is useful. The concept of rigor can also be addressed and it should be differentiated from precision and determinism. Most of the systems must be rigorous and provide high quality results, but the rigor may have various appearances.

The precision of the outputs of the system is particularly meaningful in situations where a system performs an action, such as the control of a robot or an unmanned he-

licopter; precision is one of the criteria used to evaluate the system and to validate the selected uncertainty modeling technique. It must be remarked that fuzzy systems are able to provide very precise and rigorous outputs, even though inputs may be imprecise and/or uncertain.

Objectivity Subjectivity	Numerical	Symbolic
Intrinsic (Attached to real world phenomena)	Frequentist probabilities (1) <i>Subjective probabilities (2)</i>	Approximate values (3) <i>Feet probabilities (4)</i>
Extrinsic (Due to the observation)	Sensor imprecision (5) <i>Information quality (6)</i>	Linguistic description (7) <i>Doubt on the validity (8)</i>

Figure 1: Examples of uncertainty manifestations corresponding to objective information (in normal font) or subjective information (in italics), along the two first dimensions (numericity, intrinsicity)

In other situations, the quality of the system has nothing to do with the concept of precision and an output of the form “the student has greatly improved his skills in literature and must reinforce his efforts in mathematics” can be obtained thanks to a fuzzy logic-based management of student abilities, which must obviously follow a rigorous analysis of the situation. The selection of the uncertainty modeling technique relies in this case on the necessity to obtain an expressible result and not a numerical coefficient or a mark, the evaluation of the system being made by experts.

In some other contexts, it may be interesting to preserve the uncertainty associated with the outcomes of a system and to enable the user to use his/her expertise to make a final decision. In other words, it may be important to know that two different events may occur and to be prepared to both of them, which can be achieved by means of possibility theory, fuzzy logic or probability theory, rather than to look for a deterministic decision.

A last point we want to mention is the possibility to use several uncertainty modeling techniques in a given environment. The Computing with Words paradigm is a perfect environment to integrate fuzzy logic and/or possibility theory as well as probabilities. The “probability to draw a small ball” or the construction of fuzzy decision trees on the basis of a training set providing probabilities and fuzzy modalities of attributes, are examples of situations where we do not choose one of the techniques, but we use their synergy to solve problems in a human-like approach.



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This short note is a brief summary of my presentation at the Panel on Computing with Words: Role of Fuzzy, Probability, and Measurement Concepts and Operations that was organized at WCCI-2012 in Brisbane, Australia by Professors Boris Kovalerchuk and Vladik Kreinovich. That initiative, that should be greatly appreciated by our entire community, not only fuzzy, but more generally involved in research in broadly perceived uncertainty, has responded to a real and urgent need. To be more specific, one can witness a wider and wider interest in formal models, tools and techniques, in particular those followed by algorithmic and computational implementation, that would be able to help analysts and decision makers cope with the complexity of real world problems they are faced with. Moreover, as one can clearly see, though uncertainty - or, better to say, imperfect information - has many aspects and facets, the traditional way of dealing with it is too narrow, as it is mostly based on a one sided randomness related view that implies the use of probabilistic and statistical tools. On the other hand, a wide array of other tools is available, notably - in our context - those based on fuzzy logic and its related computing with words (CWW), but their acceptance is for the time being far from what we might desire.

The panel organizers have put a couple of relevant questions related to the above issues that have touched upon both foundational and application oriented aspects, and which have been meant to yield a response what is available, what is needed, why we are far from what we might expect and wish, etc.

I will try to briefly present my view in this respect. I will follow in principle the questions posed, but will somehow rephrase them so that they better reflect my concerns or opinions. This should, in my opinion, give a better view of what I think about the relevant issues raised by the panel organizers.

To start with, let me first say that what concerns the problems we can face, there are two basic classes which may be termed as:

- data intensive,
- information/knowledge intensive.

The first class concerns all kinds of situations in which analyses and decision making are done based on large, or even huge sets of data. Judging by appearance, since we face everywhere situations in which data are input and stored freely and people do not care very much about any limitation of this because of a decreasing cost of storage and increasing power of computing machinery and software, then we tend to think that only such problems exist. This is unfortunately not the case. There is also a wide class of problems and situations, which can be termed information/knowledge intensive, in which the size of data sets does not matter so much, and a deep knowledge of the area under consideration matters. There are numerous examples in a wide variety of areas, exemplified by high level business decisions when a deep knowledge of economic situation, sentiment, perceived prospects, etc. influences the final decision by a real decision maker. He or she may be helped by an analysts who may be using huge data sets, the analysis of which may be or not helpful in the final high level decision making stage.

I would say that my interest with respect to theoretical research and applications is in the second class of problems, i.e. those in which a deep knowledge about the situation, and the environment it is proceeding in, exemplified by constraints, goals, various relations, etc., really matters. This implies my interest in tools and techniques that may help represent and handle affects, judgments, intuition, and many other intangible elements. Moreover, due to an inherently soft character of these aspects, and their clear human centricity, my interest is heavily related to all kinds of natural language related technologies, notably those which may handle imprecise and uncertain information and knowledge. Of particular relevance is here computing with words (CWW) which I basically understand in the sense of Zadeh as expressed in his well-known source papers and his recent Springer book [2] though my view differs slightly from his with respect to relations of CWW with computational linguistics technologies.

So, to start with, in my opinion, what we need to solve non-trivial real world problem is predominantly related to an ability to somehow include in our analyses inherently human specific features like intuition, sentiment,

judgment, affect, etc. that are easier to express in natural language which is the only fully natural means of articulation and communication of the human beings. Though there is a multitude of natural language based tools and techniques (maybe even “technologies”), in my view they have a limited ability to represent and manipulate imprecision that is inherent in natural language. There are many reasons for this. For instance, if one takes into account that the traditional computing may be divided into two basic classes: symbolic, that is mainly logic based, and numeric, that is mainly based on numerical calculations, one can see that both - in their traditional versions - do not provide means for handling imprecision. Therefore, those traditional computational linguistic tools and techniques, based on the above mentioned classes of computing, or even their combinations, are not best suited for handling imprecision. Zadeh’s computing with words (CWW) can come to the rescue. According to Zadeh, CWW is meant as: “a consortium of tools and techniques that would make it possible to perform computations on words instead of numbers”.

One can clearly see that computation to be involved in CWW can be both related to symbolic and numeric computation. Basically, the very essence of CWW is - in my opinion - rather related to symbolic computation but employs numerical computation within. Namely, CWW is mainly concerned with reasoning schemes augmented with some account of modalities like:

- usuality - how frequently something occurs,
- probability, possibility or certainty - the likelihood of something happening,
- obligation or necessity - how necessary it is for something to be done or to proceed in a certain way,
- ability - the ability of someone or something to do something,
- inclination - the inclination or willingness of someone to do something, though CWW is clearly not able to deal with all of them in an effective and efficient way.

However, for CWW to be a full-fledged set of tools and techniques it should incorporate those making it possible to:

- use elements of CWW to extend traditional numeric computations (models), notably in mathematical modeling and decision making, to deal with words,
- develop a theory of CWW (complexity, theory of algorithms, error analysis, ...).

Notice that the above mentioned problems of broadly perceived (numerical!) mathematical modeling are clearly dominant in science. Unfortunately, the above capabilities of CWW are still far away and this is, in my opinion, a real challenge: to extend CWW to enter predominantly numerical mathematical modeling.

It is always good to support arguments by some simple and well understood examples. Decision making is

a “meta-problem” that is omnipresent, and hence is one of such good examples, and will be used throughout this note.

While dealing with decision making one cannot neglect probabilities. On the one hand, uncertainty related to randomness is obvious in virtually all decision making situations. On the other hand, there is a huge variety of powerful decision making models that have been developed over decades or even centuries that are explicitly or implicitly probability based.

An interesting undertaking would be to use elements of CWW in such models. A natural approach may be to relate to the main modalities of natural language which we have already mentioned, that is: usuality - how frequently something occurs, probability, possibility or certainty - the likelihood of something happening, obligation or necessity - how necessary it is for things to be done or to be a certain way, ability - the ability of someone or something, to do something, and inclination - the inclination or willingness of someone to do something. It is easy to see that CWW can well handle probability, possibility or certainty and usuality. One can bear in mind that the usuality has to do with things, situations, phenomena, etc. which “usually” happen, and their recognition and handling coincides with the very essence of, for instance, statistics, and hence is of utmost relevance to a wide variety of areas in which tools and techniques based on statistics are employed. Notice also that the usuality is of primordial importance for such crucial elements of modern CWW (called by Zadeh in his recent book CWW [2]) as the linguistic data summaries. The ability and inclination are, in my view, at least for now somehow beyond the scope and reach of the present day CWW, and even more so what concerns many other modalities known in linguistics. This is certainly a challenge for CWW for the future.

Let us come back to decision making which is from the perspective of CWW clearly related to probability, i.e. the likelihood of something happening, if we use the linguistic modality perspective.

As I have already mentioned, the probability oriented perspective in decision making is predominant and a multitude of powerful results have been attained. To start with, decision making is principally a mental process which can only be modeled by some formal tools and techniques. One can therefore assume that a human perception of probability is crucial. However, as claimed and proved by Daniel Kahneman, the Nobel Prize winner in economics, and his close associate, the late Amos Tversky, humans are bad so-called intuitive statisticians. This clearly implies problems in the use and implementability of those models.

A natural solution may be to employ probability expressed by the human decision maker in natural language (fuzzy), and here CWW can play a decisive role, notably because of a wider and wider acceptance of the view that probabilistic and statistical tools should somehow be “softened” to be more realistic in this imperfect, human centered and dominated world.

But, this is unfortunately easier said than done in the sense that though the above rationale should give more realistic representation and processing tools, but there still remain a key problem that the traditional probability ba-

sed (formal!) models, which we would clearly want to employ, have some firm theoretical foundations exemplified by assumptions of the additive measure, transitivity, utility maximization, etc. Any violation of those strict assumptions can imply that results obtained by the models may be useless.

A solution may here be to deal with verbal expressions of, for instance, probabilities by using some behavioral type procedures the essence of which is the elicitation of the human perception of values of variables, parameters, etc., including probabilities, by employing some properly designed questionnaires. This may be described as a human centric and consistent “measurement”. The above mentioned issue is related to the problem of subjective judgment in the perspective of CWW. In general, the inclusion of judgment in formal decision making models has attracted much attention in recent years. If we look that “judgment” may be understood generally as a process that leads to the formation of an opinion after consideration and deliberation, it is clear that this is strongly human specific, and here again, CWW can play a role as it can make it possible to express human judgments in a natural and easy way through natural language expressions, in particular because of their inherently subjective character. Then, in our perspective, human judgments are to be employed in models and algorithms that would support the humans while making decisions.

What concerns reasoning schemes and operations within those models, they are very important and should be chosen properly. However, since they are involved in models to be used to solve a variety of real world problems, the intuition behind them should be clear and properly reflected. An example may here be the case of triangular norms and conorms which are widely employed. They have formidable mathematical properties, but one should bear in mind that, from the point of decision making, for instance, in the case of t-norms, the very essence of how the minimum acts is clear as it returns the lower element. The way the algebraic product operates may be clear, for instance, to people who have been involved in decision analyses under multiplicative utility function, but not to other ones. However, it is not clear intuitively at all how the Lukasiewicz, parametric, etc. triangular norms really work.

As we have mentioned some times, decision making we refer to so often because it is a “meta-problem”, is basically a mental process that is modeled by using different tools and techniques. Just one of them are formal, mathematical models, algorithms and procedures. They are of course rigorous because they employ mathematics. Moreover, one should also bear in mind that such a rigor is not the only aspect. The models and approaches presented should also follow some “scientific paradigm”, i.e. a set of practices, tools and techniques generally adopted at a certain time in the particular field. This is particularly important in case of models that come from “softer” fields of science and are of a behavioral type. Thus, the scientific rigor should be viewed from the point of view of a particular discipline the model is concerned with or is meant for. For instance, scientific rigor will be meant in

a different way in decision making models dealt with by using behavioral analyses, and in a quite different way if we adopt a purely mathematical perspective.

An important issue is related to which type of a perspective should be adopted, a usually faster “quick and dirty” or usually slower exact. There is no universal response to this question. One should bear in mind that all what we are talking about in this note is within the domain of applied science and hence aims at solving problems and that is why we should adopt such an approach that would make it possible to solve the problem in a sufficiently good way under available resources, for instance money or time. Another important problem, that is not always taken into account, is that the use of formal, rigorous models may lead to better solutions but provided that all conditions, usually strong in practical circumstances, are fulfilled, and also when enough time is available for obtaining an optimal solution. Otherwise, one can obtain very strange solutions that may be useless.

CWW has a very high application potential as we have been indicating by its remarkable ability to represent and handle all kinds of descriptions of values, relations, etc. that are - since we deal with human centric systems - best expressed by the humans in natural language.

Fuzzy logic control is a most widely known and cited application of linguistic modeling based on fuzzy logic. I would not say that this is a pure application of CWW because the knowledge representation and reasoning schemes employed therein are rather related to Zadeh's 1973 general approach to linguistic modeling than to his much more sophisticated works on CWW. On the other hand, as the late Abe Mamdani used to mention, his intention was to propose a linguistic model of a human operator, and this perspective is clearly closer to what I had mentioned in this note, and is also presumably closer to the very essence of CWW.

To summarize, I am sure that CWW will flourish in the future and will find more and more applications in many diverse fields. However, in my opinion, to become a “global player” in broadly perceived natural language technology, CWW should find ways to be better integrated with computational linguistics, natural language processing/generation/understanding (NLP/NLG/NLU), etc. in the spirit of Kacprzyk and Zadrozny [1]. It is true that the agenda and apparatus of CWW is somewhat different, but we should spare no effort to attain some synergistic combination and cross fertilization of both the fields.

References

- [1] Kacprzyk, J. and Zadrozny, S. (2010). Computing with words is an implementable paradigm: fuzzy queries, linguistic data summaries, and natural-language generation, *IEEE Transactions on Fuzzy Systems*, 18(3), 461-472.
- [2] Zadeh, L. A. (2012). *Computing with Words: Principal Concepts and Ideas*. Springer, Heidelberg and New York.



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On Rigorous Computing with Words

Q1: What are joint and separate areas of Fuzzy Logic (FL) and Probability Theory (PT) from the measurement perspective?

The representative measurement theory [9] in mathematical psychology develops formalized measurement procedures and the numeric measures for perception-based entities that have no natural measures and “rulers”. Unfortunately, the systematic approach to constructing fuzzy Membership Functions (MF) in this way is its infancy. Are MFs measured in the same scale as the probability – or in a weaker scale such as order scale? Clarification of scales and other MF properties, derived from the processes of eliciting MFs, will clarify the relations between FL and PT for CWW, because CWW computations start from MFs.

The confusion about the differences between FL and PT also often stems from not distinguishing probability as a mathematical term and probability as a natural language word. Consider Zadeh’s example: “Assume that Robert is 0.8 German and 0.2 French. To what degree do you believe that Robert is German?” Zadeh’s answer is that it is 0.8, and that 0.8 is not the probability that Robert is German.

From our viewpoint, 0.8 is not a probability when we view “probability” as a common **word** in the natural language (NL). In contrast, in the mathematical theory of probability the **term** “probability” means a special type of the measure in the measure theory. In this context, 0.8 is a value of such a measure and thus, 0.8 can be viewed as a probability. The fact that it is not obtained by the statistical measurement procedure does not prevent it from being called a mathematical probability. The same is true for the NL word “possibility”. It differs from NL word “probability”, but it does not prohibit modeling possibility by using the *math term* probability from the formal PT and this is doable [6].

The known view (Zadeh and others) is that: (1) FL deals with possibility and measures it, (2) PT deals with probability and measures it, and (3) a joint area of FL and PT is Computing with Words (CWW). In my view, both PT and FL model possibility and probability and complement each other in this modeling. In particular, FL can complement PT in building quickly a rigorous PT model [3,4,5,7]. This constructive opportunity still awaits

extensive development. It will switch the focus of debates from the current focus on which is better, PT or FL, to an emphasis on productive design of rigorous models.

FL and PT also have separate application areas. FL is good for building a quick solution with minimal data used. This choice has a price: a decreased scientific rigor of the solution and, usually, an increased uncertainty about applicability of the solution. CWW based on FL is in the trade-off between the rigor of the solution and the time needed to get it. CWW based on the PT is the result of a similar trade-off, the trade-off between probabilistic and fully deterministic solutions: we accept a PT model when we cannot build a fully deterministic model.

Q2: What is the justification to use fuzzy logic operations when membership values are obtained by using a probabilistic technique such as frequencies or random sets?

I have not seen a general rigorous justification. In specific cases such as nested sets, $\min(m(x), m(y))$ and $\max(m(x), m(y))$ are justified for AND and OR operations. All T-norms and T-conorms are **truth-functional**, that is $f(\mu(x), \mu(y)) = f(\mu(x), \mu(x))$ when $\mu(x) = \mu(y)$. If probability would be truth-functional it would be *context independence* in the form $P(x \& y) = P(x \& x)$, when $P(x) = P(y)$. If x and y do not overlap then $P(x \& y) = 0$, but we still have x with nonzero probability, $P(x) = P(x \& x) > 0$. In other words, T-norms and T-conorms are “**context-free**” operations that do not capture such dependencies between entities. There is a motivation – not justification – for using T-norms and T-conorms, and this motivation is based on the lack of data, time, and resources to build the conditional probabilities $P(x/y)$ along with the probabilities $P(x)$ and $P(y)$. In short, question Q2 is an open question that needs to be addressed.

Q3: Would you prefer a technique that provides a solution in a few minutes using a few very uncertain inputs, but with high uncertainty and low scientific rigor? Or would you prefer a technique that required months or years of data collection and model building, but will provide a more rigorous solution?

The answer depends on the importance of the task and

on the context. It is reasonable to put in more resources into solving more important tasks. The same task can have different importance at different times and in different environments. Thus, even for the same task, in different circumstances, different answers are more reasonable. The Figure 1 shows the time-rigor space that illustrates the links between the time (short, medium, long) available to solve the task and the rigor (low, medium, high, extreme) of the result that we may get in such time.

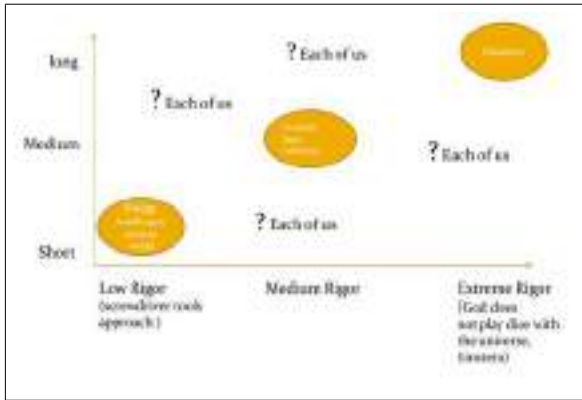


Figure 1. Solution time vs. Rigor.

Q4. Why the major applications of the fuzzy linguistic variables is in fuzzy control and not in the common natural language communications (NLCs) that had motivated CWW?

Fuzzy control works with “engineered” words that allow more flexibility to define their meaning via *free design* of Membership Functions (MFs). NLCs work with real NL words, with meaning that *already exists* in NL. We cannot call an 80 year old man young. For some age values, NL is over-complete, e.g., 40 can be at some degree young, middle-age, almost old, relatively young, and mature with the sum of these degrees being much greater than 1 – as we see, e.g., in [1]. For other ages, NL can be incomplete or complete [4,5]. Moreover, people may use different linguistic terms, e.g., some people can use for age 59 only the terms “almost old” and “old” with the sum equal to 1.

In contrast, fuzzy control uses normalized triangular membership functions and T-norms and T-conorms that can be adjusted by using inexpensive training data using Neural Networks or other Machine Learning (ML) techniques. The adjustment is more limited in NL CWW. Also, in fuzzy control the context is much more fixed in every question. We know that we control a pendulum on the Earth, not on the International Space Station. In contrast the context is not defined in the NL question: “What is the possibility that 9 people are in the midsize car?” The context can be placing people comfortably for a ride or fitting many people for an emergency or for a competition. We need to guess the context from the situation to solve this task correctly.

In fuzzy control, qualitative causal relations from physics expressed in the linguistic rules have been known in advance, e.g., we know the factors that impact motion of the inverted pendulum. For the genuine progress in CWW, we need to focus much more on experimental discovery of causal relations including operations with subjective judgments. Unfortunately, in CWW and in fuzzy

logic, such experimental work is not very active now. Consider a statement “John is tall and Peter is short”. Will we actually get from people $0.6 = \min(0.6, 0.8)$ having 0.6 and 0.8 for these statements separately? The older experimental works [2,10] with the words “metallic” and “container” have shown that min is not what humans use to combine such subjective judgments. Discovering causal relations must be done via painstaking experimental and theoretical work for each very specific challenge, as it was done in physics for centuries. Fuzzy control benefited from such prior work in physics. As history of science shows, there is no magic shortcut from such work, and FL is not the exclusion.

Q5: What is an appropriate way of obtaining fuzzy membership function (MF) values? If it will be a subjective human judgment, how to distinguish it from subjective probabilities?

For the first part of this question, we think that an appropriate way of obtaining MF values is building the processes similar to those developed in the representative measurement theory in mathematical psychology [9].

For the second part of this question, consider an *answer* that there is a *difference* in procedures to get the subjective probabilities and MF values obtained as subjective human judgments. It is difficult to defend this answer. If examples with such a claim will be generated, then we will examine them. So far I have not seen such examples.

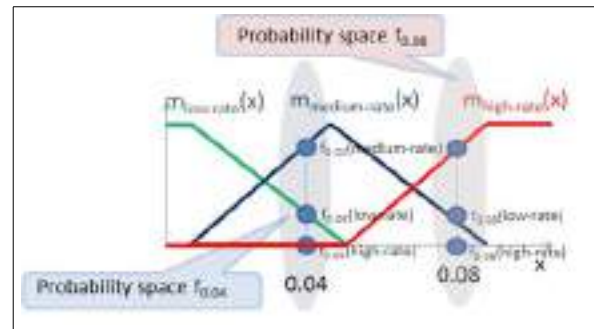


Figure 2. Fuzzy Membership Functions as cross-sections of Probability Spaces.

Now we turn to the *alternative answer* that there is *no difference* in procedures to get subjective probabilities and subjective MF values. What are consequences of accepting this answer? In this case, it is hard to claim that FL is an alternative to PT because both have the same input just named differently. What is left as a basis for the difference? There is a difference in operations in FL and PT. We have discussed it in Question 2, and had shown that the justification for the difference in operations is weak now.

Thus, we need to find some other difference. This is a difference between Membership Functions and Probability Distributions, *not between their individual values* [3,4,5,7]. This idea is illustrated in Figure 2 where a MF is *not a probability distribution, but each separate value of $\mu(x)$ is a probability* (frequency based or subjective). Each MF is viewed instead as a “*cross section*” of probability distributions. Consider a probability distribution for the interest rate 4% to be high, medium or low interest rate, $P(\text{high interest rate}/0.04) =$

0, $P(\text{medium interest rate}/0.04) = 0.7$ and $P(\text{low interest rate}/0.04) = 0.3$. Values 0.7 and 0.3 can be human subjective judgments or frequency-based probability estimates. Figure 2 shows a similar probability space for the interest 8% as well as membership functions $\mu_{\text{low-rate}}(x)$, $\mu_{\text{medium-rate}}(x)$ and $\mu_{\text{high-rate}}(x)$ that cross these probability spaces.

Such “cross-section” relations between probability distributions and MFs hold for the linguistic variables that form “exact complete context spaces” (ECCSs) [4,7].

References

- [1] Hall, L.O.; Szabo, S. and A.Kandel: On the Derivation of Memberships for Fuzzy Sets in Expert Systems, *Information Sciences*, vol. 40, 1986, pp. 39-52.
- [2] Kovalerchuk, B. and V. Talianski: Comparison of Empirical and Computed Values of Fuzzy Conjunction, *Fuzzy Sets and Systems*, vol. 46, 1992, pp. 49-53.
- [3] Kovalerchuk, B. and G. J. Klir: Linguistic Context Spaces and Modal Logic for Approximate Reasoning and Fuzzy Probability Comparison. In: *Proceedings of the Third International Symposium on Uncertainty Modeling and Analysis and NAFIPS' 95*, IEEE Press, A23 A28, 1995.
- [4] Kovalerchuk, B.: Context Spaces as Necessary Frames for Correct Approximate Reasoning, *International Journal of General Systems*, vol. 25 (1), 1996, pp. 61-80.
- [5] Kovalerchuk, B. and E. Vityaev: *Data Mining in Finance: Advances in Relational and Hybrid Methods* (chapter 7 on fuzzy systems), Boston: Kluwer, 2000.
- [6] Kovalerchuk, B.: BISC-group posts, 2010-2012, <http://mybisc.blogspot.com/>
- [7] Kovalerchuk, B.: Quest for Rigorous Combining Probabilistic and Fuzzy Logic Approaches for Computing with Words, In: Rudolf Seising, Enric Trillas, Claudio Moraga, Settimo Termini (eds.): *On Fuzziness. A Homage to Lotfi A. Zadeh*, *Studies in Fuzziness and Soft Computing* Vol. 216, Springer 2012. (In print)
- [8] Kovalerchuk, B.: Fuzzy Logic, Probability, and Measurement: Similarities and Differences in Computing with Words. 2012, *IEEE WCCI-2012 tutorial*, <http://www.cwu.edu/~borisk/pub/tutorialKovalerchuk5CWW.pdf>
- [9] Krantz, D., R. D.Luce, P. Suppes, and A.Tversky: *Foundations of Measurement*, Vol. I-3: New York: Academic Press, 1971-1990, Reprinted by Dover, 2007, New York.
- [10] Thole, U.; Zimmermann, H-J., and P. Zysno: On the Suitability of Minimum and Product Operations for the Intersection of Fuzzy Sets, *Fuzzy Sets and Systems* vol. 2, 1979, pp. 173-186.
- [11] Zadeh L.A: *Computing with Words - Principal Concepts and Ideas*. *Studies in Fuzziness and Soft Computing* 277, Springer 2012.



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Zadeh's Vision of Going from Fuzzy to Computing With Words: from the Idea's Origin to Current Successes to Remaining Challenges

Need for incorporating expert knowledge into automated systems. In order to better understand Zadeh's vision of going from fuzzy to computing with words, let us recall the reason why we need to use words in computations and why fuzzy techniques were invented in the first place. These techniques come from the need for expert knowledge. In many application areas, we rely on experts: medical doctors diagnose and cure diseases, civil engineers design reliable bridges and roads, pilots control planes, etc.

Some experts are more skilled than others. Every patient wants to be diagnosed and treated by the best doctors, every passenger wants to be flown by the best pilots, etc. The problem is that realistically, the best doctor cannot physically treat all the millions of illnesses, the best pilot cannot him- or herself fly all thousands of planes.

Since we cannot have the best medical doctor treat every patient, we should help all the other doctors use the knowledge and experience of the best ones – and maybe even allow the patients themselves to use this knowledge. Similarly, we should help all the pilots to use the knowledge and experience of the best ones. In general, we want all the experts to use the expertise of the best ones. For that, we need to incorporate the knowledge of the best experts into an automated system that others can use.

Expert knowledge is often imprecise (“fuzzy”): need to use (imprecise) words in computations. At first glance, incorporating expert knowledge into an automated system sounds straightforward: we can ask the experts how they make their decisions and incorporate the corresponding rules into the automated system. This works when experts can describe their decisions in precise terms, with rules like “if a flu patient has a fever above 101 F, the patient should take advil”. In practice, however, experts often describe their knowledge by using imprecise (“fuzzy”) words from natural language. For example, an expert driver, when describing his driving strategy, does not say “if a car is at a distance of 20 feet in front starts breaking, I hit the breaks for 0.4 second with a force of 3.6 Newtons”. Instead, a driver will say something like “If a fast car in front is close and starts breaking, I hit the breaks hard”. Similarly, a medical doctor does not express

his decision on when to perform a certain type of surgery on a tumor by specifying the tumor's exact size. Instead, the doctor uses imprecise rules with conditions like “If the tumor is small.

First Zadeh's idea: fuzzy techniques as a way to deal with imprecise (“fuzzy”) words. Fuzzy logic [4] is a technique for transforming imprecise expert rules into precise decision, precise control, etc. The main idea behind fuzzy logic is as follows: since we are not sure whether a given value x is, e.g., small, we assign a *degree* of smallness to different values x .

How can we represent these degrees inside a computer? In the computer, everything is represented as 0s and 1s. For example, “true” is usually represented as 1 and “false” as 0. We want degrees *intermediate* between 0 and 1, so it is natural to use numbers from the interval $[0, 1]$.

How to elicit fuzzy degrees. Which numbers from the interval $[0, 1]$ should we choose? There are many reasonable ways to elicit these numbers: We can poll experts and take the fraction of those believes x to be the small as the desired degree. We can ask an expert to mark his/her degree of degree on a Likert scale, e.g., from 0 to 5, and then, if the expert marks 3, take $3/5$ as the desired degree, etc.

The idea becomes more complex: need to combine fuzzy degrees. At first glance, the idea of fuzzy techniques is very simple and straightforward. However, it gets more complex if we take into account that in many practical situations, in order to make an appropriate decision, we need to find the degree of truth in a complex statement like “a car in front is close *and* going fast”. Ideally, to get such degrees, we should ask the expert about all possible combinations of distance and speed. However, there are too many possible combinations, so it is not realistically possible to ask the expert about all of them.

As a result, we need to *estimate* the degrees $d(A \& B)$ of complex statements like $A \& B$ by using only the known degrees of truth $d(A)$ and $d(B)$ of the component statements A and B . In other words, we need an algorithm $f_{\&}$ that transforms the degrees $d(A)$ and $d(B)$ into an estimate $f_{\&}(d(A), d(B))$ for $d(A \& B)$. Which algorithms $f_{\&}$ should we choose? Since $A \& B \equiv B \& A$

and $A \& (B \& C) \equiv (A \& B) \& C$, it is reasonable to select algorithms for which the resulting estimates coincide, i.e., for which $f_{\&}(a, b) = f_{\&}(b, a)$ and $f_{\&}(a, f_{\&}(b, c)) = f_{\&}(f_{\&}(a, b), c)$. Algorithms that satisfy these properties (and several other reasonable properties) are known as *t-norms*. Similar properties of an “or”-operation lead to the notion of a *t-conorm*, etc.

Comment. It is important to remember that a t-norm only provides an *estimate* for $d(A \& B)$. In reality, the degree $d(A \& B)$ depends not only on $d(A)$ and $d(B)$, but also on the relation between A and B . For example, if A and B coincide, then $d(A \& B) = d(A)$, while if A and B differ, then our degree of belief that both A and B are true is usually smaller than $d(A)$.

Which t-norm and t-conorm should we select: an additional complexity. There exist many different t-norms and t-conorms. Different t-norms and t-conorms lead, in general, to different recommendations. Which of these should we choose? At present, t-norms are selected *empirically* (if selected at all :-), so that for many complex statements, the elicited degree $d(A \& B)$ is, on average, the closest to the estimate $f_{\&}(d(A), d(B))$.

This empirical selection was first implemented for the MYCIN medical expert system [1]. The authors of the corresponding empirical study hoped that the resulting t-norm is a general description of human reasoning. Alas, when they applied their idea to geophysics, it turned out that the medically best t-norm (MYCIN) is not appropriate for geophysics at all. After the fact, it makes sense: e.g., in search for oil, it makes sense to start drilling a well once there is a reasonable expectation that this well will be productive – and it is OK that a large portion of these wells do not produce, as long as on average, we are successful. In contrast, in medicine, we do not want to perform a serious surgery on a patient unless we are absolutely sure about the diagnosis. In short, in medicine, experts use very conservative estimates, while in geophysics, they use more optimistic ones.

Yet more complexity emerges when we move from traditional fuzzy logic to more adequate implementations of computing with words. As we have just mentioned, the result of applying fuzzy techniques changes if we select a different t-norm, i.e., a different way to combine fuzzy degrees. Even with the same t-norm, the result depends on the exact values of these degrees. This dependence needs to be taken into account since, in general, for the same statement, different experts produce slightly different degrees.

Traditional fuzzy logic uses one of these degrees – or, e.g., their average. But even if we select an expert, we still have an uncertainty because usually, an expert is not sure about his or her degree of belief in a statement. Indeed, an expert may comfortably select 4 (rather than 3 or 5) on a 0 to 5 scale, so we estimate her degree of belief as $4/5 = 0.8$ (and not $3/5 = 0.6$ or $5/5 = 1.0$). However, by using this scale, we only get 6 possible degrees of belief: 0, 0.2, ..., 1.0. If we want a more accurate description of the expert's degree of belief, we need to use a larger scale, e.g., 0 to 100. However, an expert usually cannot meaningfully distinguish between 81 and 82 on this scale.

A more adequate representation of expert uncertainty is that instead of a single degree value, we use the *range*

of possible values of degree; see, e.g., [2]. For example, if an expert is comfortable with values from 80 to 85, we use the whole interval $[0.8, 0.85]$ as the description of the expert's degree of belief. An expert may also feel more comfortable with some of these possible values and less with others. To describe this, we can assign, to each value d from the corresponding interval $[d, \bar{d}]$, a degree $\mu(d)$ to which this expert is comfortable with this value d . In this *type-2* approach, for each x , the degree is not a number and not an interval, but a fuzzy set; see, e.g., [2].

Zadeh's vision of computing with words: challenge. We see that the original simple idea of Lotfi Zadeh has led to very complex implementations, with complex math, and many remaining open problems. Every time we try to solve one of these problems, we make it even more complex. Maybe it is time to rethink the whole approach? We definitely need to use words, and it is reasonable to use words in the conclusions, e.g., to conclude that the patient most probably has a flu. In other words, we need to transform words into words [3]. How this is done now: (1) we start with words from natural language; (2) we transform them into numbers (intervals, etc.); (3) we process these numbers; and (4) we transform the resulting number into a natural language word describing the conclusion.

Why we use numbers? Only because we know how to process numbers. Zadeh's vision – that he expressed many times in his talks – is to eventually cut the middleman: (1) start with words, (2) process words and (3) produce the words as a result.

In other words, his vision is to compute with words instead of computing with numbers. Of course, inside the computers we will still be processing numbers – because this is how current computers work – but all the intermediate results should be in words, so that not only the final result will be completely understandable to a human expert, but also the chain of reasoning that led to this result.

Ideally, we should operate directly with words. For example, we should be able to add small and medium and get – what? This is the gist of numerous Zadeh's examples like *Most Swedes are tall. Johannes is a Swede. What is the probability that Johannes is very tall?* **The main challenge is that we are still far from Zadeh's vision!**

References

- [1] B. G. Buchanan and E. H. Shortliffe, *Rule Based Expert Systems: The MYCIN Experiments of the Stanford Heuristic Programming Project*, Addison-Wesley, Reading, MA, 1984.
- [2] J. M. Mendel and D. Wu, *Perceptual Computing: Aiding People in Making Subjective Judgments*, John Wiley and IEEE Press, 2010.
- [3] L. A. Zadeh, “From computing with numbers to computing with words: from manipulation of measurements to manipulation of perceptions”, *IEEE Transactions on Circuits and Systems I*, 1999, Vol. 45, No. 1, pp. 105–119; reprinted in *Int. J. Appl. Math. Comput. Sci.*, 2002, Vol. 12, No. 3, pp. 307–324.
- [4] L. A. Zadeh, “Fuzzy sets”, *Information and Control*, 1965, Vol. 8, pp. 338–353.



Jerry M. Mendel

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I want to thank the organizers of this issue and the panel session that was held at FUZZ-IEEE 2012 for inviting me to provide my viewpoints on some very important questions relating to computing with words (CWW). This is an area where my students and I, motivated by Lotfi Zadeh's pioneering 1996 article [8] that equated CWW and fuzzy logic, have been working for almost 15 years (Mendel, 1999), so I obviously have some viewpoints about CWW. In the rest of this short article I will address some of the (many) questions that were posed to the panelists. Before I do this, let me state that there can be many different approaches to CWW and that my comments below are predicated on my (and my student's) own approaches to CWW.

1. *How would you identify/describe individual and joint areas for fuzzy logic and probability from the point of view of measurements?*

We believe that measurements are essential to successful applications of CWW, just as measurements are the essential bases for all scientific endeavors. We like to say (e.g., [4]) that *words mean different things to different people* and so uncertainties about words must be captured by collecting data (measurements) from a representative group of subjects (potential end-users of the CWW product). As is explained in more detail below, we treat these measurements as random, and so probability and statistics are very heavily used by us to first preprocess the measurements, to map the data uncertainties into uncertainty measures for a fuzzy set (FS) model of a word, and to establish if that model should be a left or right shoulder or an interior membership function (MF).

As is well known, statistics connects data/measurements to probability and probability is used to evaluate statistics. Analogously, fuzzistics (a term we coined some years ago [3]) connects data/measurements and their statistics to FSs, and FSs are used to explain fuzzistics [e.g., the centroid of the footprint of uncertainty (FOU) of an interval type-2 fuzzy set (IT2 FS) model of a word provides a measure of the uncertainty of the word]. So, blending fuzzy logic and probability/statistics through the use of measurements is fundamental to us for CWW.

2. *How do you create FS word models from data? What is*

an appropriate way to obtain fuzzy MF values, or in other words to measure MFs?

A FS model for a word should capture both the intra-uncertainty and the inter-uncertainty of that word. *Intra-uncertainty* is the uncertainty that an individual has about the word, whereas *inter-uncertainty* is the uncertainty that exists about the word across a group of individuals. We do not believe that both kinds of uncertainties can be modeled by type-1 FSs, which is why we model words using IT2 FSs; however, we refer to an IT2 FS word model only as a *first-order uncertainty model*, whereas if we knew how to model a word using a general T2 FS, we would call that model a *second-order uncertainty model*. How to do the latter is an important open area for research, and we believe that this will require additional/new kinds of measurements about a word than are presently collected.

Methods are needed for collecting data from a group of subjects or even from an individual that *do not introduce methodological uncertainties* into the data collection procedure. Most people do not know what a fuzzy set is (the readers of this article are of course the exception to this), and so a method that asks an individual to provide a MF for a word has methodological uncertainty that becomes co-mingled with the word uncertainty, and the two kinds of uncertainty cannot be separated. Consequently, *we do not measure MFs*.

Instead, we ask people very simple questions that have nothing to do with a MF, e.g. *On a scale of 0-10 where would you locate the end-points of an interval that you associate with this particular word?* Of course, if the variable has an actual physical scale that is associated with it, it is used. We have administered many data collection surveys that use such simple questions and have found that everyone seems to be able to answer them easily.

Our *Interval Approach* (IA) [1] is a multi-step and systematic procedure for mapping a set of data intervals for a word into an IT2 FS. This is done separately for each word that is in the vocabulary of a CWW problem. Because the IA has been improved upon, we call our improved method the *Enhanced Interval Approach* (EIA) [7]. It uses lots of probability and statistics. Not only does it capture

the essence of the above maxim that *words mean different things to different people* (e.g., each person provides a different interval for the word), but it also captures the essence of a related maxim that *words must mean similar things to different people* or else they are not able to communicate in an understandable way with one another (so our surviving data intervals need to *overlap*).

Whether a word should be modeled as a shoulder FOU or an interior FOU is not decided by us ahead of time. Instead, the data decide this within the EIA, i.e. the *data speaks*. This is done by means of a classification procedure that involves measures of the inter-uncertainty and intra-uncertainty of a word.

Note that going from data to a FS word model is an *inverse problem* that is analogous to going from random data to a probability model for that data. Each word FOU can be interpreted as a random FS generator (forward problem), although to-date they have not been used for that purpose. More specifically, in the inverse problem one begins with a collection of data intervals for each word, and, using the EIA, these intervals are mapped into an FOU. The way in which this is done is (e.g., for an interior FOU) is that each surviving data interval (established by statistical tests) is assumed to be uniformly distributed and is mapped into a triangle T1 FS. All of these T1 FSs are then bounded both from above and below to create the FOU. This FOU can then be thought of as covered by random triangles, so that when the FOU is used for the forward problem a random triangle is chosen, after which that random triangle can be mapped back into a uniformly distributed interval. This mapping from the data intervals to FOU and vice-versa is reversible by virtue of the EIA.

3. *How does one select and justify the reasoning rules and operations that are used in CWW?*

This is a very tough question because to me the word “justify” denotes “validate.” We very badly need a collection of benchmark CWW problems with their validated solutions. A new solution to such a problem could then be base-lined against the available validated solution. Reasoning rules and operations could then be tried and studied with respect to this collection of benchmark problems.

Presently, the only way to validate the solution to a CWW problem is by means of a Turing test. Space does not permit me to elaborate upon this (see [4]).

We believe that similarity will play a very important role in all of this. If, e.g. your solution is linguistically similar at an acceptable value greater than 50% (what this value is has to be agreed upon) to the baseline solution, then it should be accepted as a correct solution. Humans do not always communicate with each other using exactly the same words, and yet agreements and understandings are reached when there is enough similarity between the different words.

One thing that is usually not pointed out for a CWW problem is that its linguistic answer depends on the size of the vocabulary that is chosen for each variable. If, for example, I choose to describe pressure using only three terms-low, moderate and high-then the output of a CWW problem for pressure may sound linguistically quite different from the output that is based on a five-word vocabulary for pressure. However, when the fuzzy sets for

the two vocabularies are compared in terms of similarity, some of the terms from the five-word vocabulary will be sufficiently similar to those in the three-word vocabulary so that they can be interchanged with one another.

4. *What is the justification to use the fuzzy logic operations when membership values are obtained by using a probabilistic technique?*

This is a great question. I will answer it in the context of the way in which we collect our word data and the fact that we treat each of the data intervals as a uniformly distributed random variable. *Our IT2 FS word models are random!* This cannot be ignored. Our FOUs are complicated nonlinear transformations of uniformly distributed random variables. One therefore needs to study the stochastic convergence of word fuzzy set models, e.g. mean-square convergence. We have recently done this using statistics (we don’t know how to do this theoretically), and have demonstrated mean-square convergence of our FOU word models.

Recall that mean-square convergence implies convergence in probability, and *functions of random variables that are known to converge in probability also converge in probability* (this is called consistency carries over) [6]. A solution to a CWW problem can be interpreted (at a high level) as a very nonlinear transformation of random FOU. Because we know that our word FOUs converge in probability, we can now conclude that the solution to a CWW problem that uses those word models also (at the very least) converges in probability. You may say “So What?” To which I reply: if we expect our random word models to be taken seriously by another community that is steeped in probability they will be quite pleased to learn about this. You may also ask “What exactly are the solutions converging to?” This is a tougher question to answer and is deserving of much research.

5. *Would you prefer a technique that provides a solution in a few minutes using very few uncertain inputs, but with high uncertainty and low scientific rigor, or a technique that requires months or years of data collection and model building, but will provide a more rigorous solution?*

Another excellent question! I feel that CWW is in its infancy and so we should not rule out any kind of solution. Just as bootstrapping may let one get better results (e.g., averages, confidence intervals, etc.) by reusing a small sample of independent data, new ways are needed to generate many data intervals from a small amount of data that are collected from either one individual or a small group of subjects. Dongrui Wu and I have developed such a procedure to do this and will be reporting on it very soon [5]. I also believe that the Internet can be used to collect interval word data very quickly (we are also doing this), so it is no longer a matter of months and years, but instead is only a matter of days or weeks. By the way, software that implements the EIA is on my website sipi.usc.edu/~mendel/ (look under Research/software).

One final thought: A solution to a CWW problem is not necessarily one solution that fits all end users. A solution must be developed for a specific group of end users, and if that group changes or if we want the solution to be used by different groups then different solutions will need to be developed. Usually, what this means is that

word models used to solve a CWW problem need to be for a specific group of end users. So, it may be necessary to have one set of word models for men and another for women, or one set for Americans and another for British, etc.

References

- [1] F. Liu and J. M. Mendel, Encoding words into interval type-2 fuzzy sets using an interval approach, *IEEE Trans. on Fuzzy Systems*, vol. 16, pp. 1503-1521, Dec. 2008.
- [2] J. M. Mendel, Computing With Words, When Words Can Mean Different Things to Different People, in *Proc. of Third International ICSC Symposium on Fuzzy Logic and Applications*, Rochester Univ., Rochester, NY, June 1999.
- [3] J. M. Mendel, Computing with words and its relationships with fuzzistics, *Information Sciences*, vol. 177, pp. 988-1006, 2007.
- [4] J. M. Mendel, Computing with words: Zadeh, Turing, Popper and Occam, *IEEE Computational Intelligence Magazine*, vol. 2, pp. 10-17, November 2007.
- [5] J. M. Mendel and D. Wu, Determining word FOU's using one or only a few subjects, under preparation, 2012.
- [6] V. K. Rohatgi, *An Introduction to Probability Theory and Mathematical Statistics*, Wiley, New York, 1976.
- [7] D. Wu, J. M. Mendel and S. Coupland, Enhanced interval approach for encoding words into interval type-2 fuzzy sets and its convergence analysis, *IEEE Trans. on Fuzzy Systems*, 20 pp. 499-513, June 2012.
- [8] L. A. Zadeh, Fuzzy logic = Computing with words, *IEEE Trans. on Fuzzy Systems*, vol. 4, pp. 103-111, 1996.

REPORT

Minutes of the EUSFLAT General Assembly 2012

Catania, July 11, 2012

The assembly starts at 18:30 as scheduled. In the absence of the EUSFLAT Secretary **Martin Stepnicka**, the EUSFLAT Vice President **Gabriella Pasi** will act as Secretary during this Assembly.

Agenda

1. EUSFLAT Board report
2. Treasury report *
3. Proposal of Statute modification ***
4. Proposal of Luis Martinez to join EUSFLAT Board *
5. EUSFLAT 2013 conference
6. Acknowledgement EUSFLAT honorary member: Ulrich Bodenhofer
7. Acknowledgement EUSFLAT Scientific Excellence Award: Didier Dubois
8. Other matters

* Requires a decision

*** Requires approval of 2/3 attendants

1 - EUSFLAT Board report.

President:	Javier MONTERO, Spain
Vice President:	Gabriella PASI, Italy
Secretary:	Martin STEPNIČKA, Czech Republic
Treasurer:	Eduardo BARRENECHEA, Spain
Recruiting:	Valentina E. BALAS, Romania
EUSFLAT Magazine:	Humberto BUSTINCE, Spain
Web Coordination:	Jorge CASILLAS, Spain
BISC & IFSA News:	Asli CELIKYILMAZ, USA
Calls & Forum:	Oscar CORDÓN, Spain
Grants:	Bernard DE BAETS, Belgium
Conference Liaison:	Marcin DETYNIECKI, France
Working Groups:	Eyke HÜLLERMEIER, Germany
Outreach activities:	Radko MESIAR, Slovak Republic
Conference Endorsement:	Dragan RADOJEVIK, Serbia
Special IJCIS Issues:	Da RUAN, Belgium (†July 31, 2011)
Awards:	Eulalia SZMIDT, Poland

The President of EUSFLAT starts his report with some words in the memory of the Board member **Da Ruan**, who unexpectedly passed away on July 31, 2011. Born in Shanghai, September 10, 1960, **Da Ruan** got his Ph.D. at the University of Ghent, Belgium, 1990, being **Etienne Kerre** his Ph.D. advisor. He had been working at SCK-CEN, Belgium, since 1991, launching in 1994 the FLINS conference series, and the ISKE conference series

in 2006. **Da Ruan** was the founder of the International Journal of Computational Intelligence Systems, currently the official journal of EUSFLAT. He was the editor of 36 books and the author of more than 270 papers in journals and conferences. Leader of many fuzzy logic projects within nuclear science, decision systems and risk analysis, **Da Ruan** was a hard worker, a helpful and inspiring colleague, a good friend and an honest and warm-hearted person. His friends at EUSFLAT miss him. A book on **Da Ruan's** memory has been edited by **Jie Lu** and **Etienne Kerre**, just published by Springer ("A tribute to Prof. Dr. **Da Ruan**").

The President of EUSFLAT reminds some information from IFSA:

- IFSA PRESIDENT (2011-2013): Oscar Castillo (Mexico).
- ELECTED PRESIDENT (2013-2015): Christer Carlsson (Finland).
- IFSA 2013 (Edmonton, Canada, June 24-28, 2013).
- IFSA 2015 (Oviedo, Spain, dates to be announced), to be organized jointly with EUSFLAT, as approved in EUSFLAT Assembly at Aix-les-Bains, 2011.
- Possibility of applying for support to IFSA (conference support, best papers awards, student grants, specific educational activities, etc.)

The President of EUSFLAT congratulates **Luis Magdalena**, Director of the European Centre for Soft Computing, Mieres, Spain, for the 2012 IEEE Computational Intelligence Society Outstanding Organization Award. This award recognizes an outstanding organization that contributed to the advancement of theory, technologies, and/or applications of computational intelligence through inventions, new technology, innovative technical developments, new product implementation, or the management of innovative product design or production processes (IEEE-WCCI 2012, Brisbane, Australia, June 10-15, 2012.)

The President of EUSFLAT presents some figures about the current number of EUSFLAT members. At this moment we are more than 285 members over more than 31 countries, having stabilized membership in odd and even years with a policy that implies more presence of EUSFLAT in more related conferences, allowing interesting registration fee discounts to EUSFLAT members in a number of conferences:

- IPMU 2012 (Catania, July 9-13)
- ISCAMI 2012 (Malenovice, May 10-13)
- SUM 2012 (Marburg, Sept. 17-19)

- SMPS 2012 (Konstanz, October 4-6)
- SCBS 2012 (Natal, November 6-9)
- LFA 2012 (Compiègne, November 15-16)

In addition, EUSFLAT members could obtain additional registration fee discounts in the conferences organized by some associations we have an agreement with (HFS, NAFIPS, NSAIS, SIGEF, ACIA). The EUSFLAT Board has distributed within some conferences a EUSFLAT flyer specifically designed for this purpose as a call to join EUSFLAT. Kind personal invitations to join EUSFLAT have been also sent to EUSFLAT past members and other researchers. Please help inviting your collaborators to join EUSFLAT, since joining EUSFLAT will bring back much more advantages than the EUSFLAT fee. The recruiting campaign has been intensified with a more spread student grants policy thanks to the effort of **Bernard De Baets**.

Each EUSFLAT Working Group has been offered the edition of an Atlantis Press book (open to other authors and subject to standard peer review process and strict quality). Each WG is invited to organize special sessions at EUSFLAT 2013 conference (as done in EUSFLAT 2011):

- Aggregation Operators: **T. Calvo, A. Kolesarova, R. Mesiar**
- Fuzzy Control: **F. Matia**
- Genetic Fuzzy Systems: **B. Carse, J. Casillas**
- Learning & Data Mining: **P. Angelov, E. Hullemeier, F. Klawonn, D. Sanchez**
- Mathematical Fuzzy Logic: **P. Cintula, C. Noguera**
- Philosophical Foundations: **R. Seising, S. Termini**
- SC in Database Manag. & Inf. Retrieval: **G. De Tre, G. Pasi, S. Zadrozny**
- SC in Image Processing: **M. Nachtegaele, D. Van der Weken, E.E. Kerre**

The EUSFLAT President presents the report from **Jorge Casillas**, Web manager, who has been working on a new modern and better organized website that has been released on December 29, 2011, with the following features:

- Total integration of all resources in the same server (including Magazine and Forum)
- Powerful and friendly HTML editor via Web (it facilitates to transfer the tasks to a new webmaster)
- Complete treasury and membership management (user personal data, automatic records of PayPal payments, statistics, filters, data base management, data exporting, etc.)

- Private area for members (personal data, payment history, secure and exclusive access to IJCIS subscription, ...)
- New system to automatically check validity of membership (to check EUSFLAT membership when applying to a conference fee discount)

The main objective of these improvements is to simplify EUSFLAT management as much as possible. Thanks to **Jorge Casillas**, EUSFLAT Web manager, and special thanks to **Pablo Orantes** for his great work programming the Web.

Thanks also to Treasurer **Eduarne Barrenechea** and his team, particularly to **Carlos López Molina**, who designed the EUSFLAT awards and the EUSFLAT flyer.

Report from **Luis Martínez**, Coeditor-in-Chief of the International Journal of Computational Intelligence Systems: **Luis Martínez** presents some figures about IJCIS during the last year, showing the great effort to increase the quality of accepted papers and to reduce the special issues queue. A problem with excessive self-citations has made that the journal, being still indexed, will have no impact in 2011 and 2012, but everything should have been fixed again for 2013, so articles submitted from now will be published with the IJCIS impact back. Thanks are given to **Luis Martínez** by the President of EUSFLAT, who points out the opportunity of this problem to convince publishers to bring the scope of the journal closer to the interests of EUSFLAT. The President of EUSFLAT makes a call to submit high quality papers, and he reminds that the success of this project relies on the EUSFLAT community.

Report from **Humberto Bustince**, Editor-in-chief of Mathware and Soft Computing, The Magazine of the European Society for Fuzzy Logic and Technologies: **Humberto Bustince** makes a presentation of the first two issues of our Magazine, he explains the main sections of the Magazine, and he invites the EUSFLAT members to submit states of the art, papers, recent advances, reflections, reports of workshops, history of Fuzzy Sets by countries, Soft Computing techniques, applications, etc. The Magazine aims to reach researchers working in the field out of Europe, and it also aims at bringing connections to other related fields. Collaborations can be submitted via <http://www.eusflat.org/msc>, or directly to the Editor-in-chief at bustince@unavarra.es. The President of EUSFLAT reminds again that the success of this project relies also on the EUSFLAT community. Special thanks are given to **Humberto Bustince** and his team, particularly to **Daniel Paternain, Aránzazu Jurío, Javier Fernández, Mikel Galar**.

The President of EUSFLAT finishes this report with some short words on some ongoing projects:

- Repository for future EUSFLAT Boards, in preparation (legal issues, documents, suggestions, etc.)
- Outreaching projects, under study (Fuzzy Logic & Soft computing repository, under study, Fuzzy-Wiki)

/ Fuzzypedia / Fuzzyware, dissemination of open access packages. Links with similar projects from other associations, etc.)

- Agreements with other IFSA and national associations, under study (subject to changes in EUSFLAT statute, if approved).
- 2 years fee, hopefully for EUSFLAT 2013, in preparation.
- EUSFLAT I.D.: not necessary once membership can be checked via Web.
- Research Group membership: not recommended (rights and duties of a member have to be personal by law).
- Forum activation, in preparation (launching specific issues to be discussed).
- EUSFLAT Committer membership (approved in EUSFLAT 2011 Assembly but no application yet): 2 times regular fee (currently, 80 euro/year), decision by EUSFLAT Board based upon strict scientific criteria, can be claimed if leading a relevant funded research project.
- Activate Collaborative Entities and donations, under study.

Finally, the EUSFLAT President reports that it is being launched a correspondent network with other linked international conferences besides AGOP, ESTYLF, FSTA, ISCAMI, LFA, SUM, SMPS, WILF and of course EUSFLAT conference, in order to help for a better coordination of conference organizers and distributing information among EUSFLAT members:

- IFSA (EUSFLAT President)
- FUZZIEEE-WCCI (**Bernadette Bouchon**)
- IJCAI (**Ramón López de Mantaras**)
- IPMU (**Bernadette Bouchon**)
- AAIA (**Urszula Markowska**)
- AGOP (**Bernard De Baets**)
- CAEPIA (**Paco Herrera**)
- CEDI (**Luis Martínez**)
- ECSQARU (**Lluís Godó**)
- ESTYLF (**Lluís Godó**)
- EUROFUSE (**Bernard De Baets**)
- FCTA (**Vera Coelho**)
- FLINS (**Etienne Kerre**)
- FPM (**Rudolf Seising**)
- FSTA (**Radko Mesiar**)

- ICAISC (**Leszek Rukowski**)
- ICAFS (**Janusz Kacprzyk**)
- INCoS (**Eulalia Szmidt**)
- IS (**Eulalia Szmidt**)
- ISCAMI (**Martin Stepnicka**)
- ISDA (**Sebastian Ventura**)
- IWIFSGN (**Eulalia Szmidt**)
- LFA (**Marcin Detyniecki**)
- LINZ (**Peter Klement**)
- MANYVAL (**Brunella Gerla**)
- MDAI (**Vicenc Torra**)
- SMPS (**Rudolf Kruse**)
- SOFA (**Valentina Balas**)
- SUM (**Eyke Hullemeier**)
- WILF (**Gabriella Pasi**)
- Others under consideration.

2 - Treasured report: 2011 Budget, 2012 Estimated budget, 2013 Proposed budget.

2011 Budget meets proposal as approved last year. 2012 and 2013 budgets have been elaborated under similar criteria as in 2011 General Assembly:

- No membership fee increase, 40 euro regular membership (student, 20 euro including IJCIS access).
- Web & administrative support: 1.400 euro in 2013 (700 in 2012).
- Student Grants: 4.500 euro/year (up to 300 euro each)
- EUSFLAT 2013 Conference Awards:
 - 1 Best Student Paper: 200 euro.
 - 2 Ph.D. Thesis (2011, 2012): 2x200 euro each.

After a short discussion, 2011 Budget, estimated 2012 budget and 2013 proposed budget are approved by assent.

3 - Proposal of Statute modification.

Proposal was submitted by e-mail to all EUSFLAT members by mid June (including explanatory notes) after discussion within the EUSFLAT Board and all past EUSFLAT Presidents.

Main lacks of current EUSFLAT statute:

- Honorary membership fees as approved in the last assembly.
- Current running of EUSFLAT Working Groups.
- Too open definition of EUSFLAT Sections.
- Update legal references and obvious misprints.

New issues addressed in this proposal of EUSFLAT statute:

- Acknowledgement of a small “Executive” Board (decisions remain on EUSFLAT Board).
- Procedure to add new members to the Board (death or renounce).
- No obligation to attend General Assembly (right but not duty).
- Sections to be associated to activities (in order to allow limited agreements).
- Regular and honorary member fees.
- Particular development issues (awards and others), to be regulated by General Assembly.

Detailed description for possible discussion:

- Chapter I:
 - Art 1,4: update legal references and address, including the range of activity (Europe, not Spain).
 - Art. 2: “Fuzzy Logic and Soft Computing” instead of “Fuzzy Logic and Technologies”.
- Chapter II:
 - Art. 5: Creation of a small “Executive Board” with no decision role (mainly to prepare General Assemblies if needed): President, Vice President, Secretary and Treasurer.
 - Art. 5: Board extension of 1 year if no candidates.
 - Art. 13: Possibility of provisional Board member, no vote meanwhile not elected in Assembly (absence, renounce or death).
- Chapter III:
 - Art. 19: Introduction of current Working Groups beside Sections.
 - Art. 20: Suppression in General Assembly of acknowledged Honorary membership.
- Chapter IV:
 - Art. 21: Possibility of alternative collaborative entitlements, to be regulated in General Assembly.
 - Art. 21: Possibility of distinctions and awards, to be regulated in General Assembly.
 - Art. 23: Members should pay the fee to be considered members.
 - Art. 25: No obligation to attend General Assemblies.
 - Art. 26: Honorary members do not need to pay annual fee.

- Art. 27: Sections justified by specific activities (a delegate to be named by the EUSFLAT Board).

• Chapter VI:

- Art. 29: Technical Committees proposed by the EUSFLAT Board (as before).
- Art. 29: Working Groups justified by a common scientific topic of interest, proposed by a group of EUSFLAT members.

The proposed new statute is approved with 34 positive votes, 0 negative and 2 abstentions.

Translation into Spanish will be submitted to Spain authorities.

4 - Proposal of Luis Martinez to join de EUSFLAT Board.

The proposal to join the EUSFLAT Board is approved by consent, so **Luis Martínez** will take care of IJCIS issues within the Board.

5 - EUSFLAT 2013 conference.

Gabriella Pasi makes a presentation of the main issues related to the next EUSFLAT conference, to be held at the University of Milano-Bicocca, Italy (September 11-13, 2013). Detailed information will be accessible at the EUSFLAT 2013 web site:

<http://www.ir.disco.unimib.it/EUSFLAT2013>

The EUSFLAT President makes a call to all EUSFLAT members to actively participate.

6 - Acknowledgement EUSFLAT honorary member: Ulrich Bodenhofer.

Approved on EUSFLAT 2011 General Assembly: **Ulrich Bodenhofer**, third EUSFLAT Honorary Member with Francesc Esteva and Enric Trillas. As already approved EUSFLAT will pay their annual fees, and will be asked to supervise Best Ph.D. Thesis Awards.

It is our pleasure to welcome Dr. Ulrich Bodenhofer to the distinguished group of honorary members of our society. Dr. Bodenhofer acted as the president of EUSFLAT for two consecutive terms, from September 7, 2005 to September 13, 2007, and from September 13, 2007 to July 21, 2009. Being associated with the Johannes Kepler Universität Linz as well as the Software Competence Center Hagenberg at the time of his presidency, at the interplay between academia and industry, Dr. Bodenhofer brought a spirit of professionalism to the society, most visible to the outside world through a high-quality website. Moreover, priority was given to attracting new members by clearly communicating the benefits EUSFLAT has to offer. Last but not least, his gentle attitude marked the beginning of a period of intensifying collaboration with other societies.

Edwin Lughofer gives some words on behalf of **Ulrich Bodenhofer**.

7 - Acknowledgement EUSFLAT Scientific Excellence Award: Didier Dubois.

The committee created in the last General Assembly (all EUSFLAT Presidents plus previously awardees) has nominated **Didier Dubois** as the first EUSFLAT Scientific Excellence Award.

For his deep insight and vision which have triggered and cross-fertilized new research areas.

8 - Other matters.

The EUSFLAT President reminds again that the next EUSFLAT General Assembly will be organized at EUSFLAT 2013 Conference (jointly with WILF, Milan, Sep-

tember 11-13, 2013) where a new President and Board should be elected.

Minutes of this assembly at Catania will be communicated to all EUSFLAT members as soon as possible for revision by attendants of this assembly.

With no other issue, the Assembly finishes at 20:15.

Signed, Gabriella Pasi (EUSFLAT Vice President, acting as Secretary) Signed, Martin Stepnicka (EUSFLAT Secretary) Signed, Javier Montero (EUSFLAT President)
Date: July, 16th 2012

EUSFLAT General Assembly 2012



First row: (left) Didier Dubois receiving his nomination as the first EUSFLAT Scientific Excellence Award from Javier Montero. (Right) Edwin Lughofer giving some words on behalf of Ulrich Bodenhofer. Second row: Javier Montero, president of EUSFLAT, speaking at the General Assembly 2012, and the audience of the assembly.

CONFERENCE REPORT

IPMU 2012, 14th Information Processing and Management of Uncertainty Conference

The 14th IPMU (Information Processing and Management of Uncertainty) conference, organized by Bernadette Bouchon-Meunier (Université Pierre et Marie Curie, France), Giulianella Coletti (University of Perugia, Italy), Mario Fedrizzi (University of Trento, Italy), Salvatore Greco (University of Catania, Italy), Benedetto Matarazzo (University of Catania, Italy) and Ronald R. Yager (Iowa College, USA), has been held from 9 to 13 July 2012 at the University of Catania (Italy). It put together around 300 researchers from all the five continents.



The conference participants have enjoyed of the brilliant plenaries of the invited speakers Kalyanmoy Deb (Uncertainty Handling Using Evolutionary Multi-objective Optimization), Antonio Di Nola (Lukasiewicz logic and MV-algebras for a mathematical theory of fuzzy sets), Christophe Marsala (Fuzzy Machine Learning in Dynamical Environments), Roman Słowiński (Dominance-based Rough Set Approach to Reasoning about Vague Data) and Tomohiro Takagi (Web marketing and analogical reasoning).

Around 260 presentations were given in the following sessions: Fuzzy Machine Learning and On-line Modeling, Computing with Words and Decision Making, Fuzzy Measures and Integrals, Imprecise probabilities, Intelligent Databases and Information Systems, 40th Anniversary of the Measures of Fuzziness, Uncertainty in Profiling Systems and Applications, Sensing and Data Mining for Teaching and Learning, Theory and applications of intuitionistic fuzzy sets, Fuzzy Numbers and their Applications, Information Processing and Management of Uncertainty in Knowledge-Based Systems, Aggregation functions, Belief function theory: basics and/or applications, Game theory, Fuzzy uncertainty in economics and business, New trends in De Finetti's approach, Coopetition, Rough Sets and Complex Data Analysis: Theory and Applications, Fuzzy Implications: Theory and Applications, Basic Issues in Rough Sets, Linguistic Summarization and Description of Data, Soft Computing in Computer Vision, Probabilistic Graphical Models with Imprecision: Theory and Applications, Handling Uncertainty with Copulas, Approximate Aspects of Data Mining and Database Analytics, Philo-

sophical and Methodological Aspects of Soft Computing, Information Fusion Systems, Fuzzy Relations, Uncertainty in Privacy and Security, Uncertainty in the Spirit of Pietro Benvenuti and, obviously, Multicriteria Decision Making.

All the works have been published by Springer in a book of the series "Communications in Computer and Information Science" that will be available in September.

On Thursday afternoon the participants had the pleasure to join a tour in Syracuse during which they had the opportunity to visit many wonderful places as The Greek Theatre, The Ear of Dionysius, The Duomo Square, The Cathedral and The Maniace Castle and much other. After the excursion, the social dinner has been hold in a restaurant in Syracuse from which the conference participants could enjoy of a wonderful view.

During the social dinner have been announced the winners of three awards: the Kampé de Fèriet Award, The Genil Award and three Eusflat Grants. The Kampé de Fèriet Award has been assigned to Michio Sugeno in view of his eminent research contributions to the handling of uncertainty through fuzzy measures and fuzzy integrals, and fuzzy control using fuzzy systems. The Genil (Granada Excellence Network of Innovation Laboratories) Award, consisting in the possibility to the winner to collaborate for one month with one of the research groups that participates in GENIL has been assigned to Nuria Bertomeu Castello who presented a paper titled "Finding optimal presentation sequences for a conversational Recommender System". The three Eusflat Grants, consisting in 3 grants of 300 euro each to support students for attending the IPMU 2012 Conference, were assigned from the Eusflat Society to the following young researchers: Marco Cerami (On finitely valued Fuzzy Description Logics: The Lukasiewicz case), Mohammad GhasemiHamed (Possibilistic K-nearest neighbor regression using tolerance intervals) and Rosa Maria Rodriguez (Group Decision Making with Comparative Linguistic Terms).



The closing session on Friday ended the 14th IPMU conference looking forward to participate to the next edition which will be held in Montpellier (France) in 2014.

CONFERENCE REPORT

FLINS 2012, 10th International FLINS Conference on Uncertainty Modeling in Knowledge Engineering and Decision Making



The 10th International FLINS Conference on Uncertainty Modeling in Knowledge Engineering and Decision Making (FLINS 2012) brought together those actively involved in areas of interest to the uncertainty Modeling in Knowledge Engineering and Decision Making, to report on up-to-the-minute innovations and developments, to summarize the state-of-the-art, and to exchange ideas and advances in August 26-29, 2012, Istanbul, Turkey.

FLINS 2012 was co-organized by Istanbul Technical University and Bahcesehir University, and cosponsored by the Belgian Nuclear Research Centre (SCKoCEN) and Ghent University in Belgium, and supported by European Society for Fuzzy Logic and Technology (EUSFLAT). It offered a unique international forum to present and discuss recently developed techniques for uncertainty modeling in Knowledge Engineering and Decision Making. 212 papers from 35 countries were presented at FLINS 2012. 37% of the submissions were from Turkey; 24% and 21% of the submissions came from China and Spain, respectively. The submitted papers have been published in the World Scientific proceedings under six main titles: Part1.

Decision Making and Decision Support Systems, Part 2. Uncertainty Modeling, Part 3. Foundations of Computational Intelligence, Part 4. Statistics, Data Analysis and Data Mining, Part 5. Intelligent Information Processing, Part 6. Productivity and Reliability, and Part 7. Applied Research.

Since the founder of the FLINS Conferences, Prof. Da Ruan, suddenly passed away in July 31, 2011, the established FLINS Steering Committee decided to give two awards this year: Memorial Da Ruan award and the FLINS 2012 best paper award. Da Ruan Award was given to Prof. Irina Perfilieva from University of Ostrava. The FLINS 2012 Best Paper award was given to the paper entitled "Construction of Strong Equality Index From Implication Operators" authored by H. Bustince, J. Fernandez, J. A. Sanz, D. Paternain, M. Baczyski, G. Beliakov, R. Mesiar.

The four invited speeches were made by Prof. Etienne Kerre from Belgium, Prof. Ashok W. Deshpande from India, Prof. Jie Lu from Australia, and Prof. Burhan Turksen from Turkey. Besides, Prof. Peijun Guo from Japan gave a tutorial talk at FLINS 2012 about decision analysis under uncertainty titled: "One-shot Decision Theory-A New Scheme for Decision under Uncertainty."

Seven special issues of international journals were devoted for FLINS 2012, including International Journal of Computational Intelligence Systems (SCI-E indexed, Atlantis Press), Journal of Multiple Valued Logic and Soft Computing (SCI-E indexed, Oldcity Publishing), Knowledge-Based Systems (SCI indexed, Elsevier), International Journal of Nuclear Knowledge Management (Inderscience Publication), Journal of Enterprise Information Management (Emerald), International Journal of Information and Communication Technology (Inderscience Publication), and International Journal of Computational Vision and Robotics (Inderscience Publication).



Tribute to Prof. Dr. Da Ruan during FLINS 2012.

CONFERENCE REPORT

FedCSIS 2012, 2012 Federated Conference on Computer Science and Information Systems

The 2012 edition of the Federated Conference on Computer Science and Information Systems (FedCSIS; www.fedcsis.org) was held in Wrocław, Poland on September 8-11, 2012.



Janusz Kacprzyk during his speech.

FedCSIS events were grouped into the following conference areas of various degree of events integration; those listed below in italics (and without the superfluous indication of the year 2012) signify “abstract areas” with no direct paper submissions (i.e. paper submissions only within enclosed events).

- *AAIA'2012* - 7th International Symposium Advances in Artificial Intelligence and Applications
 - AIMA'2012 - International Workshop on Artificial Intelligence in Medical Applications
 - ASIR'2012 - 2nd International Workshop on Advances in Semantic Information Retrieval
 - RSA'2012 - International Workshop on Rough Sets Applications
 - WCO'2012 - Workshop on Computational Optimization
- WEO-DIA'2012 - 1st Workshop on Well-founded Everyday Ontologies - Design, Implementations & Applications
- *CSNS - Computer Science & Network Systems*
 - CANA'2012 - Computer Aspects of Numerical Algorithms
 - FINANS'2012 - International Symposium on Frontiers in Network Applications and Network Systems
 - MMAP'2012 - International Symposium on Multimedia Applications and Processing
 - WSN'2012 - International Conference on Wireless Sensor Networks
- *ECRM - Education, Curricula & Research Methods*
 - CSERC'2012 - 2nd Computer Science Education Research Conference
 - ISEC'2012 - Information Systems Education & Curricula Workshop
- *IT4MBS - Information Technology for Management, Business & Society*
 - ABICT'2012 - International Workshop on Advances in Business ICT
 - AITM'2012 - 10th Conference on Advanced Information Technologies for Management
 - IT4D'2012 - Information Technology for Disabilities
 - IT4L'2012 - Workshop on Information Technologies for Logistics
 - KAM'2012 - 18th Conference on Knowledge Acquisition and Management
 - TAMoCo'2012 - Techniques and Applications for Mobile Commerce
- *JAWS - Joint Agent-oriented Workshops in Synergy*
 - ABC:MF'2012 - Workshop on Agent Based Computing: from Model to Implementation
 - MAS&S'2012 - International Workshop on Multi-Agent Systems and Simulation
 - SEN-MAS'2012 - 1st International Workshop on Smart Energy Networks & Multi-Agent Systems
- *SSD&A - Software Systems Development & Applications*
 - ATSE'2012 - 3rd International Workshop Automating Test Case Design, Selection and Evaluation

- MDASD'2012 - 2nd Workshop on Model Driven Approaches in System Development
- WSS'2012 - The 4th International Symposium on Web Services



Furthermore, a tutorial entitled *Semantic Knowledge Engineering for Business Intelligence: concepts and tools* was presented by: Grzegorz J. Nalepa, Antoni Ligeza, Krzysztof Kaczor, Szymon Bobek, Weronika T. Adrian and Krzysztof Kluza from the AGH University of Technology.

The following Keynote Presentations have been delivered:

- Paweł Gepner, Intel Corporation, *Race to Exascale with Intel Architecture*
- Janusz Górski, Gdańsk University of Technology, Poland, *Using Evidence Based Arguments To Support Trust*
- Ana Luisa Nobre Fred, Technical University of Lisbon, Portugal, *Data Mining Using Clustering Ensembles*
- Thad Starner, Georgia Institute of Technology, USA, *Wearable Computing: Through the Looking Glass*

FedCSIS was organized by the Polish Information Processing Society together with the Systems Research Institute Polish Academy of Sciences, the Wrocław University of Economics and the Wrocław University of Technology, under the auspices of Prof. Barbara Kudrycka, Minister of Science and Higher Education, and Prof. Michał Kleiber, President of Polish Academy of Sciences. Technical co-sponsors of the FedCSIS 2012 conference included: (1) IEEE Region 8, (2) Computer Society Chapter, Poland, (3) Gdańsk Computer Society Chapter, Poland, (4) ACM Special Interest Group on Applied Computing, (5) Łódź ACM Charter, (6) SERSC: Science & Engineering Research Support soCiety, (7) Informatics Europe, (8) Asociación de Técnicos de Informática, (9) The Polish Association for Information Systems, (10) Polish Artificial Intelligence Society, (11) Polish Society for Business Informatics, (12) Polish Chamber of Commerce for High Technology.

Furthermore, in addition to the general FedCSIS technical collaborators, the following organizations were involved in organization of its individual events.

- The International Symposium on Advances in Artificial Intelligence and Applications was technically co-sponsored by: World Federation of Soft Computing, European Society for Fuzzy Logic and Technology, Poland Chapter of the IEEE Computational Intelligence Society, International Fuzzy Systems Association, and Polish Neural Networks Society.
- International Workshop on Rough Sets Applications was technically co-sponsored by: IDSS & GrC Section of the CS Committee, of the Polish Academy of Sciences, and the International Rough Set Society.
- Computer Science Education Research Conference was technically co-sponsored by ACM SIGCSE.
- Workshop on Agent Based Computing: from Model to Implementation IX, and the 6th International Workshop on Multi-Agent Systems and Simulation, and 1st International Workshop on Smart Energy Networks & Multi-Agent Systems, constituting the Joint Agent Workshops in Synergy (JAWS) focus area were organized in technical cooperation with the EU COST Action IC0801 "Agreement Technologies."

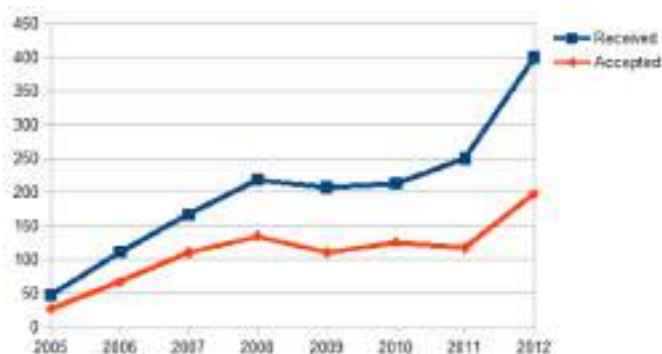
Polish Ministry of Science and Higher Education and Intel have sponsored the conference.

This year's Symposium on Advances in Artificial Intelligence and Applications (AAIA) was devoted to the recognition of work of Prof. Zdzisław Hippe. During the AAIA 2012, the Prof. Zdzisław Pawlak prize for the best paper was awarded for the seventh time. This year the winners were: Ron Adany and Tami Tamir for the paper: *Online Algorithm for Battery Utilization in Electric Vehicles*, as the Best Student Paper, and Andrzej Janusz and Dominik Ślezak for the paper: *Utilization of Attribute Clustering Methods for Scalable Computation of Reducts from High-Dimensional Data* as the Best Paper. These awards were sponsored by the Polish Information Processing Society. Furthermore, the International Fuzzy Systems Association Awards for Young Scientist were presented to: Juan Carlos Figueroa-García for the paper: *An Approximation Method for Type Reduction of an Interval Type-2 Fuzzy Set Based on A-cuts*, and to Cristiano Nattero, Massimo Paolucci, Davide Anghinolfi, Fulvio Mastrogiovanni and Giorgio Cannata for the paper: *Experimental Analysis of Different Pheromone Structures in an Ant Colony Optimization Algorithm in Robotic Skin Design*. These awards were financially sponsored by the International Fuzzy Systems Association.

English was the exclusive conference language. In 2012, FedCSIS attracted 400 papers. Out of submitted contributions, after refereeing by at least two reviewers each, 195 articles were accepted as full papers (acceptance rate of 48.75%), and 14 articles were accepted as short papers. Out of 209 texts accepted for publication, 75 articles (36%) came from Poland, while the remaining 134 (64%) from abroad (representing almost 50 countries from all continents). The conference attracted more than 290 participants.

The following figure represents the growth of the FedCSIS conference, since 2005 when it started as a Scientific

Session within the Autumn Meeting of the Polish Information Processing Society, through years 2006-10 when it was run under the name International Multiconference on Computer Science and Information Systems (IMCSIT), and 2011-12 when the current name and formula have been adopted.



Conference materials were published on USB Pen Drives (as pre-Proceedings). After the conference, papers from all FedCSIS events but CSERC, will be included in the IEEE Digital Library (ISBN 978-83-60810-48-4, IEEE Catalog Number CFP1285N-ART). The CSERC workshop is going to publish its own Proceedings in the ACM Digital Library. This way all FedCSIS contributions will be made available in two of three biggest repositories of academic publications in computer science - assuring a worldwide reach. Furthermore, Proceedings of FedCSIS in their final version (together with CSERC preProceedings) will be posted at the conference WWW site (joining Proceedings of past conferences). It should be stressed that only papers presented in the conference are going to be included in the IEEE / ACM Digital Libraries.

In a similar way as in the past, best papers accepted at FedCSIS (their modified and extended versions)

will be published in Special Issues of international journals, such as: Applied Artificial Intelligence (ISI indexed), LNCS Transactions on Rough Sets (Springer), Volume in the Springer series Studies in Computational Intelligence, LNCS Transactions on Computational Collective Intelligence, Bulletin of Institute of Automation and Robotics (Biuletyn Instytutu Automatyki i Robotyki WAT), Informatica, IJCSA: International Journal of Computer Science & Applications, Studia Informatica Universalis and in the Journal of Information, Management and Control Systems, Knowledge and Information Systems (KAIS), Springer Series: Advances in Intelligent Systems and Computing / Studies in Computational Intelligence, Logistics and Transport, ComSIS journal (ISI indexed).



Each year the acceptance rate for texts published in post-conference Special Issues of international journals is below 30%.

Submitted by the FedCSIS Conference Series Chairs,
Maria Ganzha,
Leszek Maciaszek,
Marcin Paprzycki

CONFERENCE REPORT

SUM 2012, 6th International Conference on Scalable Uncertainty Management



The International Conference on Scalable Uncertainty Management (SUM) is an annual conference that was launched in 2007 with the goal to exploit and strengthen the connection between the Artificial Intelligence and Da-

tabase communities. It aims at bringing together all those researchers interested in the management of massive amounts of uncertain, incomplete or inconsistent information. Such information originates commonly in applications where significant computational effort is needed to process data in a meaningful and semantically justifiable manner. Typical applications of that kind include databases, the Internet, and the life sciences.

The 6th conference in the SUM series was held in Marburg, Germany, September 17 - 19, 2012. It was organized by Bernhard Seeger (General Chair), Eyke Hüllermeier and Sebastian Link (PC Chairs), and Thomas Fober (Local Chair). SUM 2012 was endorsed, amongst others, by the EUSFLAT Society, which was kind enough to offer three grants for students and to help publicizing this event.

In comparison to previous years, SUM 2012 accomplished an increase in the number of submissions and accepted papers; overall, 75 papers were submitted from 24 different countries. In addition to regular papers (limited to 14 pages in Springer's LNCS format), SUM 2012 also offered the possibility to submit "short papers" (with a maximum of 6 pages). These papers were supposed to report on "cutting edge" research, which, despite not yet being fully developed, persuades through exciting ideas and promising preliminary results. Moreover, the short paper category comprises position papers expressing a significant opinion on a research topic within the scope of the conference or sketching new promising directions of research. All accepted papers were published by Springer in the *Lecture Notes on Artificial Intelligence* (LNAI) Series.

The conference attracted more than 70 participants from all continents. The program was quite dense, featuring many talks and intensive discussions: Continuing the tradition of the SUM conference, the organizers decided to stick to the single-track format; for the participants, this meant listening to more than 50 consecutive talks in three conference days. Apart from many interesting regular presentations, the conference greatly benefited from several high-level invited lectures by world-leading researchers: Minos Garofalakis (Technical University of Crete, Greece) presented his recent work on "Heisen Data: Towards Next Generation Uncertain Database Systems", Lawrence Hunter (University of Colorado, USA) gave a talk on "Knowledge-Based Analysis of Genome-Scale Data", and Joachim Buhmann (ETH Zürich, Switzerland) addressed the topic of "Content Sensitive Information: Which Bits Matter in Data?". Moreover, SUM 2012 featured an industrial talk by Ingo Mierswa from the Rapid-I Company (Dortmund, Germany), who presented the "Rapid Miner", a software tool for machine learning and data mining applications. The very first speaker, however, was

Sébastien Destercke (CNRS, Université de Technologie de Compiègne, France), whose excellent introductory talk on "Uncertainty handling and Modeling" set the stage for the rest of the conference.



The intensive scientific agenda was relaxed by a charming social program that was well received by the attendees: The welcome reception took place in a historical cave in Marburg, and the conference dinner was served in the main hall of the local castle ("Landgrafenschloss") that was built in the 11th century. Moreover, the participants had the chance to learn about the history of Marburg and its university, which is named after landgrave Philipp I., and which is the oldest university in the world that was founded as a Protestant institution in 1527. During the guided city tour, the participants could catch a glimpse of the city's 870-year history; moreover, there was a possibility to visit "St. Elisabeth Church", one of the oldest gothic churches in the German-speaking area.

More information about the conference can be found at www.sum2012.org.

Thomas Fober
Eyke Hüllermeier



CONFERENCE REPORT

II Brazilian Congress on Fuzzy Systems



In 2006 and 2008 the first steps toward the organization of a Brazilian research community around the theme: “Fuzzy” were taken. It was done through the organization of the Symposium on Applications of Fuzzy Logic (Simpósio de Aplicações de Lógica Fuzzy - SALF - in Portuguese). The idea was the establishment of a biannual meeting with a regional character. The event revealed that we were in front of an area with a great demand, as the number of participants overcame the expectations and welcomed researchers and students of universities from different states like: São Paulo, Paraná, Mato Grosso do Sul, Minas Gerais and Distrito Federal.



On September 08-11th of 2009, the Brazilian Applied Mathematical Society (SBMAC) promoted the first Minisymposium on the “Foundations and Applications of Fuzzy Logic” as a satellite event of the National Congress on Applied Mathematics, which was held in Cuiabá - MT. At that time about 2.000 CNPq Lattes curricula involving the keyword “Fuzzy” were found. With this scenario, the **Thematic Committee on Fuzzy Systems** was created in the Society, which induced the organization of an event with a national character around the theme “Fuzzy”. This event was called: **First Brazilian Congress on Fuzzy Systems** (I Congresso Brasileiro em Sistemas Fuzzy - I

CBSF; in Portuguese), substituting the III SALF which had already been planned.

The I CBSF expanded the scope of SALF, which focused mostly on applications. The word “System” assumed a broad sense, in order to capture both the investigation on Computational systems and the investigation on Logical systems that are also objects of investigation. With this scenario, the congress became the first event in Latin America about this theme and thus it was supported by the following scientific societies:

- Brazilian Society of Automatica (SBA),
- Brazilian Society of Computational Intelligence (SBIC)
- Brazilian Society on Applied and Computational Mathematics (SBMAC).
- International Fuzzy Systems Association - IFSA
- North American Fuzzy Information Processing Society (NAFIPS)



Within this context from 06th to 09th november the II CBSF was held in Natal-RN, organized by the Federal University of Rio Grande do Norte and also with the support of two more scientific societies:

- European Society for Fuzzy Logic and Technology (EUSFLAT)
- Brazilian Society of Computation (SBC)

The congress was organized in 7 plenary sessions, 3 minicourses and 21 technical sessions. The topics of the meeting were divided into two categories Theoretical and Applied aspects of Fuzzy Systems.

The event celebrated the 100 year of Alan Turing (The Father of Computing Science) and Luis Gonzaga (a very important Brazilian Composer).

The opening ceremony had the presentation of five music pieces of Luiz Gonzaga followed by the official opening and the first plenary talk given by Prof. Vladik Kreinovich.

Three minicourses were provided; namely: Introduction to Fuzzy Sets, Fuzzy Set Theory applied to Biological Phenomena and Fuzzy Pattern Recognition and Its Applications. The seven plenary talks were:

- Os Lusiadas of Computations under Uncertainty: from Probabilities to Intervals to Fuzzy to Interval-Valued Fuzzy and Beyond (**Vladik Kreinovich**)



- Constrained (Fuzzy) Intervals, (Fuzzy) Interval Spaces and (Fuzzy) Linear Equations (**Weldon Lodwick**)
- Image processing with fuzzy sets and their extensions: thresholding, edge detection, magnification and reduction (**Humberto Bustince**)
- Granular Computing (**Fernando Gomide**)
- Decidable and Undecidable Problems - The Turing Legacy (**Ruy de Queiroz**)
- Maybe not so Fuzzy (**João Marcos**)
- Variational Fuzzy Systems: Applications in Biomathematics (**Rodney Bassanezzi**).

With respect to the I CBSF the submissions and registrations increased 58% and 46% respectively (see the table below)

	I CBSF	II CBSF
Submissions	88	139
Registrations	110	160

Although most of the contributions came from the national groups, we could find some contributions from South America and some other countries.

The proceedings was published by the Brazilian Society for Applied and Computational Mathematics (SBMAC) and can be downloaded from II CBSF Proceedings. The authors of the best papers of the conference will also be invited to submit an improved version to the next issue of Mathware and Soft Computing Magazine.



Some other images can be found in <http://www.facebook.com/congressobrasileiroidesistemasfuzzy>.

The event closed with the proposal that the next CBSF will be organized together with XI International FLINS Conference on uncertainty Modeling in Knowledge Engineering and Decision Making which will be held in João Pessoa - PB (Brazil) in Aug 2014.

CONFERENCE REPORT

LFA 2012, The francophone conference on fuzzy logic and its applications

Since 1995, the francophone conference on fuzzy logic and its applications (LFA) are an opportunity for academics and industrial researchers to share their latest results and increase their knowledge about the theory of fuzzy sets - topic that has widened to include today other uncertainty theories such as the theories of imprecise probabilities, evidence, possibilities, etc.

This conference provides each year a privileged place for a fruitful discussion based on the recent work. They also allow young and experienced scientists to present innovative research and gather constructive feedback from a community experts.

After Paris, Nancy, Lyon, Rennes, Valenciennes, La Rochelle, Mons, Montpellier, Tours, Nantes, Barcelona, Toulouse, Nîmes, Lens, Annecy, Lannion and Aix-les-Bains, Compiègne was the host city of the 2012 edition of LFA. This edition of the "Rencontres Francophones sur la Logique Floue et ses Applications" presented a selection of twenty- nine articles covering pretty much all classic and emerging topics such as approximate reasoning and associated fuzzy inferences, data mining from a gradual perspective, information fusion, decision making and in particular preferences management, machine learning in the form of detection and classification, theoretical works

on integrals and measures, and application in databases . Among the topics covered this year's belief functions and possibility theory were especially present.

Moreover two invited talk enhanced the discussion. The first one presented by Ines Couso Blanco, professor at the Universidad de Oviedo in the Department of Statistics, located in Gijón, Spain. Internationally recognized for his work at the intersection of fuzzy logic and precise probabilities, titled her lecture: "Everything you always wanted to know about fuzzy random variables (but we're afraid to ask)". The second of these conferences was presented by Anne Laurent, professor at the University of Montpellier 2, and team leader of the TaToo group at the LIRMM. World-renowned expert in data mining and fuzzy systems titled her lecture "Fuzzy data mining and

patterns".

The conference was a particular success thanks to authors due to the scientific quality of their contributions, to members of the steering committee due to their sound advice, to the program committee due to the attentive selection of articles and finally to the members of the organizing committee for the practical realization of this meetings.

EUSFLAT once again supported this conference by providing one student grant.

For more information visit <https://www.hds.utc.fr/lfa2012/wp/>.

Marcin Detyniecki (Program chair)

Thierry Denoeux, Sébastien Destercke, Mylène Masson and Benjamin Quost (Program committee)



NEWS

Ph.D. Thesis defended by Mikel Galar Idoate

Department of Automatic and Computation, Universidad Pública de Navarra, Spain



Mikel Galar Idoate defended his PhD Thesis entitled “Ensembles of classifiers for multi-class classification problems: One-Vs-One, imbalanced data-sets and difficult classes” the last 18th of July. His supervisors are Edurne Barrenechea Tartas from the Universidad Pública de Navarra, Alberto Fernandez Hilario from Universidad de Jaén and Francisco Herrera Triguero from the Universidad de Granada.

The construction of the classifiers is a key issue in Machine Learning. There exist different classifier learning paradigms, which main differences are the learning procedure and the type of model inferred, that is, its interpretability and how it stores the knowledge extracted. However, and without taking into account the paradigm used to build the classifier, the combination of classifiers usually leads to systems with better accuracies. Accuracy is measured by the percentage of correctly classified examples, which were not used in the classifier learning phase. These systems combining several classifiers are referred to as ensembles or multi-classifiers. The ability of the ensembles of classifiers to increase the accuracy over the systems with single classifiers has been proved in several applications. In these systems the aggregation phase, that is, how the outputs of the base classifiers are combined in order to predict the final class is a key factor

In this dissertation, we focus on studying the usage of ensembles of classifiers in two different fields where they have shown to be beneficial, besides from another problem that arises from their use in some models.

Classification problems with multiple classes: Classification problems can be divided into two types, depending on the number of classes in the problem: binary and multi-class problems. In general, it is easier to build a classifier to distinguish only between two classes than to consider more than two classes in a problem, since the decision boundaries in the former case can be simpler. This is why binarization techniques come up, to deal with multi-class problems by dividing the original problem in more easier to solve binary classification problems, which are faced up

by independent binary classifiers. In order to classify a new instance, the outputs of all the classifiers in the ensemble are combined to decide the class used to label the instance. The usage of ensembles in multi-classification problems allows one to improve the results obtained when a single classifier is used to distinguish all the classes at the same time, due to the simplification of the initial problem. In this context, we have first studied the different aggregations for the One-vs-One and One-vs-All strategies, and we have proposed a novel methodology based on dynamic classifier selection techniques in order to improve the classification in One-vs-One scheme avoiding non-competent classifiers.

The class imbalance problem: Class imbalance problem refers to data-sets having a very different number of instances from the different classes, that is, their presence in the data-set is not balanced as expected by the classifier. This problem is usually studied in binary problems, where one of the classes is under-represented in the data-set, usually the class of interest (positive or minority class). This class is usually much more difficult to distinguish, achieving low classification rates over its examples. The usage of ensembles in combination with techniques which are usually considered to deal with the class imbalance problems (such as data pre-processing or cost-sensitive techniques) has shown its ability to improve the accuracy over data-sets suffering from this problem, enhancing the results obtained by single classifiers with the previously mentioned techniques. We have proposed a new taxonomy in order to classify these approaches and to study the most robust methods in the literature. Afterwards, we have proposed a novel ensemble method, which is able to overcome the previous ones combining the evolutionary undersampling method and a diversity promotion mechanism.

The problem of difficult classes: The difficult classes problem is more general than the class imbalance problem. A class is said to be difficult whenever the classification accuracy produced by the classifiers over it is much lower than that of the other classes, which can lead to ignore it. This problem has not received much attention in the specialized literature despite its importance. There exist several real-world problems where an equally recognition rate over all classes is much more important than being accurate over some of them. For example, in the classification of traffic signs, authors identification, cancer diagnosis, pattern detection in videos or texture classification. We have studied this problem in One-vs-One strategy, both theoretically and empirically, and we have presented a new aggregation strategy, which accounts for the difficult classes problem, trying to balance the classification rate over all classes without needing to alter the underlying base classifiers.

NEWS

Ph.D. Thesis defended by Carlos Lopez-Molina

Department of Automatic and Computation, Universidad Pública de Navarra, Spain



Carlos Lopez-Molina defended his PhD Thesis, entitled “The breakdown structure of edge detection- Analysis of individual phases and revisit of the overall structure”. This thesis was advised by Prof. Bustince, from the Universidad Pública de Navarra, and Prof. De Baets, from the Ghent University.

This thesis tackles edge detection, one of the most researched tasks of computer vision. Initially, the thesis departs from the idea that any information system must be grounded on

- (a) a clear breakdown structure representing each part of the process and
- (b) clear and objective performance metrics.

After performing deep reviews on both aspects, the author focuses at each of the phases the breakdown structure is composed of, proposing improvements to the most relevant (and employed) edge detection methods. The author analyzes the characteristics and problems at each of the phases of breakdown structure, suggesting solutions coming from Soft Computing (and Fuzzy Logic) to overcome them. These new proposals are always tested in terms of performance with the state-of-art techniques in the field,

most of them coming from fields of knowledge other than Soft Computing. Among the techniques proposed by the author we find information aggregation techniques, fuzzy representation of the edges (using both traditional and interval-valued fuzzy sets) or bio-inspired algorithms for computer vision.

The motivation for this thesis was to analyze in depth the opportunities for the application of new techniques in an already established field of knowledge, such as image processing. As Soft Computing (as well as Fuzzy Logic) reaches its maturity, its proposals should be put to the text with the state-of-art in highly-competitive fields of research. In order the Soft Computing to be well-considered as a realistic and valid tool for solving high-complexity problems, it is necessary to proof it competitive in general scenarios, where the competence comes from other fields of knowledge. Works such as the present one, in which soft-computing techniques are confronted with a wide variety of techniques, are necessary, since they bridge the gap between our community and other researchers using traditional techniques. Hence, by doing honest, exhaustive comparisons, as those in this thesis, will our community gain the interest and respect of the researchers in other areas, and hence will we open the door to stronger and more fruitful collaborations.

Different contents from this thesis have been published in journals akin to our community, such as IEEE Transactions on Fuzzy Systems or the International Journal of Computational Intelligence Systems, but also in more generalistic journals such as Pattern Recognition or Computer Vision and Image Understanding. Future lines are now opened for researching in specific applications in bio-engineering related tasks, but also for stablishing deeper methodological connections between classical signal processing techniques and soft computing-based ones.

NEWS

Ph.D. Thesis defended by Ramón González del Campo Rodríguez Barbero

Department of Software Engineering and Artificial Intelligence, Complutense University of Madrid, Spain



Ramón González del Campo Rodríguez Barbero defended his PhD Thesis entitled, in spanish, “Generalizaciones de las medidas de especificidad y de la T-transitividad para conjuntos difusos intervalo valorados” the last 3rd of October. His supervisors is Luis Garmendia Salvador, at Complutense University of Madrid, Computer Sciences Faculty, department of Software Engineering and Artificial Intelligence, Spain.

NEWS

Ph.D. Thesis defended by Jaume Monreal Garcies

Department of Mathematics and Computer Science, Universitat de les Illes Balears, Spain



Jaume Monreal Garcies defended his PhD Thesis entitled “Generació additiva de funcions d’agregació conjuntives i disjuntives discretes” the last 14th of September. His supervisor is Gaspar Mayor Forteza from the Universitat de les Illes Balears.

This work defines the concept of additive generator of discrete t-norms and discrete t-conorms on $L = \{0, 1, \dots, n\}$ by using one-place functions $f : L \rightarrow [0, +\infty)$, their pseudoinverses, which is also defined, and addition. General results on additive generation of disjunctions (t-conorms are the associative disjunctions), characterizations of basic t-conorms generators, as well as the relation-

ship between the additive generator of a disjunction and its dual conjunction, are also established. Multiplicative generation is also taken into account.

An algorithm based on Gamma algorithm of convexity theory is set out to decide when a disjunction can be additively generated. This paper also contains examples of t-conorms, disjunctions and commutative copulas –all of them discrete–; some of them can be additively generated, but others cannot.

The relationship between additive generation with ordinal sum is studied, as well as with nesting procedure, a more general method to construct disjunctions than the first one. The S_k family of t-conorms with a similar structure of Łukasiewicz t-conorms is shown, both are obtained when considering generators with range closed by addition. The concepts of concave and convex generator, respectively determining Archimedean and smooth disjunctions are also introduced. Associative convex generators are characterized. Additive generation of smooth and bi-valued disjunctions and t-conorms on L^* are also studied, a characterization of the associative ones is obtained and an algorithm to build an additive generator is determined (all of them can be additively generated). A bi-valued family of t-conorms on L^* that can be additively generated are also presented.

This study also insists on the applicability of additive generation when referring to the condition of T -transitivity for finite-valued indistinguishability relations. Finally, relationships between additive generation of a t-conorm S and the properties of its corresponding S -implication are also studied. According to order and generalized modus-ponens properties, mixt additive generators are defined. Several of these associative examples are presented at the end of this paper, built from standard additive generators of Maximum and Drastic t-conorms, and some Łukasiewicz t-conorms generators.

NEWS

Ph.D. Thesis defended by Alberto Álvarez Álvarez

European Centre for Soft Computing and Universidad de Oviedo, Spain

Alberto Álvarez Álvarez defended his PhD Thesis entitled “Linguistic Modeling of Complex Phenomena” the last 12th of November. His supervisor is Gracian Trivino Barros from the European Centre for Soft Computing.

Nowadays, it is possible to acquire and store vast volumes of data about different complex phenomena in many crucial areas. In order to be useful, this information

must be explained in an understandable way, including facts that may be derived from the data and the background knowledge available about the phenomena under study. This can only be achieved by using natural language, especially if the final information is going to be used by non-experts. Therefore, this information must be explained in an understandable way by means of lin-

guistic models. The formulation of linguistic models can be seen as a non-trivial task, and many times, linguistic modeling contributes to a better understanding of phenomena, providing a novel and previously unseen view of them. In this thesis, we follow Zadeh's computing with words and perceptions paradigm in order to extend the Computational Theory of Perceptions. The idea consists of extending Fuzzy Logic to create system models based on the way that humans make descriptions using natural language. The aim is to use complex structures of natural language to make robust imprecise models of complex phenomena, whose main advantages are the incorporation of creative, abstract and adaptive human capabilities, while minimizing undesirable aspects such as unpredictability, inconsistency, subjectivity and temporal instability. Our aim is to make use of a symbiotic relationship between the designer and the computer, in such a way that designer's motivation and creativity are strengthened by the computer's greater memory storage and higher computational performance.

We have extended the concept of Fuzzy Finite State Machine to deal with the problem of modeling each specific complex phenomenon on the basis of a linguistic, human-guided design. Moreover, since the definition of details of the Fuzzy Finite State Machine in each particular case is a complex task for experts, we have proposed a methodology which consists of a machine learning method to define the model parameters. This methodology is based

on the hybridization of Fuzzy Finite State Machines and Genetic Algorithms leading to Genetic Fuzzy Finite State Machines. The Genetic Fuzzy Finite State Machine automatically learns the fuzzy rules and membership functions of the model, while an expert defines the possible states and allowed transitions between states.

Then, we have developed the Granular Linguistic Model of a Phenomenon paradigm, which is the model needed to interpret the input data in a hierarchical fashion. The Granular Linguistic Model of a Phenomenon is able to merge different sources of knowledge in combination with the expressiveness of the Fuzzy Finite State Machine modeling paradigm. Once the Fuzzy Finite State Machine is able to model each complex phenomenon, the Granular Linguistic Model of a Phenomenon is able to produce linguistic descriptions about it and its evolution in time.

Finally, we have validated the proposed methodology with several real world applications. We have been able to model the human gait and the human activity using our linguistic modeling approach using expert and induced knowledge. Then, we have developed a system capable of modeling the gait quality and producing linguistic descriptions about it. We have also showed the generality of our proposal, showing how it works in a completely different field, namely, intelligent transportation systems, where we have been able to model and generate linguistic descriptions of the traffic evolution in roads.

NEWS

Professor Hideo Tanaka passed away



Professor Hideo Tanaka, one of the fuzzy pioneers, passed away on May 16, 2012 in Osaka, Japan, at the age of 74.

Hideo Tanaka received the BS degree in Instrument Engineering from Kobe University in 1962 and the MS and Ph.D. Degrees in Electrical Engineering from Osaka City University in 1996 and 1969, respectively. He had been with Department of Industrial Engineering at Osaka Prefecture University from July 1969 to March 2000.

From 1972 to 1973 he was a Visiting Research Associate of the Computer Science Division at University California, Berkeley, USA. From 1975 to 1977 he was an Alexander Von Humboldt Foundation Fellow at Technical University of Aachen, Germany, and from 1981 to 1982 he was a research associate of Chemical Engineering Department at Kansas State University, USA. From April 2000 to March 2002 he was a Professor of Graduate School of Management and Information Science at Toyohashi-Sozo College. After that, he was a Professor of Department of Kansei Design, Faculty of Psychological Science, Hiroshima International University. Also, he has been Emeritus Professor of Osaka Prefecture University since April 1, 2000. He was a member of the editorial boards for Int. J. of Fuzzy Sets and Systems, Fuzzy Economic Review, Mathware and Soft Computing, Fuzzy Optimization and Decision Making, Mathematical Modelling and Algorithms, and Artificial Intelligence. He was Vice President of the International Fuzzy Systems Association (IFSA) from 1987 to 1989 and President of the Japan Society for Fuzzy Theory and Systems (SOFT) from 1995 to 1997.

He has published numerous papers on fuzzy optimization, fuzzy control, fuzzy methods in economics.

CALLS

ISCAMI 2013 14th International Student Conference on Applied Mathematics and Informatics

Malenovice (Czech Republic) 2-5 May 2013



The **14th International Student Conference on Applied Mathematics and Informatics (ISCAMI)** is coming. An original idea of this traditional conference came into existence from International Student Conferences for Undergraduate and Graduate Students of Applied Mathematics initially organized in Bratislava, Slovakia.

ISCAMI 2013 is organized by the Centre of Excellence IT4Innovations - Division of the University of Ostrava - Institute for Research and Applications of Fuzzy Modeling (IRAFM) jointly with the Department of Mathematics of Faculty of Civil Engineering of the Slovak University of Technology in Bratislava and will be held in Beskydy mountains near Ostrava. We are happy and proud that the conference, as the only student conference, is marked as **EUSFLAT endorsed event**.

Participants will be invited to submit post-conference papers into special issues of chosen reviewed journals. Let us recall, that in previous years, we have used e.g. the following journals: Kybernetika (JCR), Neural Network World (JCR), Acta Polytechnica Hungarica (JCR), Acta Universitatis Matthiae Belii and Acta Mathematica Universitatis Ostraviensis.

Last year we came with an idea of summer school which met with great success. Due to this fact, ISCAMI 2013 is organized jointly with the **2nd Summer School on Applied Mathematics and Informatics** that will be composed of several interesting tutorials given by leading scientists and teachers from distinct fields on the border of applied mathematics and informatics.

Due to the support of **A-Math-Net Applied Mathematics Knowledge Transfer Network** - an ESF project reg. nr. CZ.1.07/2.4.00/17.0100 we will be again able to support most of the participants as well as invited tutorial speakers by exemption from paying registration fees.

More information at <http://irafm.osu.cz/iscami>.

General Chairpersons:

Radko Mesiar (Slovak University of Technology)
Vilém Novák (IRAFM, University of Ostrava)

Organizing Chair:

Petra Hod'áková (IRAFM, University of Ostrava)

A-Math-Net Bearer:

Martin Štěpnička (IRAFM, University of Ostrava)

CALLS

ISIPTA 2013 8th International Symposium on Imprecise Probabilities : Theories and Applications

Compiègne (France) 2-5 July 2013



The ISIPTA meetings are the primary international forum to discuss results on the theories and applications of imprecise probability, where imprecise probability is understood as a generic term for models of uncertainty not restricted to sharp uncertainties. Such models include lower expectations or previsions, sets of probability measures, fuzzy measures and Choquet capacities, probability

intervals, ...

Format

Two types of submissions are possible:

- Full papers will be reviewed: accepted papers will be included in the proceedings and presented both in a plenary sessions and in a poster sessions;
- Poster only abstracts aim at presenting preliminary results or challenges. They will be presented in poster sessions, along with full paper posters.

Important dates

Full Papers

Submission: 3 February

Notification: 7 April

Final version: 12 May

Posters with abstracts

Submission: 21 April

Notification: 19 May

Venue

The conference will take place in Compiègne, a French imperial city 75km away from Paris.

Invited speakers**1st July tutorial**

Matthias Troffaes (Durham University)

CALLS

AGOP 2013 7th International Summer School on Aggregation Operators

Pamplona (Spain) 16-20 July 2013



In many problems of practical interest arises the need of merging quantitative information. This need comes from different and complementary disciplines such as Engineering, Economics, Science, Mathematics and others.

An important tool to deal with this kind of problems is that of the so-called aggregation functions. These operators have been widely developed in the last decades, both in their theoretical and their applied side, which includes fields such as image processing, decision making, classification problems, expert systems or fuzzy control, among others.

The 7th International Summer School on Aggregation Operators (AGOP), which follows past editions in Oviedo (2001), Alcalá de Henares (2003), Lugano (2005), Ghent (2007), Palma de Mallorca (2009) and Benevento (2011), will be held at Pamplona on July 16th - 20th, 2013.

This summer school intends to bring together researchers on every area related to aggregation functions, as well as to allow young researchers to contact with recent trends and developments in the area. To ease this task, the school is not organized into parallel sessions, so that every participant has the possibility of attending every talk and/or course in the event.

The tutorials, invited talks, and plenary sessions will bring the latest trends, results and state-of-the-art overviews.

Topics of interest include, but are not limited to:

Theoretical aspects:

- Properties of aggregation functions
- New forms of aggregation functions

Thierry Denoeux (Compiègne University)

Conference talks

Alessio Benavoli (IDSIA - Lugano)

Christophe Labreuche (Thales)

Marc Tallon (Sorbonne)

Linda van der Gaag (Utrecht University)

Submission and information

Information regarding submission and the conference can be found at www.sipta.org/isipta13

Joint actions with ECSQARU

ISIPTA and ECSQARU sharing some topics of interest, we propose some joint actions (reduced fee, workshop, etc). See websites for information.

- Copulas and triangular norms
- Fuzzy measures and integrals
- Averaging aggregation operators
- Aggregations with ordinal and nominal scales
- Aggregation functions for extensions of fuzzy sets
- Implication operators

Practical aspects

- Security intelligence, analysis and decision support
- Evaluation problems
- Medical decision problems
- Hybrid intelligent systems and computational intelligence
- Approximate reasoning
- Image processing
- Model identification and parametrization
- Diagnostics and prognostics
- Data mining

Contributions, which must be between 6 and 12 pages, should be submitted before January 15th via the webpage:

<http://giara.unavarra.es/agop2013/index.php>

Important dates:**Deadline for paper submission**

1st February 2013

Notification of paper acceptance

15th April 2013

Deadline final paper submission

15th May 2013

Conference

16th - 20th July 2013