Festschrift for Lluís Godo

Preface

Lluís is a man with solid academic foundations. He studied Mathematics at the University of Barcelona and Industrial Engineering at the Technical University of Catalonia, and throughout his academic life he has been loyal to both traditions: the purely scientific and the applied. While he has published numerous theoretical works, he never shies away from finding how to model and solve a practical problem. Lluís enjoys a privileged intelligence, primed with a knack for recognising significant ideas, that he shares generously with his numerous PhD students, with everyone that collaborates with him and with anyone that attends one of his lectures. Lluís is an achiever: he is always on", quipped someone who knows him well. And this is something that —as a prominent scholar once said— is earned only through hard continued effort nurtured with care. Moreover, Lluís also has an eager curiosity (a necessary, but not sufficient, condition to be a good researcher) that makes him probe into plenty of articles that fall into his hands. This involvement attracts researchers who know that he will look into their work and provide advice. No wonder he manages to produce so many of those reviews one dreams to get: reviews that not merely evaluate ones paper but reveal new bearings for ones own research. Naturally, these qualities have led not only to a bountiful publishing with co-authors of all kinds and topics, but also to earn Lluís a place in the editorial board of the best journals in the field.

We were involved in the creation of Mathematical Fuzzy Logic under the leadership of Petr Hájek and with some other outstanding researchers. Three of them: Petr Hájek, Franco Montagna and Sigfried Gottwald are sadly no longer with us and in this introduction I would like to make them present to all of us.

I have been fortunate to share with Lluís the most productive years of my scientific career and I should say that my own scientific contributions owe much to his ideas and untiring work. I have also been fortunate to attend multiple conferences with Lluís and to share several research stays in universities around the world. This has allowed me to know him well and to build a solid friendship. We have lived so many things together! Like the time when we had the wicked idea of going skiing (during the conference that Radko Mesiar and the Slovaks organized at the Tatra Mountains) and Lluís had the bad taste of dislocating his shoulder; I ended up playing valet so he could get dressed. But fate evens things out: in our last trip to Brazil, my back was playing tricks on me and it was he who had to do the honors.

I must say that in the end, Lluís is a good person in the noblest sense of the word. Friend of his friends, he never has a no for an answer and you know you can always count on him. He is an exceptional, unique and unrepeatable human being.

This is the Lluís that we want to pay homage to by taking a look on his scientific work, with especial emphasis in those of his ideas that have been most influential and that span a considerable number of fields. Since we cannot be all-inclusive, we restrict ourselves to the topics in which we think he has made the most relevant contributions. We have done our best to include a large part of Lluís's students and his principal collaborators as authors of this volume. We hope he likes it.
Congratulations for the work done and for the anniversary!!

November 2017 Francesc Esteva

Contents

1 A DIY Man

Carles Sierra

My first recollection of Lluís is him with a folder full of documents under his arm and a huge tape, those computer magnetic tapes that were common in the 80s, containing the data and code needed to complete his Engineering Final Degree Project. I saw the tape for months and months. Years, I would say. Most probably it is still somewhere in his office under tons of printed papers and books. I forgot what his practical engineering problem was, but there was one, and he was about to solve it. He is a practical man, in theory, and a theoretical man, in practice. A very nice combination!

The fact that Lluís Godo is thus an Engineer, well, an engineer$-\epsilon$ as he still needs to finish the Final Project! and not only a (good and solid) mathematician, made that our scientific encounters along the Years included the development of practical stuff. We have done a lot of theoretical work together as well (e.g. [37, 35, 133, 132, 139]), but the practical works have been much more entertaining from my point of view. In our joint theoretical works his contributions were far more significant by grounding our intuitions and making them sound. However, in the construction of practical applications we had a more equal and balanced role and that is why I probably enjoyed it more. He has always believed that the development of theory has to have an application side, and that although theoretical research *per se* is an acceptable and respectful enterprise, when it comes accompanied by useful applications is when it gets its full *raison-d'être*.

My PhD work (finished in 1989) involved the design and implementation of a knowledge-based inference engine based on multi-valued logic [106]. During those PhD Years we worked together very closely, as the engine and its applications were a good testbed for his work in logic. It was a major engineering endeavour with several large applications in medicine [107, 105], Control Theory [137], VLSI chip-Architecture Selection [87], and the classification of marine sponges [53]. The results were extraordinary as our systems provided proficient diagnostic and therapeutic decisions for pneumoniae and reumathology with reasoning capabilities comparable to those of human experts [140, 21, 54].

At about that time, we spent several months in Germany, at Siemens. They were interested in our work on inference engines using multi-valued logic. During that time, apart from gaining 10kg in weight thanks to the light diet in Bavaria (Schweinshaxen, potatoes, and beer, loads of beer) and thus becoming unrecognizable to our wives, we worked really hard in writing 9000 lines of code in Prolog. Yes, Lluís is also an excellent programmer! Our code was written in less than two months and passed all the tests made by Siemens. It is hard to believe that level of quality given the amount of time we spent gnawing Schweinshaxen bones. Those months also showed me that Lluís has a practical mind for mundane things. When our car wiper washer broke on a Sunday, 100km south of Munich, pouring down and lost our hope to find any open mechanics, he attached two ropes to the wiper washer. The two ropes would get into the car thought the slightly open windows so that I, as copilot, could pull alternatively from both ends to allow him see and drive! For 100 km!!

Well, sorry for the digression. Going back to science. Knowledge representation is one of the oldest areas of research in Artificial Intelligence. How to automate reasoning processes has been a quest for generations of researchers. I dare say that Llus's research has entirely focused on this automation. A perfect match for his mathematical and engineering mind. I vividly remember that the main requirement put by all the experts we worked with during those years, specially the medical ones, was that our systems had to be able to answer *why* a particular decision was suggested. As they would do in their clinical sessions, challenging one another. Users needed to know the reasons supporting a course of action, the alternative options, their pros and cons, and the uncertainty associated with each one. *Explainability* had to be at the core of the reasoning technologies, and this was a really challenging requirement. Related to this, we also had to put significant effort in explaining the meaning of the different uncertainty degrees and why a multivalued representation was preferable to a probabilistic modelling, precisely because symbolic degrees were easier to interpret by humans. This is in sharp contrast with current developments in Machine Learning where explainability remains as a big issue not properly addressed. I wonder how comfortable would be our medical experts endorsing decisions suggested by data crunching algorithms without any justification based on first principles.

In the 90s and 00s we worked together in the extension of reasoning capabilities in a multiagent setting. Reasoning has an obvious social side: opinions are hold by individuals, arguments are exchanged, beliefs need to be updated from interactions with others and the world. The theoretical contributions we made on BDI logics (cf. [35, 37]) had also practical developments in a recommender system for tourism [34, 36]. The recommender was on Argentinian destinations, a country we have also visited together in several occasions, enjoying its gastronomy. (It is difficult to make Lluís happier than being in front of a 'Bife' and a bottle of Malbec wine.)

More recently, the work on BDI was put in the context of planning with uncertainty, and although the work was mostly theoretical, emphasis was given in its application in a robotics scenario implemented over a variant of AgentSpeak [19, 20]. Always the practical side of things in Lluís' work!

I have enjoyed working with Lluís for almost 30 Years now, and hope this will continue like this for many many Years to come!

2 Lluís Godo's research work on argumentation

Teresa Alsinet, Ramón Béjar, Carlos Chesnevar, Pere Pardo, Guillermo Simari

Lluís Godo's research work on argumentation started in 2004 [38], motivated by adding a sound possibilistic foundation to the argumentation formalism Defeasible Logic Programming (DeLP) [98]. As DeLP cannot deal with explicit uncertainty, nor with vague knowledge, Lluís Godo along with other researchers developed P-DeLP (Possibilistic Defeasible Logic Programming), a new logic programming language that extends original DeLP capabilities for qualitative reasoning by incorporating the treatment of possibilistic uncertainty and fuzzy knowledge. Such features were formalized on the basis of PGL, a possibilistic logic based on Gödel fuzzy logic. Part of his research in the same direction led to characterizing two nonmonotonic operators for P-DeLP [39] which model the expansion of a given program P by adding new weighted facts associated with argument conclusions and warranted literals, studying as well different logical properties. The ultimate formalization of P-DeLP, along with the analysis of case studies for real-world applications appeared in 2008 in an article in *Fuzzy Sets and Systems* [12]. Lluís' research work also contributed to solving an important limitation in P-DeLP, as fuzzy information could not be expressed in the object language. As an alternative, he worked on including in P-DeLP the use of PGL^+, a possibilistic logic over Gödel logic extended with fuzzy constants. This led to formalizing DePGL^+, a possibilistic defeasible logic programming language that extends P-DeLP to incorporate fuzzy constants and a fuzzy unification mechanism for them. The formalization of DePGL^+ appeared in the *Intelligent Journal of Approximate Reasoning* in 2008 [12].

The computation of warranted arguments in P-DeLP (as in any argumentation framework) was a central issue, and providing a sound and efficient procedure was very important. To this end, Lluís worked on a novel level-based approach to computing warranted arguments in P-DeLP which ensured the satisfaction of so-called rationality postulates for rule-based argumentation systems [10, 3]. As a consequence, this led to the characterization of a recursive semantics for warrant in a general defeasible argumentation framework by formalizing a notion of collective (non-binary) conflict among arguments. The general defeasible argumentation framework was extended by assigning levels of preference to defeasible knowledge items and by providing a level-wise definition of warranted and blocked conclusions. An efficient algorithm was specified for computing warranted conclusions in polynomial space [2]. Characterizing this novel recursive semantics led to the formalization of RP-DeLP. A maximal ideal output of an RP-DeLP program was defined as the set of conclusions which are ultimately warranted. An algorithm was also specified for computing them in polynomial space and with an upper bound on complexity equal to P^{NP} [4]. This semantics for RP-DeLP and its computation algorithm were further analyzed in [8], where the hardest computational queries performed by the algorithm are reduced to SAT encodings, and the performance of the algorithm was analyzed on randomly created sets of RP-DeLP instances. An implementation based on Answer Set Programming was also defined and evaluated in [5]. The maximal ideal output of an RP-DeLP program gives an unique output for it, but an alternative semantics based on multiple outputs was also defined and studied by the same authors [9, 6].

In 2011, Lluís Godo along with his then PhD student Pere Pardo worked on extending DeLP into temporal logic programs and multi-agent planning. A temporal logic t-DeLP program [126, 127] is a set of temporal literals and durative rules. These temporal facts and rules combine into durative arguments representing temporal processes, that permit to reason defeasibly about future states. The resulting notion of logical consequence, or warrant, is slightly different from that of DeLP, due to its temporal aspects.

The argumentation-based DeLP-POP system (see [99]) for partial order planning on top of DeLP was extended into the cooperative multi-agent case in [129]. Multi-agent planning on top of t-DeLP was fully characterized for t-DeLP [128], also with a focus on cooperative scenarios. In these multi-agent planning systems, actions and arguments (combinations of rules and facts) may be used to enforce some goal, if their conditions (are known to) apply and arguments are not defeated by other arguments applying. In a cooperative planning problem a team of agents share a set of goals but have diverse abilities and beliefs. In order to plan for these goals, agents start a stepwise dialogue consisting of exchanges of plan proposals, plus arguments against them. Since these dialogues instantiate an A^* search algorithm, these agents will find a solution if some solution exists, and moreover, it will be provably optimal (according to their knowledge).

Finally, a model for argumentation-based negotiation was explored in [125] for t-DeLP-POP, a partial order planning system that incorporates temporal defeasible logic. This logic combines temporal facts and durative rules into temporal arguments. A dialogue protocol was developed for the negotiation of plans that models a variety of scenarios for argumentative negotiation of complex services.

Lluís Godo's most recent work on argumentation concerned adding weighted facts to P-DeLP programs, analyzing the models that result from expanding the set of warranted conclusions. Along with other collegues, in [7] worked on exploring the relationship between the exhaustive dialectical analysis-based semantics of P-DeLP and the recursive-based semantics of RP-DeLP, considering a non-monotonic inference operator for RP-DeLP which models the expansion of a given program by adding new weighted facts associated with warranted conclusions. An implementation of an argumentation framework for RP-DeLP is provided that is able not only to compute the output of warranted and blocked conclusions, but also to explain the reasons behind the status of each conclusion.

3 Modal Fuzzy Logics for Uncertain Reasoning

Tommaso Flaminio

The two main logico-mathematical theories to model vagueness and uncertainty are, respectively, fuzzy set theory and probability theory together with their logical counterparts: fuzzy logic and probabilistic logic. These formalisms, although sharing the common feature of evaluating a proposition in a real number between 0 and 1, are deeply different in nature. Indeed, while fuzzy logics are meant to capture the gradual, and possibly partial, *truth* of a proposition, probability functions are aimed at quantifying the *belief* that an agent may have about a precise, yet unknown, state of the world. However, as it was firstly suggested in [118], if the uncertainty of a formula φ is regarded as a physical variable (like pressure or temperature), rather than an atomic sentence, we can immagine a modal assertion $P(\varphi)$ saying "φ is *probable*" in such a way that its truth-degree becomes the probability of φ.

These rough ideas were made precise and formalized one year later in a paper that Lluís Godo coauthored with

Petr Hájek and Francesc Esteva (cf. [116]) where the fuzzy probabilistic logic FP(RPL) was introduced, axiomatized and proved to be complete with respect to probabilistic models.

In order to explain why the methodological path that, starting from FP(RPL), led to its further generalizations, we need to expand a little on the technical aspects of this modal fuzzy logic: First of all, the ground logic RPL is a propositional logic obtained from Łukasiewicz logic (Ł in symbols) by adding truth-constants $\overline{r}$, one for each rational number in $[0, 1]$, and axioms ensuring every symbol $\overline{r}$ to be interpreted in the rational number r (see [114, §3.3] for further details). Thus, FP(RPL) is obtained by expanding the language of RPL by a unary modality P (for "probably"). A key feature of this modal logic is that nonmodal formulas (i.e., formulas of classical logic that represents "events") and modal formulas (which are obtained by applying the modality P to nonmodal formulas and then by applying RPL connectives) are kept separated. For instance, if φ and ψ are classical formulas, $P(\varphi)$ and $P(\varphi) \to P(\psi)$ are w.f.f., whilst neither $\varphi \to P(\psi)$, nor $P(P(\psi))$ are formulas because nonmodal and modal formulas cannot interplay and the modality P cannot occur nested. Therefore, the modality P is a *partial* operator that acts from the logic for events (in this case, classical logic) to the logic for probabilistic formulas (RPL). It is also worth noticing that the choice of RPL as ground setting for probabilistic reasoning is motivated by the fact that this logic has a connective, inherited from Ł, denoted $\oplus$, whose standard semantics is the usual sum truncated to 1 and which allows to express, in the language of FP(RPL), the fundamental axiom of probability functions: the additivity law.

This new idea of modeling uncertain statements by fuzzy modal formulas, besides providing a reconciliation between fuzzy set theory and probability, paved the way for a completely new research field that Lluís Godo, along with other researchers, is leading since the late 90's. Indeed, after the publication of [116], an important issue in the community of fuzzy logics was to understand up to which extent this approach could be pushed forward and which other uncertainty measures, besides probability, could be captured by the same lines of thoughts.

Lluís Godo research work in modal fuzzy logics for uncertain reasoning took, since then, several directions. The first natural goal to achieve concerned with conditional probability and Lluís coauthored several papers on this issue approaching to conditional measures in two ways: by defining a conditional measure from an unconditional one, and considering conditional probability as a primitive notion. The former approach was achieved by replacing in FP(RPL) the ground logic by the stronger system $Ł\Pi\frac{1}{2}$

[78] where the presence of the product residuum connective $\rightarrow_\Pi$ allows to define the conditional probability $P(\varphi \mid \psi)$ as $P(\varphi \wedge \psi) \rightarrow_\Pi P(\psi)$, whenever $P(\psi)$ is not zero (cf. [116]). At the same time, conditional probability can be axiomatized as a binary modality $P(\cdot \mid \cdot)$. This latter ideas were developed in [108] where the the logic FCP(ŁΠ$\frac{1}{2}$) (where FCP stands for Fuzzy Conditional Probabilistic) was also applied to characterize, in purely logical terms, de Finetti's foundations of coherent conditional probability.

Still in the lines of probabilistic reasoning, the second path of Lluís's activity was to extend the previous approach to deal with nonclassical events. A first step in this direction was to replace, in FP(RPL), classical logic with a finitely-valued Łukasiewicz logic $Ł_k$ as logic for events, and Łukasiewicz logic for probabilistic formulas. The so resulting modal logic FP($Ł_k$, Ł) was proved to be sound and complete with respect to two classes of models that have been named *strong* and *weak* probabilistic models (see [89]). In FP($Ł_k$, Ł), one can deal with the uncertainty of events which, rather than being precise, express properties which are more suitably evaluated in a multiple-valued (yet finite) scale. More precisely, events of FP($Ł_k$, Ł) are evaluated in the interval $\{0, 1/k, \ldots, (k-1)/k, 1\}$. Furthermore, in the same paper, a logic FCP($Ł_k$, ŁΠ) for conditional probability of many-valued events was axiomatized and proved to be complete with respect to conditional probabilistic models.

Beyond probabilistic reasoning, there are two alternative theories of uncertainty that Lluís intensively studied: the theory of idempotent uncertainty measures (in particular, possibility and necessity measures) and belief functions, the mathematical models of Dempster and Shafer theory of evidence.

Lluís studied extensions of idempotent measures to the framework of many-valued events showing a characterization of these functionals in terms of generalized Sugeno integrals [92] and provided a geometrical description of possibility and necessity measures in terms of convex tropical geometry [94]. Furthermore, the fuzzy modal logic $FN(Ł_k, Ł)$ was introduced in [92] as an expansion of Łukasiewicz propositional calculus, to deal with necessity (and dually, possibility) measures on many-valued events. As a matter of facts, necessity measures do not need, for their axiomatization, the full strength of Łukasiewicz language and, in particular, the $\oplus$ connective results to be redundant since they are not additive as probability functions. This observation guided Lluís and his coauthors to introduce in [49] several modal expansions of Gödel logic for necessity measures. Gödel logic, in a sense, provides the minimal many-valued logic which allows an axiomatization of idempotent measures such as necessity and possibility functions.

Lluís, Petr Hájek and Francesc Esteva, introduced a logic for belief functions on classical events in [104]. The innovative idea underlying this approach consists in regarding a belief function Bel as a combination of a probability measure P with the classical S5 necessity operator $\Box$. Thus, the belief $Bel(\varphi)$ of a classical formula φ becomes the truth-degree of the modal formula $P(\Box\varphi)$. Extending this approach to deal with nonclassical events was the main issue of [95] where Lluís and his coauthors axiomatized the logic $\mathrm{FP}(\Lambda_k, \text{Ł})$: a probabilistic logic on the minimal modal logic Λ_k built up on Ł_k [27]. The results and technical insights contained in [95] shed a light also on the foundation of belief function theory and disclosed, among other things, a way to provide an operational interpretation for belief functions [90].

Finally we would like to recall two book chapters that Lluís recently coauthored: the first one [88] contains a very general approach to fuzzy modal logic for uncertain reasoning, while [91] is concerned with measure-theoretical results about belief functions on many-valued events.

4 Lluís Godo on Mathematical Fuzzy Logic

Pilar Dellunde, Carles Noguera

Godo's contributions to pure mathematical logic are a natural consequence of his interests in logic-based applications. As described elsewhere in this article, already in his initial research endeavors Godo focused on a variety of practical problems that required, among others, mathematical tools for computations with many-valued scales (in any of their intended intepretations, e.g. intermediate degrees of truth of vague statements, degrees of uncertainty, degrees of belief, degrees of preference, etc.).

Fuzzy set theory (FST, often misleadingly also called *fuzzy logic*), introduced in 1965 by Zadeh [145], had become, already at the time of Godo's early works, a succesful mathematical framework for a plethora of engineering applications that employed many-valued scales in their models. The central notion was that of fuzzy set, that is, a classical set endowed with a membership function ranging over a linearly ordered scale (typically the real interval $[0, 1]$) that gives for each element of the domain the degree to which it belongs to the fuzzy set. Zadeh and his followers had enriched FST with a number of research works that studied functions for the pointwise combination of fuzzy sets through suitable generalizations of the classical set-theoretic operations (union, intersection, complement) and related operations. Godo's PhD dissertation was as well a contribution to this field. However, many applications required, besides the combination of membership degrees, some notion of inference that, given an information body, would allow to extract new pieces of information. This could be expressed, in slightly more precise terms, as saying that fuzzy inference should allow to derive partially valid statements from partially statements, which seemed to invite the usage of some logical apparatus that had been initially (and for many years) absent from the field of FST. Zadeh himself acknowledged the need for a *fuzzy logic in narrow sense* which, as opposed to the standard *fuzzy logic in broad sense* (that is, FST and its applications), would be an extension of the works done in many-valued logic, with an emphasis on some particular issues given by the needs of FST. Systems of many-valued had indeed been studied for a long time, including $[0,1]$-valued logics such as the infinitely-valued Łukasiewicz logic Ł [121] and Gödel–Dummett logic G [62], but such developments belonged to the realm of pure mathematical logic and had not yet influenced the FST research.

Godo was a crucial member of the reduced group of pionneers that in the mid 1990s started the ambitious project of bringing FST and many-valued closer with the purpose of building a solid logical foundation for the developments in fuzzy set theory and their applications. The Czech logician Petr Hájek was the main driving force in this endevor that received a (first) culmination in his landmark monograph [114] establishing the area of mathematical fuzzy logic (MFL).

Godo's had started his fruitful cooperation with Hájek already a few years before the MFL program was defined, because of their shared interests in application-oriented research. As explained in other sections of this paper, Godo and Hájek worked in a number of topics, including the management of uncertainty proposing some logical systems that later evolved into what is known today as modal fuzzy logics. Such works paved the way for the creation of MFL.

A fundamental step was taken in [117] where, together with Godo's long time collaborator Francesc Esteva, they proposed the product logic Π, a new system of many-valued logic which, like Ł and G was semantically defined over the real interval $[0, 1]$ but, unlike these logics, used the standard product of reals as interpretation of the conjunction connective. These three logics has been considered since then the three fundamental fuzzy logics, because they were all defined over $[0, 1]$, like Zadeh's fuzzy sets, by means of very simple arithmetical operations, and because in all cases the conjunction was interpreted by continuous t-norms, a particular kind of binary of functions that had been proposed in FST to deal with intersection of fuzzy sets.

Godo and Hájek surveyed these deductive systems in [115] and offered a general discussion of the relevance of mathematical logic for the foundations of inference in FST in the paper [103], a testament to Godo's decisive influence in Hájek's MFL program.

A cornerstone of Hájek's conception of MFL was the proposal of a basic fuzzy logic that he envisioned as the logic of all continuous t-norms and would have Ł, G, and Π as particular axiomatic extensions. To this end Hájek proposed an axiomatic system, which he called BL, and conjectured that it was complete with respect to the semantics given by all continuous t-norms defined over $[0, 1]$. The conjecture was proved true by Godo (in a joint work with Cignoli, Esteva and Torrens) in [43], showing that BL was indeed the basic fuzzy logic in the sense of Hájek.

However, Godo and Esteva soon observed that the essential feature for a t-norm to define a semantics for fuzzy logics was the existence of an associated residuum to interpret the implication connective. The necessary and sufficient condition for the existence of such residuum is leftcontinuity, hence a condition weaker than the continuity required by Hájek for his BL. Therefore, they proposed a weaker system that they called MTL (for *monoidal t-norm-based logic*) as a more basic fuzzy logic that should capture this more general semantics, the class of all residuated t-norms. The paper that introduced MTL [73] is one of the most crucial and most widely cited works in MFL. Shortly after, Jenei and Montagna proved that MTL is indeed complete with respect to the semantics given by all left-continuous t-norms [120].

All the works we have so far cited, by Godo and his cooperators, set the stage of MFL as a new field in mathematical logic with many challenging issues and a lot of room for development, as witnessed by the proliferation of papers that have built a wide and deep mathematical corpus in the last two decades (see it in a systematized form in [45]). Godo has remained a leading developer of the field during all this time. His main lines of subsequent research in MFL can be summarized as follows:

- In the years immediately after the inception of MTL, Godo continued studying the main systems of fuzzy logic, with an emphasis on the extensions of MTL. In cooperation with Francesc Esteva and several coauthors, he considered the problem of axiomatizating and proving completeness for many fuzzy logics stronger than MTL, showed their exact relationship with the family of substructural logics, studied the falsity-free fragments, and characterized their completeness properties in the papers [70, 40, 74, 75, 44].

- Since the early days of MFL Godo has had a strong interest in logical systems with high expressivity, because of their better applicability in modelling computer science problems. Again in cooperation with other experts he made decisive contributions in this area by introducing logical systems combining the connectives of Łukasiewicz and product logics, logics with additional involutive negations, logics with additional constants for intermediate truth-values (following the proposal of Jan Pavelka [130]), and logics with unary connectives for linguistic hedges [72, 78, 76, 85, 84, 83, 138, 41, 71, 81, 82, 80, 143, 77].
- Godo has also played a central role in the mathematical study of semantics for fuzzy logics. In particular, he has cooperated in the description of special classes of BL-algebras and their corresponding logics, has discovered a method to provide equational basis for varieties of algebras generated by continuous-t-norm-based algebras, studied modifications of left-continuous t-norms by suitable negation functions

generalizing the definition of the nilpotent minimum t-norm and contributed to the still open problem of classifying of left-continuous t-norms [50, 51, 52, 79, 42, 124].

- Finally, Godo has worked in the creation and development of an alternative paradigm for fuzzy logics in which, instead of the defining logical consequence as preservation of full truth, one only requires that the conclusion is not less true than the premisses. This degree-preserving paradigm has given rise to fuzzy logics with radically different properties that often display paraconsistent features (that is, are non-explosive, in the sense that some contradictions may not bring explosion). Godo and his cooperators have studied these logics in detail in the papers [24, 65, 46, 47].

As important as his mathematical results are his contributions to the creation and growth of the international community of Mathematical Fuzzy Logic. He is an important member of ManyVal (working group on Many-Valued Logics of the European Research Consortium for Informatics and Mathematics) and was one of the promoters of MathFuzzLog (working group of the European Society for Fuzzy Logic and Technology), being vice-president of the

European Society for Fuzzy Logic and Technology (2005-2009).

As principal investigator of many research projects, he has been personally involved in supporting the younger members of the community of MFL, always trying to secure the necessary resources and funds for their job positions and mobility. His excellent mentoring skills have been demonstrated in several PhD thesis in pure and applied logic written by his students. Another defining aspect of Godo's constant dedication to the community is his tireless work as editor of Fuzzy Sets and Systems and reviewer of papers for many international journals and conferences. Moreover, he has been a permanent contributor to conferences and workshops, presenting his own work and enriching the discussion with his mathematical insight and healthy irony.

He has also been one of the backbones of the Catalan community of logicians, since the early times of the Catalan Logic Congress (organized in the Science Museum of Barcelona until 1998), supporting and contributing to the international conferences of ACIA (Catalan Association for Artificial Intelligence) and the weekly seminar of non-classical logic of the University of Barcelona As researchers in MFL and friends of Lluís, we would like to thank him for his mentorship during all these years.

5 Possibility theory: logic, similarity and decision

Didier Dubois, Henri Prade

The many contributions of Lluis Godo to theoretical artificial intelligence deal on the one hand with the investigation of triangular-norm based multiple-valued logics that take their roots in the development of fuzzy sets, and on the other hand in similarity-based reasoning and in the possibilistic handling of uncertainty. In the following, we more particularly focus on this latter aspect.

Lluis Godo has been naturally interested from the start by possibility theory and its connection to logics and reasoning about knowledge. Indeed in his early research work, under the guidance of Enric Trillas, and Francesc Esteva, among others, he focused on the theory of approximate reasoning after Zadeh, which can be viewed as an extension of the model-based semantics of classical logic to fuzzy sets interpreted as possibility distributions. He was also interested by the similarity-based semantics of fuzzy sets due to Ruspini, that has a clear connection with modal logics. It explains why many of his early papers deal with various understandings of possibilistic reasoning [67] and similarity-based reasoning [61, 131]. He also contributed to the application of possibility theory to temporal reasoning [113]. It seems that much of the research work done by Lluis Godo falls under the key words many-valued logic, possibility theory and similarity, all three of them in connection with fuzzy sets.

There is a close connection between possibility theory and modal logic since KD necessity and possibility modalities are crisp versions of numerical necessity and possibility functions. This connection was made quite early by Lluis Godo and colleagues [119] who deliberately added KD modalities to many-valued logics. Subsequently, this step naturally led to extensions of possibilistic logic, replacing classical logic by many-valued logics, especially Goedel logic [49] In this way, we get a formal system to declare the more or less certainty of fuzzy propositions, thus clearly exhibiting the orthogonal scales for truth and possibility (or certainty) respectively. More recently Lluis studied algebraic properties of possibility distributions over MV-algebras [94].

This kind of joint extension of classical logic and possibilistic logic to multiple-valued predicate was in fact much developed by Lluis Godo and his Ph.D student Teresa Alsinet, with a view to define possibilistic logic extensions of logic programming [13, 16]. The extension of this approach to include similarity based reasoning was also carried out [14].

More recently, the framework of generalized possibilistic logic we have proposed, which generalizes possibilistic logic to a multimodal logic of depth 1 with simplified semantics in terms of possibility distributions was also extended replacing classical logic embedded in the modalities by many-valued logics [29]. We also joint efforts to lay bare an S5 version of possibilistic logic [17].

We are very grateful to Lluis for his significant contributions to joint surveys we had the privilege to write with him, and that cover many of the above issues and provide unified views of various aspects and developments around approximate reasoning, possibility theory and many-valued logics [30, 56] and also various understandings and formal models of vagueness [55]. We would also like to mention the early and fruitful collaboration with Lluis on the handling of vague quantifiers such as few and most in the setting of interval-valued probabilities, where we identified robust patterns of inference with such quantifiers that are not sensitive to a too precise interpretation of them [57].

Lluis was also much interested in the application of possibilistic logic as a framework for argumentation that was developed with colleagues from Argentina [11, 1]. No doubt he was the main proposer for this particular development where the strength of arguments becomes naturally a matter of degree.

The similarity trend in Lluis research work naturally led him to contribute to less usual domains of application of fuzzy sets and possibility theory such as case-based reasoning [59], and case-based decision theory [58]. Along with his Ph. D. Student A. Zapico, he contributed to the formal foundations of possibilistic decision theory [146, 100], where uncertainty is represented by a possibility distribution. Finally Lluis published a pioneering work on the use of possibility theory for reasoning about of preferences in the BDI framework, based on so-called guaranteed possibility functions [37]. He also recently contributed to the computation of optimal policies in Markov possibilistic decision processes [18].

Overall it is clear from this modest overview that possibility theory has played a key role in the research work done by Lluis Godo. Moreover we strongly benefited in our own work from his contributions, and were very happy to cooperate with him on several projects. Last, but not least, we would like to emphasize that working with Lluis is always a pleasure mixing intellectual achievements and true friendliness.

Thanks a lot, Lluis, for all these beautiful contributions and for so many pleasant collaborations over years!

6 Similarity Reasoning

Ricardo O. Rodriguez

Similarity is the basics for at least three cognitive tasks: classification, case-based reasoning, and interpolation. In classification tasks, objects are put in the same class insofar as they are indistinguishable with respect to suitable criteria. Case-based reasoning exploits the similarity between already solved problems and a new given problem to be solved in order to build up a solution to it. Interpolation mechanisms can be understood as reasoning methods to adapt solutions of already solved problems taking into account the similarity between the new problem and the solved ones. So it is worthwhile to formalize the similarity-based reasoning underlying these cognitive tasks (and many others) by means of Logical Systems. There are many different ways of modelling (in the logical sense) the notion of similarity. One of them is to equip the set of interpretations or possible worlds with a fuzzy similarity relation (that is reflexive, symmetry, and t-norm transitive fuzzy relation). This approach was originally proposed by Ruspini in order to cover fuzzy patterns of inferences. That

is the approach followed by Lluís Godo and where he has produced very important results. This line of work was in a direct connection with his Ph.D. dissertation what with his owner interested in formalizing uncertainty reasoning.
In June 1993, I took a short course lectured by Ruspini on "Approximate Reasoning" in Buenos Aires, Argentina, where he gave me a copy of his paper [136] which I found amazing and flooded my mind with a lot of fresh ideas. At the end of that year, I moved from Buenos Aires to Barcelona to start working on my Ph.D. and then, I met Lluís Godo.
Both Lluís Godo and Pere Garcia, my other Ph.D. advisor, accepted the idea of formalizing Ruspinis semantics using modal logics right away (see [135]). In this approach, lines of research presented in sections 3 and 5 are merged very naturally. As mentioned along different overviews, Lluís has always been interested in understanding and identifying different approximate reasoning models. Right from the beginning he understood that Ruspinis semantics characterizes a type of reasoning known as Truthlikeness ([123]) more than Fuzzy Reasoning or Uncertainty Reasoning. And precisely in [111] these three types of reasoning are clearly observed and discussed. There, several logic systems are also introduced formalizing syntactically the notion of Truthlikeness. From the identification of the different reasoning models, the idea of combining them under

one single and unique formalism comes up only naturally. This is the reason for his research work in Fuzzy modal logics on which he has been working strongly over the last decade but which he had already been exploring in the beginning with Hájek in [119]. It is worth pointing out that even though all research papers published up to now have a theoretical approach, Lluís has always had practical applications in mind. In that sense, he does not hesitate in going from an overall comprehensive case to analyze specific cases which may be applicable. A list of his contributions are present in Logical Systems for Similarity Reasoning: [66, 101, 97, 68, 112, 14]

Within the same context of Similarity Reasoning, Lluís has contributed in reaching important results in characterizing Fuzzy Approximate Entailments. These papers have had a considerable impact in the Artificial Intelligence community. The most important ones are: [69, 67, 60, 134, 110, 61, 86, 141, 102]

Finally, I would like to close this brief overview by saying that in twenty-five years of scientific cooperation with Lluís, I have always enjoyed working with him not only because of his intellectual greed and capability, but also because of his generosity, enthusiasm and commitment. But most of all because Lluís will always give priority to human principles over scientific ones. In him, I have found a friend more than a colleague. I feel very fortunate and proud in having his friendship. This is the reason why it is a pleasure to be part of this celebration and well earned recognition.

7 Paraconsistent fuzzy logics

Marcelo E. Coniglio,
Rodolfo C. Ertola-Biraben

A logic **L** is said to be *paraconsistent* if it contains a negation $\neg$ which is not *explosive*, that is: there exists a non-trivial, contradictory (with respect to $\neg$) theory Γ in **L**. This is equivalent to saying that there exist formulas φ and ψ such that ψ is not derivable in **L** from the contradiction $\{\varphi, \neg\varphi\}$. The first paraconsistent logic presented in formal terms is the so-called *discussive logic*, introduced by S. Jaskowśki in 1948. However, the first systematic study of paraconsistency traces back to N. da Costa, who introduces in 1963 the hierarchy $(C_n)_{n\geq 1}$ of the so-called *C-systems.* His approach to paraconsistency (which initiated the so-called *Brazilian school* of paraconsistency) was generalized by W. Carnielli and J. Marcos through the notion of *Logics of Formal Inconsistency* (**LFI**s) in [33] (see also [32, 31]). The basic idea of **LFI**s is that the explosive behavior of negation can be recovered in a controlled way by means of a unary *consistency* conective $\circ$ (primitive or not) in the following sense: a contradiction $\{\varphi, \neg\varphi\}$

does not derive any formula ψ, in general, since the logic is paraconsistent with respect to $\neg$; however, any formula is derivable from $\{\varphi, \neg\varphi, \circ\varphi\}$. This feature is called *gently explosiveness*. In the general case, consistency can be expressed by means of a set of formulas $\bigcirc(p)$, instead of using a single formula $\circ(p)$, where in both cases p is a propositional variable. Given an **LFI**, say **L**, the assumption of consistency of some formulas allows to recover within **L** the full power of classical logic in a *local* (or *controlled*) way. For instance, in **mbC** (the basic **LFI** based on positive classical logic) $\neg\psi \to \neg\varphi$ does not follow from $\varphi \to \psi$, but it follows from $\{\circ\psi, \varphi \to \psi\}$. This is why the consistency operator $\circ$ is considered as a *recovery operator*. In da Costa's C-systems the consistency operators are not primitive, but they are defined in terms of others connectives in the signature (namely, conjunction and paraconsistent negation). For instance, $\circ\varphi =_{def} \neg(\varphi \wedge \neg\varphi)$ in C_1. Each C-system C_n is therefore a special case of **LFI**s.

It is useful to consider that in paraconsistent logics (and, in particular, in **LFI**s) formulas represent *information*, which sometimes can be dubious or unreliable. This justifies that one can have *evidences* or *support* to accept φ and its negation $\neg\varphi$ simultaneously (more details on an epistemic interpretation of paraconsistency can be found in [31, Chapter 1]). On the other hand, fuzzy logics constitute a powerful tool for reasoning with imprecise information; in particular, for reasoning with propositions containing *vague predicates*. Given that both paradigms deal with information –unreliable, in the case of paraconsistent logics, and imprecise, in the case of fuzzy logics– it is reasonable to consider logics which combine both aspects. Such systems of paraconsistent fuzzy logics would be able to deal with unreliable and imprecise information, so allowing contradictions.

The formal study of paraconsistent fuzzy logic is one of the many contributions Lluís Godo made to Logic. The idea of considering such heterogeneous logic systems began during a visit of Carles Noguera, in the first semester of 2012, and of Lluís Godo, Francesc Esteva and Tommaso Flaminio, in the second semester of the same year, to the Centre for Logic, Epistemology and the History of Science (CLE) in Campinas, Brazil, in the context of the MaToMUVI project (IRSES/Marie Curie Actions fellowships). From the interaction between both groups of researchers some concrete proposals were produced, given origin to several papers (see [64], [65], [46], and [47]).

Let us firstly describe the main contributions of [64] and [65]. The t-norm-based fuzzy logics, in particular the weakest of them, MTL (*monoidal t-norm based fuzzy logic*) introduced by Esteva an Godo in 2001 (see [73]), are not paraconsistent. This is a direct consequence of the fact that these logics (as happens with most of the logics in the realm of *Mathematical Fuzzy Logic*) are defined under the paradigm of *truth-preservation*, which states that a formula follows from a set of premises if every algebraic evaluation that interprets the premises as 'true' also interprets the conclusion as 'true'. Thus, despite of the fact that the semantics is given by algebras with many truth values, the only values relevant to consequence (i.e., those that have to be preserved) are exacly those in a designated set of values in the algebras (frequently there is just one designated value, for instance in Łukasiewicz logics). There is, however, an alternative semantical approach, the so-called *degree-preservation paradigm* (see [24] and [96]), in which a conclusion follows from a set of premises if, for every algebraic evaluation, the truth degree of the conclusion is not lower than that of the premises. Arguably, this approach is more coherent with the commitment of many-valued logics to truth-degree semantics, given that every truth-value (seen as a truth-degree) is considered in the notion of logical consequence.

In [64] and [65], it was shown that delta-core fuzzy logics under the truth-preserving paradigm cannot handle contradiction, due to being explosive with respect to their residual negation. On the contrary, their degree-preserving companions are paraconsistent, provided that they are not an expansion of SMTL, i.e. assuming that the pseudo-complementation law $(\varphi \wedge \neg\varphi) \to 0$ does not hold. However, these logics are *partially explosive* with respect to *tertium non-datur*, that is: from a contradiction $(\varphi \wedge \neg\varphi)$ any formula of the form $(\psi \vee \neg\psi)$ follows. This means that these logics are not *boldly paraconsistent*.

Since a paraconsistent logic is an **LFI** if and only if it is gently explosive with respect to a set of formulas (or a connective) expressing consistency, the question of whether a fuzzy logic is gently explosive was analized for some special cases. To this respect, the conditions under which the degree-preserving fuzzy logic of an expansion of an MTL-chain is an **LFI** with respect to the residual negation were characterized in algebraic terms. As interesting examples, it was observed that if $\mathbf{L}$ has the Monteiro-Baaz's $\triangle$ connective (as primitive or definable), then the degree-preserving logic $\mathbf{L}^{\leq}$ is gently explosive, where the consistency operator is given by $\circ\varphi =_{def} \triangle(\varphi \vee \neg\varphi)$. On the other hand, the degree-preserving companion $Ł^{\leq}$ of Łukasiewicz logic, is not gently explosive.

Expansions of a core fuzzy logic $\mathbf{L}$ and of its degree-preserving companion $\mathbf{L}^{\leq}$ obtained by adding either the dual intuitionistic negation D, or an involutive negation $\sim$, were also considered, proving that D may be defined as the residual negation composed with the Monteiro-Baaz operator $\triangle$. It was also proved that the degree-preserving companion is D-paraconsistent and gently D-paraconsistent, where $\circ p$ is defined as $\triangle(p \vee \neg p) = \neg D(p \vee \neg p)$.

Finally, degree-preserving first-order fuzzy logics with paraconsistency properties were also studied. Though not difficult to define, degree-preserving first order fuzzy logics had not been previously considered in the literature. Now, as the notions of paraconsistency considered here are essentially propositional, the same results as for propositional logics were obtained for first-order fuzzy logics.

In the approach to fuzzy **LFI**s proposed in [64] and [65], the consistency operator $\circ$ is defined in terms of the other connectives. Thus, these logics belong to a sub-class of **LFI**s known as **dC**-*systems* (see [33, Subsection 3.8], [32, Definition 32] and [31, Section 3.3]). In [46] this approach was generalized to fuzzy **LFI**s in which the consistency operator is primitive. In more precise terms, in [46] extensions of the fuzzy logic MTL by means of primitive operators for consistency and inconsistency were introduced, allowing the definition of **LFI**s based on (extensions of) MTL. The main novelty was the definition of postulates for primitive consistency and inconsistency fuzzy operators over the algebras associated to (extensions of) MTL. As a particular case, it was shown how to define consistency and inconsistency operators over MTL-algebras. As in the previous approach, a degree-preserving consequence relation was adopted in order to obtain a paraconsistent version of MTL as well as some of its extensions.

It is worth noting that one of the requirements imposed by da Costa to his C-systems was the *propagation of consistency* property, namely: from the consistency of both φ and ψ (that is, from $\circ\varphi \wedge \circ\psi$) it follows that $(\varphi\#\psi)$ is consistent (that is, $\circ(\varphi\#\psi)$), for any $\# \in \{\wedge, \vee, \rightarrow\}$. The propagation of consistency was also studied in [46] in the framework of **LFI**s based on (extensions of) MTL. Additionally, it was proposed a fuzzy **LFI** able to recover classical logic by considering additional hypothesis on the consistency operator. Finally, fuzzy **LFI**s defined in terms of inconsistency operators instead of consistency operators were considered, showing the relationship between the previous systems by means of logical translations.

Paraconsistent fuzzy logics were also studied in [47], but from another perspective, not directly related to **LFI**s. Observe that, in terms of their consequence relations, the degree-preserving logic $\mathbf{L}^{\leq}$ is included in $\mathbf{L}$, for every fuzzy logic $\mathbf{L}$ (despite having the same theorems). In particular, this holds for Łukasiewicz infinite-valued logic Ł. Being so, a natural question that arises in this setting is to ask about all the possible intermediate logics between Ł$^{\leq}$ and Ł. In particular, it would be interesting to investigate which of them are paraconsistent and which of them are explosive. With this aim in view, and from a syntactical perspective, some families of inference rules (inspired in the explosion rule) that are admissible in Ł$^{\leq}$ and derivable in Ł were introduced in [47], and the corresponding intermediate logics were characterized. From a semantical point of view, some families of logics characterized by families of matrices $([0,1]_{MV}, F)$ were studied, where $F \subseteq (0,1]$ is a lattice filter, proving that there are another intermediate logics (like the one defined by the explosion inference rule) that are not semantically defined by these matrices. Finally, the case of finite-valued Łukasiewicz logics was analyzed, and a large family of intermediate logics defined by families of matrices $(\mathbf{A}, F)$, with $\mathbf{A}$ being a finite MV-algebra and F is a lattice filter, were axiomatized.

For us, it has been a pleasure and privilege having the opportunity to know and to work with such an amazing person like Lluís. His powerful insights were crucial to the development of the research described in the paragraphs above. Together with this, we would like to emphasize his human qualities, in particular his generosity and deep sense of hospitality and friendship.

8 Fuzzy Modal Logics

Ricardo O. Rodriguez

In previous sections, it has already been stressed that Lluís Godo is recognized as a prominent scientist not only for his outstanding theoretical contributions in many different topics but also for being a researcher that has also considered an applied perspective in his research. The current section aims to show that an important part of his scientific work has been devoted to developing both theoretical and practical results on many-valued modal logics.

Many-valued modal logic is an important branch of logic developed firstly in the context of non-classical fuzzy logics by Fitting, and which is now widely used as a formalism for knowledge representation in artificial intelligence and analysis tools in computer science. The kingpin in the pioneer work of Fitting is a natural generalization of Kripke semantics by considering a fuzzy accessibility relationship and an underling fuzzy interpretation of propositional variables. This generalization has been followed by Lluís Godo and his colleagues.

The first works of Godo under the scope of this section focused on logics to reason about uncertainty by means of fuzzy modalities. This topic was initiated by a joint paper with Petr Hájek (see e.g. [119, 116]) where probability over classical propositions was modeled as modalities over Rational Pavelka logic. This approach has been extended later to modalities that capture different uncertainty measures, like possibility and necessity measures or upper and lower probability measures, over both classical and many-valued propositions (see e.g. [104]). The novel and central idea in this approach is to interpret a probability degree on a Boolean proposition φ as a truth degree, but not of the very φ itself but of another proposition $P\varphi$, read as "φ is probable". This idea is complemented with another important observation, which is that the standard Łukasiewicz logic connectives provide a proper modeling of the Kolmogorov axioms of finitely additive probabilities. This framework can be extended to conditional probabilities, as it is shown in [122]. Finally, let us to mention that Godo's paper [119] was generalized in [26] for finite MTL-chains.

The rest of Godo's contributions could be classified according to different criteria. For instance, an important line of his researches is devoted to possibilistic reasoning over fuzzy events. In this case, the starting point is a structure $\langle W, \pi, e\rangle$ where W is a non-empty set, $\pi : W \mapsto [0, 1]$ is a normalized possibility distribution and $e : Var \times$

$W \mapsto [0,1]$ is a valuation of propositional variables which can be extended in the usual way to non-modal operators and as follows to necessity:

$$e(Nec(\varphi), w) = \inf_{v \in W} \{\pi(v) \Rightarrow e(\varphi, v)\}$$

where the operator $\Rightarrow$ may be interpreted in many different ways given place to alternative approaches. For instance, in [11, 12, 15, 39, 109], an argumentation framework on possibilistic logic programming is studied, where $\Rightarrow$ is the reciprocal of Gödel many-valued implication, defined as $x \Rightarrow y = 1$ if $x \leq y$ and $x \Rightarrow y = 1 - x$ otherwise. Other alternative interpretations for $\Rightarrow$ (Kleene-Dienes and Lukasiewicz) are explored in [48, 49] where it is tried to capture different notions of necessity (in the sense of Possibility theory) for Gödel logic formulas. It is worth mentioning that an application on medical diagnosis of last mentioned jobs is reported in [63]. An alternative approach to possibilistic reasoning was also developed by taking Łukasiewicz events instead of Gödel one. This path is opened in [94, 93]

Another classification topic of the commented logics is by the type of the underlying classical modal system which is generalized. In particular, many of Godo's papers are about modeling the notion of belief on fuzzy propositions. For example, in [23] it is introduced generalizations of the main classical propositional modal logics of belief (K45, KD45, S5) based on finitely-valued Lukasiewicz logic with truth constants. In this same line, in [29], a possibilistic KD45 on Gödel logic is introduced.

There is a more theoretical approach to many-valued modal logics which was initiated with [25] and it was followed by [28, 27]. The whole of these papers has the virtue of putting some clarification on the topic of the Minimum Many-Valued Modal Logic on residuated lattices. In this theoretical line, it can be also included Vidals PhD thesis [142] and the paper [144].

All of us, Lluís' colleagues and friends, believe that the collaboration with him has been really fruitful, we have learned a lot from Lluís Godo, and during all this time that we have shared with him, we have enjoyed his personality, ideas, and friendship. We dedicate this paper to him in the occasion of his sixtieth anniversary. Thanks, Lluís for being a referent, for your stimulating scientific ideas and for your friendship, in summary, for being as you are.

9 My appreciations of an outstanding person

Ramon López de Màntaras

I have the privilege of having met Lluís very long time ago, when the field of AI started at the Spanish National Research Council in the Centre of Advanced Studies of Blanes in the mid eighties, and since then we have been not just colleagues but also good friends. Lluís is one of the most brilliant persons I have ever met. He has been, and is, a pillar of the Artificial Intelligence Research Institute. Indeed, his background both as a mathematician and engineer gives him a unique baggage that his colleagues at the Artificial Intelligence Research Institute, and elsewhere, appreciate a great deal, particularly his PhD students. For instance, when I was working with him and other colleagues in the design and development of MILORD's approximate reasoning capabilities and its extensions to deal with qualitatively expressed uncertainty, We were very impressed by his solid and broad knowledge of mathematical logic as well as his capacity to think also as an engineer to implement the theoretical ideas he had. I remember very well that at the time of writing papers whenever we were not sure about the correctness of some theoretical contents of the paper, following his suggestions and corrections was a must. If Lluís stated that it was correct then we could be sure about it even late at night, after a big dinner with good wines and after-dinner drinks! It is not a joke, it actually happened. Once, he, Carles Sierra, and myself were finishing writing a paper in the living room of my apartment at 2 am after lots of food, good wines and some more drinks and, nevertheless, his mind was so clear that he was correcting many formal details in the paper. By the way, this paper received the "1987 Digital European AI Research" paper award that distinguished the best paper published in European conferences related to AI that year. After that we conjectured that alcoholic beverage was a good ingredient to help in writing good papers! Another remarkable fact about Lluís is his willingness to help. As already mentioned by Francesc Esteva in the preface, he never has a "no" as an answer. He is a personification of a NGO. Among other effects, this trait of his personality makes him an outstanding reviewer. His reviews are always extremely helpful for the authors of the papers and this is fundamental for the progress of science. Dear Lluís, it is an honour to have you among my collaborators and I hope that at the IIIA we will continue having the privilege of your wisdom and friendship for many years to come!

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