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In Memoriam

Philippe Smets (1938–2005)

Professor Philippe Smets passed away on Monday night November the 14th, 2005, at home with his family around. He had been suffering from a brain tumor for several months. For those interested in uncertainty modeling and handling, he was an outstanding researcher in this area, in some sense a guiding light.

Philippe Smets was born in Brussels (Belgium) on November 27, 1938. He first received a medical doctor degree in 1963 from the Université Libre de Bruxelles (ULB), then a Master degree in experimental statistics from North Carolina State University, and, finally, his PhD degree in medical statistics from ULB in 1978. His PhD dissertation [19], the starting point of his research work, already contained the seeds of many of the ideas and results on belief functions that Philippe Smets was going to develop in the next two decades. Philippe Smets was the founder in 1985 of the IRIDIA laboratory (Institut de Recherches Interdisciplinaires et de Développements en Intelligence Artificielle) at ULB, and its director until he retired in 1999. Under his leadership, IRIDIA became a major Belgian research institute in Artificial Intelligence and related topics, and an internationally renowned place. Due to the unusual personality of Philippe Smets, IRIDIA was also, in the words of his present director, a very unique place to work: it was Philippe's idea that in order to be a good place to work and think an institute should first be a good place to live. A place where people enjoy life, and a stimulating place where to share ideas, this was what Philippe Smets had turned IRIDIA into. All scientists who knew him and worked with him can testify about Philippe's knack for sharing his enthusiasm about unchartered territories of uncertainty modeling, especially if such scientific discussions could take place in a good restaurant. He was also a very open-minded person, caring for younger researchers, helping them endlessly. After his retirement in 1999, Philippe had more time to develop his own research

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works, visiting different academic institutions, and cooperating with many colleagues in the world.

Uncertainty representation and management is a central issue in Information Fusion, and the contribution of Philippe Smets in this area is enormous. His name is primarily associated with the "Transferable Belief Model" (TBM), a subjectivist and non probabilistic view of the Dempster–Shafer (DS) theory of evidence [49,43]. Some of the main ideas underlying the TBM are:

- the interpretation of belief functions as representing weighted opinions held by an agent, irrespective of any underlying probabilistic model [30,36];
- a clear separation between the *credal level*, where beliefs are entertained, and the *decision level* where standard utility theory applies, the belief functions being converted into probabilities using the *pignistic transformation* [26,34,16];
- the notions of unnormalized belief function and unnormalized conjunctive rule of combination, and the interpretation of the mass $m(\emptyset)$ assigned to the empty set, under the *open-world assumption*, as a degree of belief in the event that the frame of discernment does not contain the true value of the variable of interest [25, 29].

He contributed more than 100 papers to this theory, and to its comparison with alternative theories of uncertainty such as Bayesian probability theory [24], imprecise probabilities [17,36], random sets [31], and possibility theory [27]. He also contributed to a better understanding of fundamental issues concerning the representation of uncertainty [28,3,4,41,42]. Among his key technical contributions, let us particularly mention

- the axiomatic justifications for the Dempster's rule of combination [25], for the use of belief functions [35,32,39] and the pignistic transformation [47];
- the study of the relative information content of belief functions via the notion of specialization matrices [11];
- the Generalized Bayesian Theorem [33], an extension of Bayes' theorem where conditional and a priori probabilities are replaced by (possibly vacuous) belief functions;
- the canonical decomposition of a belief function, which paves the way to the bipolar representation of knowledge [37];
- the development of algorithmic tools for the easy computational handling of belief functions, including the Fast Möbius Transform [9,10], algorithms for reasoning in evidential networks [54,56,55], and a matrix calculus for belief functions [46].

In addition to these and other important theoretical contributions, Philippe Smets attached a great importance to practical applications [44] during all his life. His initial motivation for studying uncertain reasoning was the modeling of medical diagnosis [19,18,38,40], but he later became increasingly interested by engineering applications and developed, with co-workers, methods for classification [8], sensor fusion [7], data association [1,15], tracking [53,14], target identification [2,13], etc.

For many years the management of uncertainty community and the fusion community conducted research without much communication in between. This changed in 2000 at the 3rd International Conference on Information Fusion held in Paris, France. Philippe Smets made significant contributions in bringing the two communities closer. At the Paris conference he gave a plenary talk entitled "Data Fusion in the transferable belief model" describing numerous practical data fusion applications using his TBM model [45]. He also continued his participation with the information fusion conferences by giving very well received tutorials on the TBM at the 2002 and 2004 Information Fusion conferences, in Annapolis, USA and Stockholm, Sweden. In 2004, he was a member of the program committee, presented a paper on the "Kalman filter and Joint Tracking and Classification in the TBM framework" [53] that was selected for a forthcoming special double issue on the Fusion 2004 conference with the journal Information Fusion later this year. He also participated with the Information Fusion conference in 2005 serving as a reviewer, authoring a paper on counter-deception with the TBM [48] and was scheduled to give one more tutorial on the TBM, but was unable to attend the conference and do so. At the upcoming 9th International Conference on Information Fusion (Fusion 2006) in Florence, Italy this July 2006 a special session on belief functions will be organized in his memory. His impact on the information fusion community was great. Most authors publishing papers on belief functions refer to his TBM model. As a simple example, all authors in the belief function sessions at the 2004 and 2005 Information Fusion conferences did so, spanning application fields from military to medical applications. It is safe to conclude that his impact in the information fusion community has become as significant as it has been for a long time in the management of uncertainty community.

Although his main research focus was on belief functions, Philippe Smets also wrote noticeable papers in fuzzy logic and possibility theory. His first conference paper in 1977 relates belief functions and fuzzy sets [50], and was the basis for his definition of the degree of belief in a fuzzy event based on a Choquet integral [21,20,23]. Later with Paul Magrez, he provided an original axiomatic justification of Lukasiewicz implication in the setting of fuzzy if-then rule-based reasoning [51,12]. He also very early (in 1982!) pointed out connections between likelihood functions and possibility measures [22] and recently (in 2002) provided the basis for an operational semantics of quantitative possibility theory [5,6].

Philippe Smets was not only a visionary scientist, but also a highly efficient organizer. In particular, he was instrumental in the development of the research

community dealing with uncertainty in artificial intelligence. He was indeed the main coordinator and the prime contractor of a series of European workshops or projects (DRUMS – I and II), that gathered many researchers working on different uncertainty approaches. These projects resulted in a series of edited volumes on Non-Standard Logics for Automated Reasoning (with A. Mamdani, D. Dubois and H. Prade, Academic Press, New York, 1988), on Uncertainty Management in Information Systems (with A. Motro, Kluwer Academic Publ., 1998), on Defeasible Reasoning and Uncertainty Management Systems (a Handbook series in 7 volumes, with D. Gabbay, Kluwer Acad. Publ., 1998.), or on special issues of Journals on Uncertainty, Conditionals and Non-Monotonicity (Journal of Applied Non-Classical Logics 1(2), 1991), or on Data and Knowledge Fusion (Int. Journal of Intelligent Systems 16(10–11), 2001). Especially worth mentioning is Vol. 1 in the DRUMS series, that he edited himself (Quantified Representation of Uncertainty and Imprecision, Kluwer Acad. Publ., 1998), which gathers a wide range of contributions from classical and non-classical probability theories to multi-valued and fuzzy logics. It is particularly characteristic of Philippe's concern for a unified view of uncertainty theories that may reconcile logic and probability.

In the same spirit, Philippe Smets is also the father of the European Conference on Symbolic and Quantitative Approaches to Reasoning with Uncertainty (ECSQARU), which has taken place every two years since 1991. He was also an active participant of the annual Uncertainty in Artificial Intelligence (UAI) Conference in the nineties and was the first European UAI co-program chair in 1991. He served on the editorial boards of many journals including the *International Journal of Approximate Reasoning*, the *Journal of Logic and Computation*, *Information Sciences*, *Fuzzy Sets and Systems*, the *IEEE Transactions on Fuzzy Systems*, the *International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems*, the *Journal of Applied Non Classical Logics*, and *Mathware and Soft Computing*.

Philippe Smets was a highly recognized and respected researcher in the Artificial Intelligence community. His innovative work on the treatment of belief functions is well known and appreciated by everyone in the field. He was primarily a researcher combining a vast culture and interest on classical and non-classical approaches to uncertainty (ranging from statistics to non standard logics); with a will to develop original lines of research that significantly depart from traditional views. For many of his colleagues, and us in particular, he was much more than that; he was the friend, the careful adviser, the companion of so many beautiful research projects. Thanks to his keen work, his open-mindedness and his great human qualities, he had succeeded in creating and federating a whole community of researchers in Europe, through a series of projects and conferences of which he had been the principal carrier. His sudden illness and his death while he was still in full creative activity came as a terrible shock, for us, for all his friends and colleagues, and many of us feel like orphans. He will be deeply missed for a long time. But one may venture to predict that his published works will continue to be read by future researchers in statistics and uncertainty, as being seminal contributions written by a XXth century major scholar in the formal representation of belief.

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