Scientific Evaluations: How Misunderstandings and Disagreements May Last

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Abstract: What happens when scientists invoke multiple orders of worth and use heterogeneous principles of evaluation to publicly assess the validity and value of a scientific statement? Based on case study in the field of artificial intelligence, I argue that straightforward agreement is not inevitably reached. On the contrary, misunderstandings and antagonistic viewpoints may last.

Keywords: Evaluation, Misunderstanding, Disagreement, Demonstration, Scientific Debate, Culturalism.

Scientific Evaluations:
How Misunderstandings and Disagreements May Last

Claude Rosental[1]

How are claims and proofs of theorems assessed in artificial intelligence (AI)? In particular, what happens when AI scientists use heterogeneous principles of evaluation to produce antagonistic judgments about the validity and value of a demonstration expressed in symbolic or ordinary language? In order to address these issues, I study how a well-known paper in artificial intelligence has been publicly assessed in the framework of a recent debate. I analyze how multiple orders of worth have been mobilized in this scientific debate, and I examine its dynamics and outcome. Why study this?

Scientific controversies have been abundantly studied since social studies of science have developed (Bloor 1976; Collins 1985; Latour 1987). However, AI and its debates have not attracted much attention compared to the experimental sciences and their controversies (Collins 1990; Guice 1998). Besides, recent studies of assessment practices suggest that analyzing tensions between principles of evaluation represents a fruitful approach if one wants to grasp the ins and outs of science in development (Lamont 2009; Rosental 2010). This approach may allow us to compare assessment practices in different social spaces, in particular in the artistic and scientific fields (Quemin 2005). It is also helpful to understand how antagonistic references to separate orders of worth (Boltanski and Thevenot 2006), dissonances between different evaluative principles (Stark 2009), or irritations between value systems (Hutter and Throsby 2008) may be a source of innovation. Finally, it represents an opportunity to investigate if conflicts or dissonances between different evaluative principles are always overcome, or if, on the contrary, they may last - even in science.

The debate under study here originated in a paper written in the 1990s by an assistant professor at the University of California San Diego, Charles Elkan (1993). This paper was published originally in the proceedings of the annual conference of the American Association

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for Artificial Intelligence (AAAI). Elkan denounced the "paradoxical success" of electronic and computer applications of a theory called "fuzzy logic." Fuzzy logic is a subfield of artificial intelligence that has been developed since the mid 1960's (Zadeh 1965). Its technological applications, such as fuzzy cameras and washing machines, may be found in numerous industrial sectors (Rosental 2004).

Elkan's denunciation was based on the proof of a theorem stating that fuzzy logic, characterized by a system of four specific axioms, is in fact nothing but classical binary logic. The author presented this result as a direct challenge to one of the founding ideas of fuzzy logic, which is supposed to allow for the expression of an infinite number of degrees of truth along a continuum with poles true and false (like half true for example).

The paper was published in a context of strong competition between proponents of various approaches to artificial intelligence. It attracted a great deal of attention and generated a major controversy in this field. Initially, points of view were exchanged in an electronic bulletin board (or newsgroup) devoted to fuzzy logic, called *comp.ai.fuzzy*.

Authors and readers of messages posted on *comp.ai.fuzzy* were, for the most part, academics, researchers, and engineers working for universities and industrial organizations in the field of AI, and in particular of fuzzy logic. Due to its absence of selective or editorial constraints, the forum helped to open relatively broad debate, allowing the public expression of many points of view. *Comp.ai.fuzzy* became the main locus of an exchange of opinions on Elkan's paper for a period of 6 months, until these first reactions were consolidated in the form of articles published by specialized journals.

Public access to the electronic forum's archives allowed me to reconstruct the discussions. I also interviewed the actors involved in the debate and had access to the content of private mail. Besides, I carried out ethnographical observations in places such as an AI conference and I analyzed works published in AI journals. All this allowed me to relate the authors' written production to various actions conducted outside the electronic forum. I could also grasp the dynamics of the debate and its outcome.

Participants to the debate used different principles of evaluation to publicly assess Elkan's demonstration, as well as fuzzy logic itself. Public evaluations took the form of

demonstrations supporting, or counter-demonstrations against, Elkan's views. These demonstrations were themselves subject to public assessment. Principles of evaluations of Elkan's demonstration, of the demonstrations of his interlocutors and of the properties and success of fuzzy logic were based on logical, technological, economic, business, organizational, psychological, linguistic, sociological and cultural considerations. Participants invoked various orders of worth of fuzzy logic and of the arguments produced during the debate. These orders of worth corresponded to different value systems that were shaped among others by cultural or anti-culturalist approaches. I will examine some of the demonstrative registers used by the arguers before I analyze the dynamics of the debate and its outcome.[2]

Technological Assessments of a Paradox

Elkan put forward the contradictory character of fuzzy logic in his article in order to denounce the paradoxical dimension of the success of its putative applications. The display of properties of fuzzy logic in computer systems thus came to be opposed in *comp.ai.fuzzy* to the results of symbolic demonstrations, or else those properties were evoked, on the contrary, in order to underline the correctness of these demonstrations. In other words, the same message could include intersecting considerations on Elkan's proof and the causes of the working of a given electronic device. The way a particular machine worked could for example be attributed to quite general properties of fuzzy logic, and presented by that very token as calling back into question the validity of Elkan's overall demonstration (including the proof of his theorem regarding the contradictions of fuzzy logic).

The debates dealt in fact not only with the reality and the nature of the properties of fuzzy logic, but also with the modalities of the staging of those properties in the texts of the various participants. Readers could then witness a sequential linking of constructionist and deconstructionist undertakings, the appearances of properties attributed to fuzzy logic in certain messages being deconstructed to the profit of others during later exchanges.

It is now useful to study closely, with an eye to pinpointing their specificity, the principles of evaluation of fuzzy logic properties and of demonstrations weighing against each

[2] For further analysis of the debate and its dynamics, as well as for preliminary versions of parts of this paper, see Rosental (2003, 2008).

other in the forum. I will begin by analyzing a first excerpt from a message written by J. Wiegand from Temple University that puts the properties of fuzzy logic in electronic and computer systems on display in the face of the critiques developed by Elkan:

> >[M]ost of the applications in the control area using FL [Fuzzy Logic]
> >have been too simple to date to show the inherent
> >weaknesses of the technique.
>
> Like the fuzzy predictive controller that handles the Sendai trains? Or the Otis elevator scheduler that uses both predictive and interactive inputs? How complicated does it need to be? 100,000,000 rules?
>
> >Once these weaknesses become apparent then FL will
> >turn out to be just as problematic to use as other
> >knowledge-based techniques (and he seems to imply
> >possibly more so).
>
> Well, it IS problematic if you don't understand it. It has taken me well over three years to grasp the philosophical basis of FL. What other AI technique has the properties of universality and proximality? Just neural nets, and they are closely related to FL. The Japanese tried AI in their Fifth Generation project, and it got them nowhere. But now they lead the world in fuzzy patents. Comparison? Just the opposite of what Elkan is saying. . . . The properties of FL should be obvious to anyone who has investigated it with an open mind.[3]

This excerpt is an example of calling Elkan's demonstration back into question without going through a critique of the details of the symbolic proof of the theorem. The evaluation of fuzzy logic properties in play stems from a practice of *bringing to the fore* (*faire valoir*): It consists, in the face of an enterprise of devalorizing fuzzy logic, of seeking to display, magnify and valorize properties of fuzzy logic in electronic equipment. To this end, Wiegand exhibits commercial products emblematic of brands and of a technology, fuzzy logic in this case. The author presents these devices as literally embodying certain properties of fuzzy logic. The successful operation of controllers used by the Sendai train and an Otis elevator is thus put into the balance against Elkan's demonstration.

[3] J. Wiegand, *comp.ai.fuzzy*, message 767. Use of the symbol ">", generated by e-mail software in the formulation of answers to former messages, corresponds to quotes.

The author uses additional demonstrative registers here. Paralleling the reference to the operating principles behind trains and elevators, Wiegand evokes elements as heterogeneous as Japanese leadership in the realm of fuzzy patents and the so-called impasse of a research program in AI mobilizing a logic with two truth values (the “fifth generation project”) to exhibit very general properties of fuzzy logic, characterized as “philosophical” (like the property of “universality”).

Wiegand goes on to mobilize an additional demonstrative register: a discourse about the self-evidence of the properties of fuzzy logic taken as an object. Wiegand insists on the ideal self-evidence of certain properties of fuzzy logic; then, to account for the fact that this self-evidence may not appear as such in Elkan’s eyes, he invokes contingencies and, above all, psychological resistances. For the author, such blindness may stem from a biased attitude that originates in the mind of its victim: a lack of open-mindedness would be its cause. Moreover, Wiegand evokes the long process of decantation that may prove necessary to accede to that self-evidence, however immediate it may be from an ideal viewpoint. That affirmation is shored up by testimony, since the author makes much of the three years he needed to apprehend it as such.

Elkan formulated a response to these criticisms and to other participants to the debate in an elaborate message he posted on the electronic forum. The set of demonstrative registers he mobilized for the occasion needs to be analyzed with special care:

> FUZZY LOGIC IS USEFUL IN ENGINEERING The paper is not meant to be “damning of FL for productive engineering purposes.” Fuzzy logic has been and will be very successful in heuristic control applications, for example for Sendai subway train braking and for elevator speed control. However these systems are small compared to other knowledge-based systems. They use less than 100 rules, compared to many thousand for many expert systems. The fact that Japan leads the world in fuzzy patents and in fuzzy controllers has several plausible non-mystical explanations: (a) Japan leads the world in manufacturing high-technology consumer products. These are the largest natural application area for fuzzy controllers. (b) Japan leads the world in patents overall. The number of patents per year that a company chooses to take out is a business decision influenced by many concerns and is not perfectly

> correlated with the company's overall success in research OR development. (c) Fuzzy logic controllers are engineered in an iterative, heuristic process of incremental improvement. This is congruent with traditional Japanese strengths in incremental quality improvement. (d) The reasons fuzzy controllers work well are that they (1) are rule-based and (2) have many tunable numerical coefficients. More applications outside Japan may use these two features without using the keyword "fuzzy."[4]

Here, Elkan accompanies his original demonstration by translating it, that is, by reformulating it thanks to new demonstrative registers. In particular, he refuses to attribute the success of fuzzy systems to properties of fuzzy logic. He deconstructs that causal chain in order to make a new one. He associates the large volume of fuzzy controllers produced in Japan with a general economic dynamics, Japanese leadership in the realm of production of high-technology goods (the cause of the success evoked is thus displaced a first time: it stems from a more general phenomenon). Then he dissociates the data concerning the volume of patents held by Japanese companies from the success of these companies in the realm of research and development. He then associates the creation of fuzzy controllers in Japan to a Japanese cultural specificity in working methods: the latter would rest on step-by-step improvements in the devices that are being developed. Finally, he associates the successful operation of fuzzy controllers not with specific properties of fuzzy logic, now, but with the fact that they are developed on the basis of rules and numerical coefficients capable of being optimized.

Elkan thus deploys a set of heterogeneous demonstrative registers to defend his original demonstration: socio-techno-economic considerations on the market in high-technology goods, putative expertise in the organization of labor, production, and management in Japanese businesses, as well as a paternity trial bearing on the causes of the proper functioning of fuzzy controllers - or in other words, a trial bearing on what engenders this proper functioning. Elkan ends up advocating that the emblem "fuzzy logic" no longer be used to account for these mechanisms.

[4] C. Elkan, message 794.

In the face of this work of respecification of the causal chains, several participants in *comp.ai.fuzzy* plunged into analogous paternity trials. Some sought to bring the emblem of fuzzy logic to the fore once again by presenting the properties of fuzzy logic as embodied in technological devices. The electronic forum was thus the theater for a series of reevaluations based on appearances.

Cultural and Anti-Culturalist Evaluations

Some participants in *comp.ai.fuzzy* attempted to defuse Elkan's critique and in particular to show that fuzzy logic was not the victim of the paradox evoked, by positing a cultural incommensurability between the approach taken in Elkan's demonstration and the approach attributed to fuzzy logic. In their messages, they presented fuzzy logic as indissociably linked to an Eastern mode of thought and to Asian civilization. The concepts of binary logic, especially what they referred to as "the" – supposedly unique and well-identified - notion of paradox, associated with Western civilization and a tradition of Aristotelian thought, would not make it possible to grasp the subtleties of fuzzy logic.

By adopting this culturalist position, some participants in *comp.ai.fuzzy* attempted to show that the contradictions Elkan evoked were relative to a mode of thought that valorized a particular notion of precision, one that cannot be retained in efforts to conceive of the coherence that is proper to fuzzy logic and the value of fuzziness. A new way of evaluating Elkan's demonstration was thus introduced to short-circuit the debates over the details of the proofs. This evaluation proceeded from a form of cultural relativism.[5] The following excerpt of a message by J. Wiegand illustrates this approach:

> >Last week at AAAI, a paper by Charles Elkan of UCSD was given
> >with the above title. It concludes that a "standard version" of fuzzy
> >logic collapses mathematically to binary logic.
>
> I should hope so! Fuzzy logic is the generalization of binary logic. It sounds as if Mr. Elkan has slipped back into the trap of Aristotelian logic. Witness the title: "The

[5] This form of slippage from cultural relativism to logical relativism can be compared to the possible passage from cultural relativism to aesthetic relativism. On this subject, see Menger (1989).

> Paradoxical Success . . .” There are no such things as paradoxes, only semantic dead-ends that result from the Western mindset.[6]

The demonstrative schema used in this message is easy to identify. Rejecting the very notion of paradox, the author opposes Elkan’s patient demonstrative efforts. The notion of paradox, mobilized by Elkan to stigmatize an impasse proper to the approach of fuzzy logic, is exhibited here as an impasse inherent in the Western mode of thought. To organize this shift of focus, the writer identifies and then disparages as a whole the tradition of thought of Western civilization in general. Wiegand is not simply adhering to cultural relativism here; he moves on to establish a hierarchy among the cultures he identifies. The exhibition of fuzzy logic as a generalization of binary logic (also labeled Aristotelian) leads him to consecrate an Eastern mode of thought as triumphing over the failures (the “impasses”) of the Western mode of thought. Asserting the opposite of the text he is citing, the writer thus offers a new evaluation of Elkan’s demonstration, which is reduced to an absolute misunderstanding of fuzzy logic that originates in a fundamental cultural limitation.

In the face of such a positioning of the debate, several participants intervene to denounce an excessive culturalism. We can analyze some of the demonstrative strategies used to confront this new evaluation by studying excerpts from a few messages. I will begin by examining a response formulated by Elkan himself to this type of critique:

> PHILOSOPHICAL AND MATHEMATICAL ISSUES The claimed binary opposition between a Western discrete mindset and a continuous Eastern mindset is ridiculous. In the history of Western thought, there have always been competing holistic, continuous and reductionist, discrete points of view. It makes reasonable sense to talk of “Western” thought because there has been continuity in philosophy from the Greeks to the present. I know almost nothing about non-Western philosophy. However I am willing to conjecture that “Eastern” thought is much less of a unitary tradition, and that in any particular division of Eastern thought (for example Confucianism) there are also parallel strands of continuous and discrete points of view.[7]

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[6] J. Wiegand, message 767.
[7] C. Elkan, message 794.

To defend his demonstration and bring back into view contradictions proper to fuzzy logic, Elkan adopts a strategy consisting of calling the nature and scope of the dichotomy between Eastern and Western modes of thought back into question. To this end, he sets himself up as a historian of civilizations and philosophy: he challenges the distinctions made between two modes of thought by evoking the diversity of their respective tendencies, their hybridization, even their possible unity; in the process, he formulates a thesis about the continuity of Western philosophical thought from the Greeks to our own day, and develops hypotheses on the history of the various tendencies of Confucianism.

We see here to what extent debates about an article in artificial intelligence can consist in writing or rewriting the cultural history of philosophy and civilizations. The work of the actors, far from being limited to the drafting of symbolic proofs, also consists in producing reflections stemming from epistemology, from the history of science, or even from philosophy and history in general.

In fact, it may be noticed that the development of the exchanges on *comp.ai.fuzzy* is related to the introduction of an increasing volume of considerations, including competing viewpoints as to what it is acceptable and important to debate, and what can legitimately stem from a scientific exercise. In other words, the disagreements spread to the definition of borders between what may or may not constitute an acceptable element for discussion, between what may or may not be considered as legitimately arising from a debate in artificial intelligence, or between what does or does not constitute a good evaluation.

Elkan benefits here from the support of converging points of view. Several participants express decided and sometimes virulent opposition to the type of culturalist thesis examined above, as the next excerpt attests:

> I do object to the characterization of anyone who doesn't use or accept fuzzy logic as “Aristotelean” or “Western,” as if fuzzy logic were the Holy Grail, and the entire universe has changed since its introduction.[8]

[8] W. Dwinnell, message 769.

The attempt to neutralize Elkan's demonstration by recourse to culturalism hardly garners the support of all. It is met with vigorous hostility from contributors who deem this register unacceptable. In the message above, the writer contests a form of reductionism that consists in judging that the rejection of fuzzy logic by an individual would stem essentially from the latter's Western origins. He also simultaneously opposes any reconstruction of the history of civilizations around the discovery of fuzzy logic, targeting the praise of fuzzy logic and Eastern civilization simultaneously.

The shared rejection of cultural relativism paired with a form of orientalism gives Elkan an opportunity to rally actors around his cause. Antagonism constitutes the glue binding together several evaluations intended to neutralize a demonstrative register that threatened Elkan's demonstration, with at least indirect support for the latter as a consequence.

As another example, the various ways in which a matter of fashion in Japan is invoked should be noted: an infatuation with fuzzy systems on the national scale would explain the surge in their development. This thesis is suggested in the following passage:

> >One possible reason for Fuzzy's popularity there is
> >that it fits iterative development so well - not
> >because of some attraction for imprecision.
> >Controlling subway cars doesn't have much in common
> >with Zen archery.
>
> Apparently not, it seems that in Japan, Fuzzy Set Theory is a fad and anything fuzzy is to the consumer a warm and . . . (wap!) . . . {sorry}[9]

This contributor rejects the culturalist arguments in his turn even as he gives a new orientation to the readers' shift of focus, a shift initiated by the author he cites. Instead of exhibiting a discourse celebrating fuzziness and explaining its emergence by invoking a structural equivalence between techniques for perfecting fuzzy systems and traditional working methods, he refers to a social phenomenon, a fashion affecting Japanese consumers. The Japanese are not shown here as determined in their behavior by a distinctive mode of

[9] M. Aichlmayer, message 789.

thought. Their singular behavior is explained as a function of a local phenomenon, whose principle (fashion) is not itself associated with any eastern cultural specificity.

Here, the indirect defense of Elkan's demonstration in the face of orientalism thus passes through a reformatting of the Japanese mode of thought, evaluated according to a more universalist mode. This reformatting is pursued in other texts, moreover, through the invocation of linguistic particularities. In these messages, instead of invoking differences in mental structures, the writers put forward specific connotations of the term "fuzzy" in English and in Japanese in order to account for the differentiated infatuations with fuzzy logic in the United States and in Japan. The following messages are illustrative:

> Fuzzy seems a very practical tool for us. Now if it only had a better name . . .[10]
>
> >The fact that Japan leads the world in fuzzy patents
> >and in fuzzy controllers has several plausible non-
> >mystical explanations: . . .
>
> Here is another: Both Japan and America use the same word "fuzzy." In America, the word has many old negative connotations. In Japan, it has no old connotation, positive or negative. (And it is a wonderful sounding word.) Thus, "fuzzy camera" sounds high-tech in Japan, and goofy in the U.S.[11]

In these two texts, and more specifically in the second, particular attention is paid to the word "fuzzy" in order to account both for a certain hostility to fuzzy logic in the United States and for the attractiveness of fuzzy logic in Japan. The writers do not invoke the existence of distinct mental structures that would characterize Japanese people on the one hand, Americans on the other. They assess the dissimilar effects that the use of the same expression in two different spaces allegedly induces, in terms of linguistic idiosyncrasies. In other words, the reformatting of the Japanese mode of thought that we are considering here depends on the substitution of a sociolinguistic register for an orientalist register. It is no longer a question, in these messages, of a gap between two civilizations, but simply of language effects. The people concerned are no longer so foreign; they are endowed with identical cognitive and behavioral faculties.

[10] H. Bonney, message 787.
[11] C. Kadie, message 798.

Dissonance and After: The Emergence of a Collective Statement

We have seen how heterogeneous principles of evaluation were used on *comp.ai.fuzzy* to produce antagonistic judgments about the value and success of fuzzy logic, as well as the validity and value of Elkan's and other arguers' demonstrations. Multiple orders of worth of fuzzy logic and of everybody's arguments were invoked in the framework of the debate. They were based on logical, technological, economic, business, organizational, psychological, linguistic, sociological and cultural considerations. What came out of this dissonance, if not cacophony? Could the latter be transcended in one way or another and lead to an innovation? If so, what did this innovation consist of? In order to address these issues, it is now useful to study the dynamics of the debate and its outcome.

Although highly fragmented and contradictory points of view about Elkan's paper and fuzzy logic resulted from the discussions on *comp.ai.fuzzy*, some few points of view began to acquire more visibility than others after a few months: those of Elkan and those of fuzzy logic personalities working in computer science, such as Didier Dubois and Henri Prade from the CNRS (France) and Enrique Ruspini from SRI (United States). Before they could express themselves in journals, Dubois, Prade, and Ruspini had put in token appearances in the forum to counterbalance the proliferation of representations of fuzzy logic, and of Elkan's paper, that were too distant from what they considered to be reasonable or desirable. Some researchers adopted several mechanisms to make certain messages more visible than others: citations and frequent reappearance, with placement of some texts in a data base accessible via Internet, the electronic address of which was often displayed.

Mechanisms such as these promoted differentiated visibility of messages; the texts displayed in the forum did not have the same impact on the shaping of representations of Elkan's paper. The capacity for conviction that could be granted to these new demonstrations and counterdemonstrations was therefore not only limited; in the very frame of this material economy of access to texts, it was also variable.

Messages posted on *comp.ai.fuzzy* show that the shaping of representations of Elkan's paper in the context of the forum did not derive from a sum of individual homogeneous examinations obtained from attentive readings of an easily accessible text (Rosental 2008).

Nor was this process reducible to an exchange of arguments, or even discussions, given the scriptural dimension of these interactions and the aforementioned material economy of access to texts. The process of dialectical evaluation to which Elkan's paper had been subjected by no means resulted in a clear and uniform collective view. Even the apparently simple question of the exact scope and significance of the theorem was the object of a multiplicity of representations. Now what were the consequences, from the point of view of representations of Elkan's demonstration, of the continuation of debate in other forums?

In the eyes of many leaders in fuzzy logic, the publication of Elkan's paper could have resulted in a substantial loss of credibility for their research domain. Several of these leaders rallied together to organize a counterattack on several fronts. In conjunction with their intervention in the electronic forum, they addressed a protest letter to the organizers of the AAAI, and made plans for the publication of several responses to Elkan's article.

Thus, several months after the conference, the center of debate shifted from the electronic forum to journals that specialized in artificial intelligence. This shift of exhibited interaction to other arenas was accompanied by a radical transformation in the time-scale of debates and a substantial rise in the barriers to be surmounted to stay in the game. Making a point of view public now required authors to produce polished texts and to subject them to editorial constraints. Some authors could reuse many arguments they had posted in the electronic forum, but not all of them, and some of them needed to be reformulated. Making a point of view public also required full investment in a milieu in which interindividual relations and reputations were essential in the processes of selecting (and often commissioning) articles, as Davis and Hersh (1987) have noted for the field of mathematics.

Some of the leading researchers in fuzzy logic already had extensive experience in facing criticisms. The reactions of this group to Elkan's article were thus based on already well-established know-how and wide experience with methods of counterattack. Endowed with these specific competencies, several of the defenders of fuzzy logic united to formulate a response that would stand in deliberate contrast to the dissonance, if not cacophony of messages in the electronic forum. The repetition, the constant attack on the same elements of counterproof, was a source of discredit to Elkan's theses but was at the same time likely to give the impression that all researchers in fuzzy logic stood against Elkan in a knee-jerk fashion. No fewer than eight major researchers in fuzzy logic, including Dubois and Prade,

cosigned an article whose content was close to that of a message in the electronic forum, thus subjecting Elkan's point of view to the test of numbers in case their approach was not enough to marginalize it (Berenji et al. 1994).

The multiplicity of counterdemonstrations formulated in the electronic forum were thus succeeded by only a small number of interventions by recognized spokespersons for fuzzy logic organized around united points of view. "The" theorem of Elkan (as if its formulation was unique and clearly identified) was presented, in particular, as a result that was in fact very simple when reformulated appropriately, known for a long time and without any effect on the foundations of fuzzy logic. The image of two-sided confrontation between Elkan's viewpoint and that of researchers in fuzzy logic was progressively built up through additional approaches such as publication in journals (and shortly afterwards in the electronic forum) of abstracts of papers, in which the standpoints of participants in the debate were simplified and frozen in a conflict reduced to its simplest expression.

As mentioned above, considering editorial constraints, which required a heavier investment in contributions to the debate, the possibilities for publicly expressing a point of view were substantially reduced for some. The journal *IEEE Expert*, by eventually devoting a special issue in August 1994 to the debate on Elkan's article, had nevertheless opened an exceptional forum for the question. But even this apparent opening remained relatively limited: The fuzzy logic authors it included were “stars” of the field, such as Didier Dubois, Henri Prade, Enrique Ruspini, and the computer scientist Lotfi Zadeh from UC-Berkeley, who was generally reputed to have invented fuzzy logic.

The number of participants in the debate was very small, and most of those who earlier had participated in the interaction in the forum disappeared. This did not mean, however, that they had been convinced by the very few emerging points of view and had adhered to them. The sudden unity stemmed from the fact that some had managed to remain in the debate and to enhance its resonance, while others had kept silent because they were unable or unwilling to overcome the obstacles to asserting their opinions. This singular dynamic worked powerfully toward stabilizing the debate. What about Elkan's approach and that of his partisans? How did they react to this counter-attack?

The series of viewpoints researchers in fuzzy logic expressed in the forum and in private letters sent to Elkan, as well as in personal conversations with him, had allowed him an opportunity to clearly perceive the divisions that existed between researchers, especially regarding the definition of their own research objects and their representations of his arguments. The existence of these evolving rifts gave Elkan the opportunity to multiply reformulations and personalized approaches. This, in turn, afforded him the chance to quiet antagonistic reactions and to solidify his results – or, more precisely, what he could re-present in each case as the nature of his results. This was a considerable resource for Elkan, for it emerged in circumstances wherein little support for his theses had been publicly expressed during the months immediately following publication of his article.

Elkan thus had the opportunity to elaborate and test several different reformulations on diverse interlocutors. He adapted his talks to suit his interlocutors and the forums at which he presented, adjusting his presentations in a differentiated, evolving, and sometimes personalized way. To a certain extent, Elkan was more involved in dramatic than in communicative acting (Goffman 1959; Habermas 1984). His talks could possibly help to curb the virulence of the counterattack by fuzzy logic researchers without, for all that, deceiving researchers in so-called classical AI.

For example, Elkan formulated the following private answer to criticism of his supposedly implicit introduction into his proof of an axiom (equivalent to the law of excluded middle[12]) rejected by fuzzy logic, in order to obtain the theorem: The average user of fuzzy logic could fail to be aware of the impossibility of mobilizing this type of axiom, despite it being so usual. Although, according to one of Elkan's interlocutors, the author affirmed on the day he delivered his paper at the AAAI conference that he did not see why he could not introduce the law of the excluded middle, Elkan subsequently claimed, in another context, that he had used an equivalent axiom in his proof by attributing an essentially educational value to his theorem.

Such nuances underline the primacy of public expression for grasping acts of enunciation (Quéré 1990). Because his article, a singular material device launched in the world, eventually proved somewhat ineffective in countering criticism, Elkan added to it by

[12] The law of the excluded middle is generally defined as, “every statement is either true or false.”

producing new texts and new speeches. He thus provided new instructions for his text's interpretation and general comprehension, thereby forging new tools for changing readers' relationship to his original text.[13] Such adjustments also helped to stabilize debate because they limited disagreements by making them appear, retrospectively, and at least partly, as misunderstandings (which differed, of course, depending on the interlocutors and the publics).

Elkan thus undertook a fundamentally different exercise than did his opponents. While their idea was to organize their debate as a unified and coordinated counterattack, Elkan proved to be a highly mobile target and was a talented mediator capable of producing different and evolving responses. He had to be more skilled at improvisation than orchestration. For him this exercise appeared to be no routine exercise but rather a new, ad hoc approach.

Yet after a few months Elkan had forged tools that enabled him to limit his production of differentiated answers that had become consuming, both in time and energy. In a new version of his article, published in the journal *IEEE Expert* and available on the Internet at the end of 1993, he perfected reformulations that he could present to widely diverse publics. Considering their polysemic nature, their effect was twofold. After the different readers or listeners had read or heard these reformulations, they could adopt radically divergent points of view on the nature and meaning of his demonstration. But at the same time they could agree to grant it a form of validity and value that was obviously variable.

For example, in the new version of his text, Elkan stated that the four axioms he had used to prove his theorem offered an "apparently reasonable" description of fuzzy logic. This expression could be interpreted in different ways by its readers. For some researchers in fuzzy logic who were relatively well-informed as to current debate on the subject, the use of this expression might have signified that Elkan had taken into account criticism on the limited scope of his theorem, and that the misunderstanding was over. However, a reader who had little knowledge of the debates and fuzzy logic literature could attribute a far more general scope to his theorem.

[13] For an illustration over a longer period of the fully historical nature of readings in the field of mathematics, see Goldstein (1995) on the case of Fermat's theorem.

Elkan could easily use this type of text in discussions with proponents of so-called classical AI to assert that he had stood his ground and shown the limits of fuzzy logic. But he could also affirm to fuzzy logic researchers, supposedly without any contradiction, that he had essentially formulated constructive criticism and had delivered an educational message, to the point of being able to consider collaboration with them in the future. Indeed, after a long discussion with one of the leading figures in fuzzy logic, Elkan and his interlocutor had considered co-authoring a paper.

The polysemic nature of Elkan's text thus enabled him to assert its validity and value in his private interaction. He could also rely on a single reformulation of his article for all his answers, thus avoiding the need to multiply adjustments to suit the forums in which he had to express himself.

Yet the stabilization of Elkan's formulations caused the debate to run out of steam because different forms of agreement became possible. After *IEEE Expert* had devoted a special issue in August 1994 to reactions to Elkan’s article, in which a few papers by important representatives of both fuzzy logic and so-called classical AI were published side-by-side, there seemed to be no fundamentally new elements left to advance. Although these debates finally appeared to be drawing to a close, however, no real consensus had been reached. Partial agreement that seemed to have formed around the validity and value of Elkan's demonstration was simply apparent and must be understood in relation to the distribution of the distinct, and often antagonistic, points of view to which its expression corresponded. It was a matter not of a univocal statement overcoming or sublimating temporary divergences, but of a *collective statement* in Alain Boureau’s (1989, 1992) sense. The medievalist Boureau coined the term to refer to a “verbal or iconic fragment that creates around itself a certain convergence of languages and thoughts, through the play of a structural fuzziness allowing to capture a still implicit thematic and to welcome the most diverse projections and appropriations” (Boureau 1992: 1072).

Here, "the validity and value of Elkan's demonstration" may be seen as a collective statement as it was appropriated by each participant in the debate into its own specific mode of agreement, while at the same time the statement managed to serve as a point of coordination for various points of views regarding fuzzy logic. Thus, although it became necessary to talk about the relative recognition of Elkan's demonstration, such recognition

was possible only as a distribution of partly united representations in a void produced by the increasing scarcity of publicly expressed points of view.

Details of arguments and the way they were handled, no less than social positions and relations, all played a role in the dynamics of the debate under study and its outcome. A reductionist analysis that would have put exclusive attention to one of these dimensions would not have allowed us to grasp the social process at stake. More particularly, the changing shape and general evolution of representations of Elkan's demonstration - like the reduction of a set of points of view expressed publicly in a small number of contributions to journals - did not occur as a simple formulation of more or less convincing univocal arguments. Other factors also played a decisive role in this dynamic - especially polysemy, certain actors' capacities, depending on the case, to coordinate with, to consult, and to co-opt one another, to materially manage the visibility of their texts, to show flexibility by producing evolving and differentiated discourses, or to accompany their claims by reformulating them as much as necessary. Such competencies were all instrumental in stabilizing debate and played a key role in the emergence of a demonstration lastingly endowed with multiple significations.

Indeed, I found traces of comments on Elkan's article that supplemented citations in *comp.ai.fuzzy* and in specialized journals since 1994. A few articles have been devoted to continuing the debate,[14] but on the whole the controversy has clearly run out of steam since 1994. The arguments put forward have not been really new and have triggered no new outbursts of reactions. An analysis of the context of citations of Elkan's article provides some evidence that the representations of Elkan's paper have hardly evolved since summer 1994.[15] To date, the outcome of the process, as described here, appears to have lasted.

Lasting Dissonances and Misunderstandings

To conclude, one may say that the dissonant evaluations that were produced during the debate have led to a scientific innovation, namely the emergence of a collective statement - "the validity and value of Elkan's demonstration." This statement has become part of the world and served as a point of reference for various judgments and actions (Rosental 2008).

[14] For references, see Rosental 2008: 237–238.
[15] The analysis could be conducted thanks to Nec Research Institute's Citeseer Search Engine (http://citeseer.nj.nec.com) and the Science Citation Index.

To a limited extent, the scientific community has eventually recognized and valorized the last version of Elkan's demonstration that was produced after the first months of the debate. But these recognition and valorization have not been based on a simple process of conviction or on the clear victory of one side over others. Only partial agreement on the validity and value of the demonstration has been reached, largely based on misunderstanding. Besides, only a few contradictory points of view have become more visible than others finally. But it does not mean that those who became silent in public shared the same viewpoints. Conflicts between evaluative principles and what could be called different scientific cultures could not be overcome here. Most participants did not change positions once the debate was over: they stuck to their guns on different modes of evaluation of fuzzy logic and of demonstrations and kept contradictory views on the validity and value of Elkan's arguments.

This case shows how misunderstanding, like dissonance, may play a decisive role in the dynamics of the scientific field, no less than in other fields and social spaces. Such is the case of the artistic field in which experts produce a large set of dissonant evaluative principles (Quemin 2005). In other spaces, Proust (1927: 565–568) demonstrates, through his characters, how individuals have diverging viewpoints and very different ways of apprehending signs that might seem most likely to support a single interpretation and a programmed effect. Besides, people are often confronted with polysemic formulations that are intended to convey distinctly different messages to different actors. But such communicative aims regularly fail too. As a result, misunderstandings and dissonances represent significant aspects of ordinary life.

This case also illustrates how conflicts or dissonances between different evaluative principles and value systems may lead to an innovation – a collective statement here – although they may not be surmounted or transcended in a straightforward way. Dissonance is not necessarily resolved and may last, even in science. Scientific statements like technologies may have a "permanently beta" status (Neff and Stark 2004). But a stable status granted to a given scientific statement may be based in fact on permanent disagreement and misunderstanding. Contradictory viewpoints may co-exist until scientists die (Bloor 1978). Even under conditions that may seem favourable such as when science is taught, misunderstandings and disagreements (between students and professors) may not be resolved (Rosental 2009).

Since antagonistic viewpoints produced during a scientific debate are not inevitably transcended or sublimated in a clear-cut way, reaching transcendence or something equivalent to it appears to require very specific conditions of possibility that are not always met. This raises an important issue: Under what conditions can dissonances be transcended and in what sense? Hopefully, future research will help answer this question and help us better understand how innovations are socially produced, and what they are made of.[16]

References

Berenji, H. R., Bezdek, J. C., Bonissone, P. P., Dubois, D., Kruse, R., Prade, H., Smets, P. and Yager, R. R. (1994). A Reply to the Paradoxical Success of Fuzzy Logic. *AI Magazine,* Spring: 6–8.

Bloor, D. (1976). *Knowledge and Social Imagery*. London: Routledge.

Bloor, D. (1978). Polyhedra and the Abominations of Leviticus. *British Journal for the History of Science* 2(39): 245–272.

Boltanski, L. and Thévenot, L. (2006). *On Justification: The Economies of Worth.* Princeton, NJ: Princeton University Press.

Boureau, A. (1989). Propositions pour une Histoire Restreinte des Mentalités. [Propositions for a Limited History of Mentalities]. *Annales ESC* 6: 1491–1504.

Boureau, A. (1992). L'adage *Vox Populi, Vox Dei* et l'Invention de la Nation Anglaise (VIIIe-XIIe siècle). [The Proverb 'The Voice of the People is the Voice of God' and the Invention of the English Nation, 8-12th Century]. *Annales ESC* 4–5: 1071–1089.

Collins, H. M. (1985). *Changing Order: Replication and Induction in Scientific Practice*. London: Sage.

Collins, H. M. (1990). *Artificial Experts: Social Knowledge and Intelligent Machines.* Cambridge, MA: MIT Press.

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Davis, P. J. and Hersh, R. (1987). Rhetoric and Mathematics. In J. S. Nelson, A. Megill and D. N. McCloskey (eds.), *The Rhetoric of the Human Sciences: Language and Argument in Scholarship and Public Affairs*. Madison: University of Wisconsin Press, 53–68.

Elkan, C. (1993). The Paradoxical Success of Fuzzy Logic. In *Proceedings of the Eleventh National Conference on Artificial Intelligence*. Menlo Park, CA: AAAI Press. Cambridge: MIT Press, 698–703.

Goffman, E. (1959). *The Presentation of Self in Everyday Life*. Garden City, N.Y.: Doubleday.

Goldstein, C. (1995). *Un Théorème de Fermat et ses Lecteurs*. [One of Fermat's Theorems and its Readers]. Saint-Denis: Presses Universitaires de Vincennes.

Guice, J. (1998). Controversy and the State: Lord ARPA and Intelligent Computing. *Social Studies of Science* 28: 103–138.

Habermas, J. (1984). *The Theory of Communicative Action*. Boston, MA: Beacon Press.

Hutter, M. and Throsby, D. (2008). (eds.). *Beyond Price. Value in Culture, Economics and the Arts*. Cambridge: Cambridge University Press.

Lamont, M. (2009). *How Professors Think: Inside the Curious World of Academic Judgment*. Cambridge, MA: Harvard University Press.

Latour, B. (1987). *Science in Action: How to Follow Scientists and Engineers through Society*. Cambridge, MA: Harvard University Press.

Menger, P. M. (1989). *Les Laboratoires de la Création Musicale. Acteurs, Organisations et Politique de la Recherche Musicale*. [The Laboratories of Musical Creation]. Paris: La Documentation Française.

Neff, G. and Stark, D. (2004). Permanently Beta. Responsive Organization in the Internet Era. In P. N. Howard and S. Jones (eds.), *Society Online: The Internet in Context*. London: Sage, 173–188.

Proust, M. (1927). *The Captive.* In *Remembrance of Things Past.* Vol. 2. New York: Random House.

Quemin, A. (2005). L'Art plus Fort que la Science ? L'Affrontement entre Expertise Stylistique et Expertise Scientifique dans une Querelle sur l'Authenticité d'une Oeuvre d'Art: l'Affaire Sésostris III. [Art Stronger than Science?]. *Sociedade e Estado* 20(2): 403–424.

Quéré, L. (1990). Agir dans l'Espace Public: L'Intentionnalité des Actions comme Phénomène Social. [Acting in Public Space]. In P. Pharo and L. Quéré (eds.), *Les Formes de l'Action.* Paris: Editions de l'EHESS, 85–112.

Rosental, C. (2003). Certifying Knowledge: The Sociology of a Logical Theorem in Artificial Intelligence. *American Sociological Review* 68: 623–644.

Rosental, C. (2004). Fuzzyfying the World: Social Practices of Showing the Properties of Fuzzy Logic. In M. N. Wise (ed.) *Growing Explanations: Historical Perspectives on Recent Science.* Durham, N.C.: Duke University Press, 279–319.

Rosental, C. (2008). *Weaving Self-Evidence: A Sociology of Logic*. Princeton: Princeton University Press.

Rosental, C. (2009). L'Erreur en Logique. [Error in Logic]. In C. Chauviré, A. Ogien and L. Quéré (eds.), *Dynamiques de l'Erreur*. Paris, Éditions de l'EHESS (« Raisons Pratiques » N° 19), 285–307.

Rosental, C. (2010). Social Studies of Evaluation. *Social Studies of Science* 40(3): 481–484.

Stark, D. (2009). *The Sense of Dissonance: Accounts of Worth in Economic Life*. Princeton, NJ: Princeton University Press.

Zadeh, L. A. (1965). Fuzzy Sets. *Information and Control* 8: 338–353.