

## Reflections on Technology and Human Sciences: rediscovering a common thread through the analysis of a few epistemological features of fuzziness

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**Abstract** A number of reasons, both historical and philosophical, has caused Technology and Human Sciences to be perceived as disjoint domains. In opposition, we claim that there exists a strong methodological affinity between these apparently disconnected fields of knowledge. Our view is further corroborated by new hints from Information Sciences, in which new scientific concepts and tools such as *fuzziness* have emerged. Comparing the ways in which both Technology and Literature offer a *model of reality* we shall see that their approaches preserve a strong connection with the “description” of the pieces of reality they aim to model, against the Galileian hard sciences’ approach of making bold hypotheses, not necessarily linked to the surface description of reality. Moreover, we will discuss the surprising fact that a fruitful use of fuzzy logic in both Technology and Human Sciences presents strong (methodological) similarities, and is markedly different – in nature – from its possible embodiment in Hard Sciences.

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# 1 Introduction

The present paper, extending preliminary considerations presented in [1], in turn based on related ideas discussed in [2–10], is one step in a planned analysis of the relationships existing among human sciences, hard sciences and technology in the light of the emergence of fuzziness as a new scientific concept, supported by the family of conceptual tools stemming from such inception. What we want to specifically deal with is the fact that, while hard sciences and technology have always been considered strongly connected, one as the realization of the other, there exists an even stronger connection, and – by extension – a significative similarity between human sciences and technology, defining a relationship that is more powerful than the ones joining hard sciences and technology on one side and hard and human sciences on the other.

We aim to show that fuzzy logic has a crucial (double) role to play in this framework due to its peculiar, *neutral* language. By exploiting examples from classical works – such as the one by Mamdani and Assilian in Control Engineering [11] – as well as from some recent innovative trends stressing the importance of nourishing an “experimental” attitude (peculiarly evident in some of Enric Trillas’ recent works (e.g. [12]) and, subsequently, [13–15]), we shall outline a tentative analysis of some of its significant features. Its capacity of transferring ideas between technology and human sciences helps in corroborating our thesis and focusing on such common characteristics defining humanities and technology.

In our opinion such *trait d’union* can be usefully formalized through tools which, while remaining at a close distance from common sense, at the same time offer a level of abstraction strong enough to provide a chance for building models of such aspects of reality. Let us remark that, although every new idea can – in principle – be born and develop independently from the context, (i.e. can arise in any context), it is common experience that some environments are more favourable than others for a correct appreciation of innovative content. In the following Section we shall then briefly outline the context in which some of the ideas in the present discussion have been conceived and grew up.

Such approach has even a more subtle *raison d’être* than the one that has already been mentioned: the fact that these ideas are the basic elements of a network of new concepts that are at the core of the basic innovations of 20th century and deserve to be known and understood also by its own merits, since a thorough understanding of their main features is what may allow suitable new developments regarding the innovative conceptual aspects introduced by new scientific notions in general, and the notion of fuzziness in particular.

Let us stress that many of the points in this paper will be deliberately presented in a very rough form that may appear as provocative. And as a matter of fact what we want is to provoke a debate around our main claims:

- technology and human science have a strong methodological similarity;
- Fuzzy Set Theory can provide a bag of conceptual tools for studying this similarity as well as problems coming from the relationship between humanities, hard sciences and technology.

The remainder of this paper is organized as follows: in Sections 3, 4 and 5 three different ways of modeling reality (namely: Mamdani-Assilian's, 19th Century Novel, and Galileian's scientific approach) and some of their epistemological consequences are discussed, compared and then commented in the following *intermezzo* (Section 6). In Section 7 we shall then return to the fuzzy-theoretical modeling in order to further clarify its role in the outlined context while providing more evidence of its methodological flexibility. Finally, in Section 8 some conclusions are drawn, aiming to show how our analysis could help to find a fruitful path for the future.

## 2 The interdisciplinary scientific “milieu” of the old-fashioned Cybernetics as the “natural” Context

Let us now start by pointing at the context in which we should put ourselves in order to ask the main questions we are concerned with. Differently from traditional disciplines (e.g. mathematics, physics) which - now - usually come already equipped with a natural scientific background, this latter must be carefully identified, and even *reconstructed*, in the case of newborn fields of investigation or interdisciplinary domains, in which there is a strong interaction among different disciplines.

Cybernetics, as it is well known (and very well argued and documented by Rudolf Seising in [16, 17]), has been a reference point for all those topics dealing with information (in a broad sense) during the middle of last Century. Despite cybernetics is nowadays a neglected name, it can be useful to look at its history and development in order to characterize some important features of the development of information sciences (for some aspects see also [18], the volume [19] and [20]). This discipline – in spite of its obsolete fashion – seems to matter because of its capacity of posing, for the first time, questions and problems that still today are crucial for all the entire field of information sciences. Cybernetics has always aspired to be considered a *classical* scientific discipline; however, two arguments in particular weight against this ambition: a) its very scattered nature and b) its interdisciplinary attitude. Two very useful features indeed, but which do not usually appear in classical disciplines. In what follows, we will discuss both points.

## 2.1 A scattered discipline

If we look at the historical development of cybernetics, it is clear how its way of encompassing a lot of sub-disciplines is in sharp contrast with older, scientific disciplines such as mathematics or physics that fused into a single (and coherent) whole. This is particularly evident yet in the subtitle of Wiener's book "Communication and Control in the Animal and the Machine", which can be considered as the original (broad) definition of the discipline [21]. It, in fact, encompasses many different fields, competences and aims, and reflects what happened in the forties and the fifties of the 20th century, during which cybernetics catalysed efforts coming from different disciplines, getting new concepts and formalisms flow into a unique, very creative (as well as disordered) stream of ideas breaking the edges imposed by traditional disciplines.

Eduardo Caianiello – one of the founders of neural network theory who *mathematized* [22] McCulloch and Pitts logically oriented neuron model [23] – proposed the thesis that a major unifying element for the entire cybernetics research program was the vague yet fundamental concept of intelligence – having so a better shot at the unity of the discipline. In his view, a characterization of cybernetics could be done by considering its substantiation as a scientific approach to the modeling of various aspects of intelligence. As it is known, this attempt at unification failed, mainly because the different schools of thought did not succeed in conciliate their different attitudes to the problem posed by the new framework, even if they individually enjoyed the concept of intelligence search. See also [20,24–27], for some further views on this problem. For having an idea of the way in which these questions "work" in practice, we refer to the book *Memoria e Progetto* [28] which can be considered a case study. It, in fact, can be read (also) as a sort of "catalogue" of the problems, great potentialities and strong difficulties met - along 40 years - by a research Institute which referred to cybernetics also in its name.

## 2.2 Interdisciplinarity and cybernetics

As we already have introduced, interdisciplinarity played a crucial role in cybernetics. To get the point, one can just think to the fact that it is sometimes defined as a transdisciplinary approach to system control and replication. However, due to its very nature, the role interdisciplinarity played in the development of cybernetics is always difficult to assess in a complete and clear way, and it deserves yet to be analyzed as a model of investigation and research, unsystematic, chaotic but still full of innovative insights and ideas.

But why does interdisciplinarity play a central role in cybernetics, while it seems to play no role at all or, anyway, a not important one in older, traditional disciplines such as mathematics or physics (and many others)? In our opinion, this question is crucial to assess the real role that interdisciplinarity plays in scientific development. We should carefully clarify, however, that in this anal-

ysis we maintain that interdisciplinarity is not a feature that if “sticked” to any subject of study instantly makes it deep and better; on the contrary, if used in a superficial way, it often creates problems while hiding its inability of discussing innovative problems. These negative effects of a degenerate interdisciplinarity were discussed - with regard to the more general problem of the role of University in our Society - by Bill Readings in his still current and full of hindsight “The university in ruins” [29], in which he acknowledges that “the benefits of interdisciplinary openness are numerous”, but also warns against its negative role:

“we can be interdisciplinary in the name of excellence, because excellence only preserves preexisting disciplinary boundaries insofar as they make no larger claim on the entirety of the system and pose no obstacle to its growth and integration. To put this another way, the appeal to excellence marks the fact that there is no longer any idea of the University, or rather that the idea has now lost all content.” (ibidem, p. 39)

At this point, it is appropriate to make a distinction between two ways in which to refer to the utterance “discipline”; one could distinguish two meanings of this notion, discipline<sub>1</sub> and discipline<sub>2</sub>, giving place to two classes: *scientific disciplines* and *academic disciplines*. The former are those overflowing of problems and which are related to the (theoretical) construction of the connections of the *answers* provided to the *questions* posed by them while the latter are those coming out from the stabilization of the results obtained by studying important yet old problems and which are present in a standard form in the research Institutions. In this context, interdisciplinarity is often useful because of its capacity of discussing new, potentially important problems in the discipline itself in the light of a fresh perspective, while highlighting the uneasiness in facing (or posing) new problems posed by the academic sector in a precise historical moment. Unless an essentialist attitude is assumed, which follows what could be called an “Aristotelian paradigm”, categorizing phenomena according to their presumed “true” nature, it is obvious that problems do not belong to a single discipline: this is reflected by the fact scientific discipline’s boundaries are never sharp and their differences depend upon their very development and the historical moment in which they were born. Nonetheless such boundaries are not fixed: think for example to Maxwell theory that merged together optics, electricity and magnetism which had been previously considered as separated topics of investigation. However at some point in their development, scientific disciplines may become more rigid academic disciplines, which obey a socially induced division of labor. In academia interests as different as it is humanly possible from the pure development of scientific ideas are present, and in some periods preponderant.

In this situation interdisciplinarity comes in help telling us that a new

problem can be handled only by escaping the established boundaries imposed by the system of well-assessed disciplines and therefore inducing an update of themselves as they're organized. As an example of this kind we can consider the resolution problems linked to the use of information theory in the setting of aesthetics, more easily approachable (as suggested in [2,4]) through the use of concepts such as the theory of measures of fuzziness [30–32]. It helps also in overtaking the rigidity of the academic disciplines, which can obstruct the way for a clear explication of scientific results to be obtained. The development of cybernetics clearly shows its positive impact on all those disciplines which interacted with it, that often (and not only in its heydays) were renewed thanks to its undogmatic methodology. This heritage should be (ideally fully) drawn by information sciences in their most general sense.

### **3 Mamdani-Assilian model and some epistemological consequences**

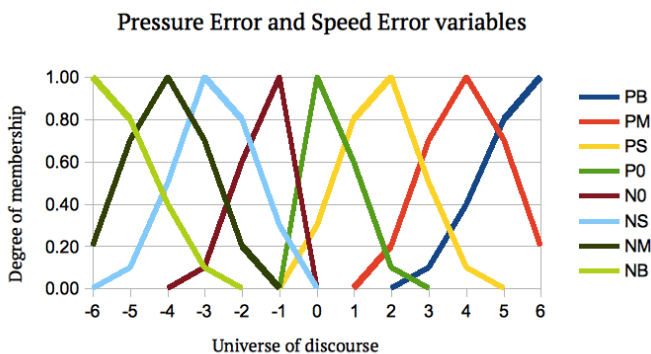
In history of computing, methods and technologies from the FST domain have been applied with plentiful of results to different domains, and more often than not such fruitful coupling has been the result of following twisted paths, neither expected nor forecast by the protagonist of the scientific undertaking – a parallel of which we can trace to real history, and a large distance as it can be from “rational reconstructions”. Clear examples of this even go back to the early days of the discipline: Rudolf Seising [16, and elsewhere in this issue] reminds how Lotfi A. Zadeh's original forecast for the application of fuzzy sets was strongly linked with its application to problems specific to the domain of humanities and social sciences; this is clearly stated in Zadeh's interview with Betty Blair [33]:

“I expected people in the social sciences, economics, psychology, philosophy, linguistics, politics, sociology, religion and numerous other areas to pick up on it. It's been somewhat of a mystery to me why even to this day, so few social scientists have discovered how useful it could be.”

This regret is based on historical facts: at the beginning, in fact, applications and theorizations in Fuzzy Logic went the way of engineering, a path encouraged by the strong applicative results due to Mamdani-Assilian model of fuzzy control, while theoretical developments followed the traditional methodological approach of hard sciences.

Let us now start by analysing some typical features of the approach employed by Mamdani and Assilian, in order to clarify the important epistemological impact of their work in the setting we are concerned with.

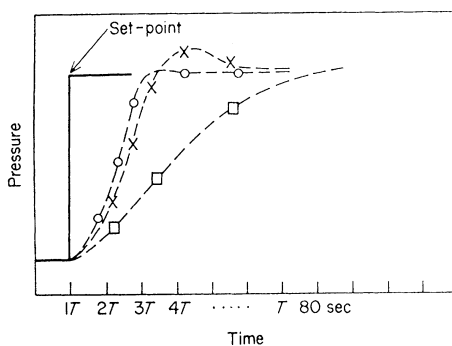
The path followed by Ebrahim H. Mamdani and his doctoral student Sedrack Assilian was in fact quite different from the typical approach of hard sciences, in a way that can be described as such: Mamdani wished to design a



(a)

If PE=(NB or NM) then (If CPE=NS then HC=PM)  
 If PE=NS then (If CPE=PS then HC=PM)  
 If PE=N0 then (If CPE=(PB or PM) then HC=PM)  
 If PE=N0 then (If CPE=(NB or NM) then HC=NM)  
 If PE=(P0 or N0) then (If CPE=N0 then HC=N0)  
 If PE=P0 then (If CPE=(NB or NM) then HC=PM)  
 If PE=P0 then (If CPE=(PB or PM) then HC=NM)  
 If PE=PS then (If CPE=(PS or N0) then HC=NM)  
 If PE=(PB or PM) then (If CPE=NS then HC=NM)

(b)



(c)

Figure 1: Membership functions, fuzzy IF-THEN rules and effectivity of the original Mamdani-Assilian's fuzzy controller. (a) Pressure Error and Speed Error variables (b) Fuzzy rules used in the controller. Meaning of the abbreviations: ZE=zero; PZ=positive zero; PS=positive small; PM=positive medium; PB=positive big, and the same for negative values NZ, NS, NM and NB; PE=pressure error; CPE=change in pressure error; HC=amount of change in the head. (c) Fuzzy steam engine controller (○) vs. classic DDC algorithm (×, □) [11]

control system that used linguistic statements (including vague expressions) in contraposition to Winograd's controller of a robot arm [34] whose aims were achieved by manipulating symbolic expressions. His fuzzy-controlled steam engine, in fact, was designed by means of a strictly subjective modeling of the linguistic terms involved in the computations. The entire system, that consisted of a steam engine and a boiler, was highly nonlinear; it had two input variables (engine throttle, heat supplied to the boiler) and two output variables (pressure in the boiler, engine speed) to be controlled in order to reach and attain a predetermined pressure (called set point). To this end, they firstly designed the fuzzy sets representing the subjective meanings of the linguistic terms involved (see Figure 1a for an example), and then combined them into a rather natural, "human-like" way, by implementing the following rules: «if the system already reached the set point, then no action has to be taken», «if the pressure error is negative and big, then the heat change has to be positive and big», and so on (the complete table of rules is shown in Figure 1b, while Figure 1c shows the performance of the model.). These vague statements of the form "if X is A then Y is B", that resemble very nearly the way in which knowledge is acquired and managed by human beings, are usually called "fuzzy IF-THEN rules", while the entire control system is sometimes referred to as "Mamdani's model"<sup>1</sup>.

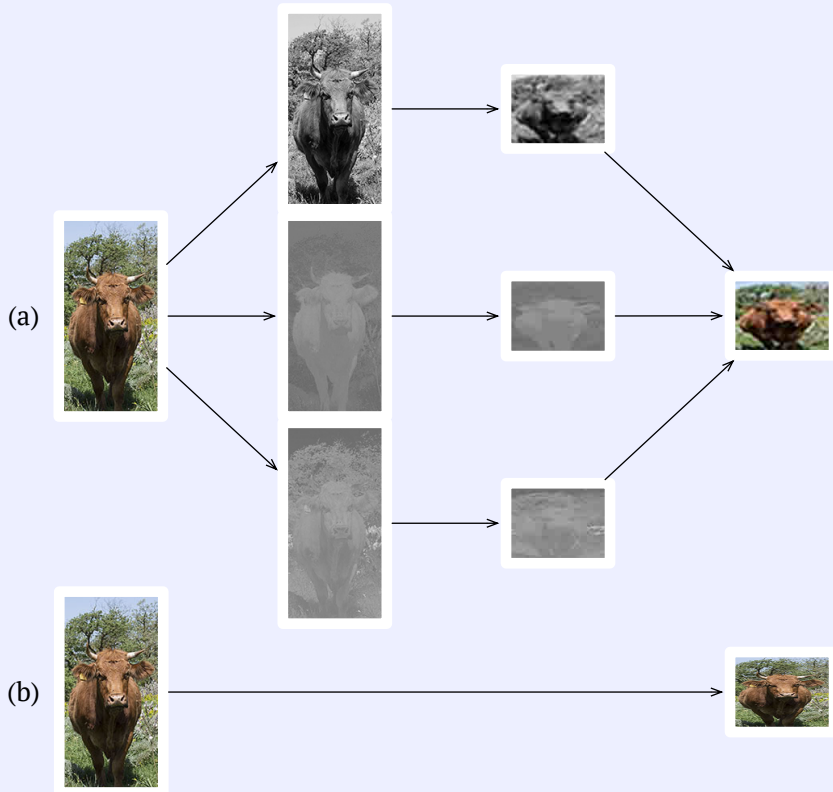
It is now important to underline the epistemological innovation brought by the work of Mamdani and Assilian. An historical analysis could also reconstruct the path leading to further innovations produced by Takagi and Sugeno [35], as well as subsequent developments [36]. Here we limit ourselves to remark the evident difference – only attaining to this particular case – with the classical approaches of control theory, in which systems are usually described using (partial) differential equations whose expression diverges decisively from the direct intuition of the modeled phenomenon. Not only such approaches are much closer to the natural way of reasoning and expressing such reasoning, but also uses directly the available information and it is more performing. Let us observe that the connection between a simple approach close to the commonsense reasoning and intuition, and the direct use of the available information is not strange.

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<sup>1</sup>Lofti Zadeh seems not to agree with this designation. In a 2001 interview, in fact, he declared to Rudolf Seising: "Assilian never got any credit. [...] It is a little bit unfortunate because, after all, that was his Ph.D. thesis. So this particular point requires some historical correction." ([16])



## BOX 1 - An analogy for Fuzzy logic controller



As Mamdani and Assilian have shown in [11], fuzzy logic controllers are more effective and faster than classical controllers. This fact can be metaphorically represented by the process of resizing an image. In the methodology we have chosen for its analogy with the classical control theory approach, shown in (a), an image is divided in its fundamental components (luminance, chrominance A/B) that are individually compressed, scaled and then recombined. This process is appreciably longer and, due to the compression applied to any single step which is burdensome and then need approximations, the result is significantly worse than the one shown in (b), that achieves the same aim by using the entire information in the input image at once. We are not affirming that the classical approach always leads to worst results in a longer time. We are registering that – in some cases, as the one treated by Mamdani-Assilian – a *direct, smart* use of available information produces faster (and better) results then the ones obtainable by classical procedures which require – due to the complexity of the obtained model – very drastic approximations for obtaining a solution.

We have just seen how, while the classical control theory followed a paradigm that we can associate with the “make bold hypotheses, make the necessary approximations and then test” approach, both the Mamdani-Assilian’s fuzzy controlled steam engine and Sugeno’s inverted pendulum followed a semi-qualitative/quantitative, *descriptive* model, which representation is nearer to reality, without making unintuitive abstractions. In Box 1 we illustrate the difference between the two strategies outlined above through an analogy taken from the domain of image processing.

#### 4 (XIX Century)-literature modeling of reality

In order to establish a comparison between Mamdani’s model and other methodologies, it is of great interest to see how reality is modeled in a literary text. Of course the situation is more complex than this and also accepting this simplification, we must observe that every text is a different (methodological) model and interprets “reality” in a different way. But let us proceed in a very naive way. At a first glance, it could seem that (a good amount of) literature proceeds by describing reality “as it is”. Actually, this view is supported by a lot of examples: saying this, what we have in mind are novels by outstanding 19th century authors such as Dickens, Hugo, Tolstoj, Twain. Their attempts at modeling reality are descriptive (although not *only* - or *merely* - descriptive), as one can clearly see from the following excerpts:

“[Uriah’s face] was quite as cadaverous as it had looked in the window, though in the grain of it there was that tinge of red which is sometimes to be observed in the skins of red-haired people. It belonged to a red-haired person—a youth of fifteen, as I take it now, but looking much older—whose hair was cropped as close as the closest stubble; who had hardly any eyebrows, and no eyelashes, and eyes of a red-brown, so unsheltered and unshaded, that I remember wondering how he went to sleep. He was high-shouldered and bony; dressed in decent black, with a white wisp of a neck-cloth; buttoned up to the throat; and had a long, lank, skeleton hand, which particularly attracted my attention, as he stood at the pony’s head, rubbing his chin with it, and looking up at us in the chaise.” [37]

“The hideous old man seemed like some loathsome reptile, engendered in the slime and darkness through which he moved: crawling forth, by night, in search of some rich offal for a meal.” [38]

“Javert, though frightful, had nothing ignoble about him. Probity, sincerity, candor, conviction, the sense of duty, are things which may become hideous when wrongly directed; but which, even

when hideous, remain grand: their majesty, the majesty peculiar to the human conscience, clings to them in the midst of horror; they are virtues which have one vice, – error. The honest, pitiless joy of a fanatic in the full flood of his atrocity preserves a certain lugubriously venerable radiance. Without himself suspecting the fact, Javert in his formidable happiness was to be pitied, as is every ignorant man who triumphs. Nothing could be so poignant and so terrible as this face, wherein was displayed all that may be designated as the evil of the good.” [39]

These characters are presented in a rather descriptive way: as we read the text, we get more and more information and “realistic” features which should help to form a picture, as clear as possible, of the given character in the reader’s mind. We can argue that the (implicit) methodology they are following, which proceeds by providing natural descriptions of certain aspects of reality, resembles in some way the just discussed Mamdani-Assilian’s one in control engineering. An interesting aspect of this similarity is that it suggests between the lines that, since it was already used aplenty in the world of literature, the methodology here in exam can be seen as a *rediscovery* by Mamdani and Assilian (as we have seen, a very fruitful and effective one) in the field of engineering. Thanks to this fascinating similarity we are able to glimpse a preliminary point of contact between the two domains of human sciences and technology.

## 5 Galileian’s scientific modeling

But why are we now concerned with these arguments? As we have already argued, our main aim is to highlight a major epistemological difference between the descriptive attitude of literature and technology and the traditional methodology of hard sciences which we have called “Galileian”. In fact, Galileian scientific method proceeds by making bold hypotheses<sup>2</sup> (“In vacuum, objects fall at the same rate”), which have to be subsequently tested against nature by means of experiments. This is strongly departing from the preceding Aristotelian view, that limited itself to a more straightforward description of the observed facts (“Objects fall at a rate which is proportional to their weights”). Hard sciences (at least from Galileo on) decidedly deviate from common sense and from an analysis of reality rooted in the idea that what has to be examined is a class of “natural” or “social” phenomena, to be accepted as the starting points not reducible to an inner structure. Just to give a hint of what happened after Galileo, we can consider how a model of theoretical physics does bold hypotheses that are completely different from the ones that can

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<sup>2</sup>Informally we call an hypothesis *bold* when it is not a elaboration or abstraction from something which can be directly observed. A classical ancient example is the atomic hypothesis in pre-socratic philosophy.

be made for the surface description of the phenomenon that these same hypotheses want to explain. The connection is recovered, later, at the level of the necessary consequences of those bold hypotheses – even if this process is not always possible on the researcher’s intended terms, and when it is its complexity is not necessarily tractable in the full terms we expect to deal with.

It is important here to note that hard sciences, following Galileian’s scientific method, use technology as a medium in order to falsify or corroborate their (bold) hypotheses. Technology instead tends to follow a more traditional, commonsense way of doing things. While obviously the technological artifact is rooted in locally based results from hard sciences, such as can be the laws of electromagnetism for the inner working of a memory chip or a set of basic mathematical principles for the microprocessor’s architecture, the way of getting the final, obtained/obtainable object still follows the traditional route highlighted above. It is easy to see that both in technology and in art (pick any of the *septem artes liberales*) the principal object of analysis and synthesis is the artifact, that is *something man made*, while findings and results from hard sciences, though often evoked by or directed at technological applications themselves, deal just with *nature* and its complicated, proper mechanisms on whose creation man has given no contribution at all and can only try to discover.

Even in a field of technology that seems to be more inextricably woven with hard science the artifact paradigm presents itself in a striking manner: an example of this is thermodynamics. As it is well known, the origin of thermodynamics as a theory is strictly connected with the attempt of modeling what was empirically known about the working of thermal machines, without making too bold hypotheses. These were done in the setting of statistical mechanics and the attempts of completely reducing the former theory to the latter have encountered strong technical difficulties.

## 6 *Intermezzo*

We have explicitly written in the previous pages that (traditional) hard sciences usually proceed “by bold hypotheses” often completely disconnected from the surface description of the studied phenomenon (or piece of reality) whereas in human and social sciences all the theories and the attempts at understanding remain more or less connected with the surface description of the object of study. Is this absolutely (and always) true? Of course, no. It is certainly “statistically” true in the sense that the overwhelming majority of theories in these two domains do, in fact, satisfy this general rule; but there is no theoretical reason for that. One can consider a strong supporting reason of the alleged methodological similarity between human sciences and technology the fact that both deal with man made artifacts. A thesis corroborated also by what Vico wrote about history and our knowledge of history. See his

conception of "verum ipsum factum", according to which we can really know only what we have done (constructed, realized). So, Men can "really" know only History (and we would add: technology) but not Nature, which - according to him - can be known only by God. We do not share his position for what regards the possibility of knowing Nature, although we like the fact that his observations add arguments to our thesis about the "resemblance" between technology and human sciences. We can develop very different strategies and methodologies for studying this problem, but we cannot but recognize that a similarity exists. Symmetrical to this similarity stands up the "ontological" dissimilarity between "natural" sciences and all the sciences having as their natural domain man-made objects and entities. Once granted that, it does not follow that the methodologies used in the two subdomains *must* be different.

Finally, two question remains open whether information sciences ask for different completely new conceptual categories or can be analyzed in a satisfactory way by using the classical, traditional conceptual categories used to study mathematics on one side and the sciences of Nature on the other side. We shall return to this point later. Now let us come back to the question of the epistemological implications of the (dis)similarities between technology, human sciences and natural sciences. When we affirm that both technology and human sciences have to do with man made artifacts we are simply noticing a fact. There is an evident, plain ontological difference between the objects of study proper to technology and human sciences and the ones proper to sciences of nature. Does this difference necessarily imply that a methodological analysis of the way in which the afforded problems are studied and approached will show deep differences in the way in which conceptual categories which are used? Let us repeat again: not necessarily so!

The difference, the methodological difference, we are stressing in the present paper was not present in Greek science nor in the science (and the culture) of Renaissance. It is something that starting from Galileo finally assumes the specific form we referred to at the beginning of the paper only (relatively) recently. Reducing this attitude to a sort of slogan and - as such - surely a very strong simplification of the approach, we can say that the starting explicative hypotheses of a certain piece of nature are not related to the surface *description* and so to the surface *appearance* of the considered piece of reality. We are allowed to do very bold hypotheses, we are allowed to "imagine" whatever we want - satisfying whatever relation - at the condition that these hypotheses - however strange - necessarily imply some consequences that have strong connections with what happens at the level of the "surface description" of the phenomena that those very abstract bold hypotheses want to explain. This step - that in its stronger form has been done relatively recently - can be considered to afford his root in Galileian revolution for at least two reasons.

The first has to do with the procedure of abstraction which is methodological the same both in the assumption that we can abstract away from the ex-

istence of "friction" when looking for the laws of motion and – for instance – in whatever hypothesis we do regarding the inner structure of the Universe. There are no meaningful methodological differences although it is, of course, evident that a long journey in the levels of abstraction has been done. The second point is that a central role has been already assigned to mathematics. This is crucial for the - by far - wild abstractions that are usually done today in scientific investigations. In Galileo's vision the central role assigned to mathematics is justified by the fact that "Nature is written in the language of mathematic"; today we can be critical or skeptical about that and certainly our attitude regarding the reasons why mathematical techniques and results work so well in physics is extremely more sophisticated than the one of Galileo or Newton. However these incredibly high levels of abstractions can be considered acceptable only because the mathematical tools allow us to connect (via a controllable chain of connections) those bold hypotheses to testable properties, to specific behaviour of Nature appearing at the surface description. So we can say that the attitude (or the necessity) of doing bold abstraction from the surface description is a historical product of the evolution of the study and of the knowledge of certain pieces of Nature.

Is it impossible to do the same when studying a social phenomena? We do not know. We, now, simply register the fact that in many topics in human or social sciences a good understanding can be obtained by carefully analyzing in a critical way a "surface" description of the studied phenomenon. We can also say that in many cases this is more satisfactory than some attempts at constructing models which abstract too much from the surface description and in which the "abstractions" are not controlled and connected to the piece of reality which is studied with a clarity comparable to the one present in the construction of models of physics. This is exactly the story we have presented in the previous sections.

We have also seen that - in certain (specific) historical periods at least - literature (specifically, 19th Century Novel; paradigmatically: Dickens, Hugo, Tolstoj) can be analyzed also as a way of understanding the coeval society, and this was done by providing a "model" of the society which can be seen - as we have already stressed - as a "surface description" integrated by (suitably controlled) elements of idealization.

Every thoughtful reader would at this point immediately add that the same cannot be said of some masterpieces of 20th century literature. Joyce's *Finnegans Wake* (and to a great extent also *Ulysses*) and Samuel Beckett's major works can be read - only partly - in this way. We completely agree with this objection and add also that - if we want to use a reading of these masterpieces as models (more, as "critical" models) of the described reality - we can certainly see and pick up many elements we could consider pertaining to what in these pages we have baptized a "methodology of bold hypotheses". Such are the uses of language in *Finnegans wake* (and in Pound's *Cantos*) as well as the characters

of many of Beckett's works, just to indicate a few examples. We will no more proceed along this road, a burden which can be sustained only by means of a very specific "expertise" that we do not possess. It was our desire, however, to stress - also by pointing to specific examples - that the methodological separation which we have presented as a banner in this paper is not viewed by us as something perennial (or having an ontological character) but only as something useful *now*.

As another example in the same direction, we wish to refer to a series of (relatively) recent papers by Franco Moretti, which - starting from general "conjectures" on how to study "World Literature" today [40] - proceeds outlining the usefulness of "abstract Models" for Literary History [41–43]. It may be of interest to quote *in extenso* the beginning of the first of these three articles:

"What follows is the first of three interconnected articles, whose common purpose is to delineate a transformation in the study of literature. Literature, the old territory; but within it, a *shift* from the *close reading* of individual texts to the construction of *abstract models*. The models are drawn from three disciplines — quantitative history, geography and evolutionary theory: graphs, maps and trees—with which literary criticism has had little or no interaction; but which have many things to teach us, and may change the way we work." (italic ours)

The "close reading" of individual texts resembles the "surface description" we dealt with previously as well as the construction of "abstract models" drawn from distant disciplines "with which literary criticism has had little or no interaction" resembles - in turn - the "bold hypotheses" approach. So, it seems that we can fruitfully proceed with "bold" abstractions also in such distant fields from hard sciences as "the study of literature". The use of one methodology or another must be adapted to the particular cases and seen and valued inside a comprehensive scheme. An analysis (and also a detailed report) of Moretti's approach is far beyond our "intellectual possibilities" and, in any case, beyond the scope of the present paper. A reference to it, instead, is crucial for a further and better clarification of our position. Let us go back to what we wrote at the beginning of this Section: we are not maintaining an "ontological" diversity between ways of knowing the world. A descriptive surface-mimicking modeling and a strongly abstraction-based modeling; the former more apt to human sciences (and technology), the latter better tailored for hard sciences. We are only "registering the fact" that these two different ways of modeling (pieces of) reality exist and that they are applied and used in different guise in different fields. Moretti's approach indicates that a non "surface-mimicking" methodology can be tentatively used also in the analysis of literature when it is seen as a global enterprise.

Let us attempt a working hypothesis for future reflections. Literary criticism (like art criticism or any other kind of criticism - for what matters at this very general level) deals with something “given” (the literary, or artistic, *opus*) in the same way in which hard sciences deal with another “something given” (*nature*). So, attempts like the one by Moretti, cited above, are perfectly tuned with our general view.

In the following Section we shall try to indicate the crucial role that the notion of fuzziness can play in all these apparent conundrums, allowing to clarify parts of the questions due to its many-sided or faceted nature. Fuzziness can be used to provide different mathematical representations of very subtle questions in quantum theory as well as helping in the analysis of literary texts along innovative avenues, which allow preserving the richness of the original text.

## 7 Fuzzy-theoretical approaches

In the present Section we shall go back to fuzzy-theoretical modeling, and show more evidence of its (methodological) flexibility. In Section 3 we have discussed how Mamdani approach produces a (very satisfactory) model of a typical engineering problem. The novelty here – as we have seen – had to do with its *outstanding* performance, surprisingly obtained with very *elementary* means. It was not related to the domain of application of the methodology, since it is very strictly connected with Zadeh’s native academic specialization: furthermore it is not very unusual to obtain good (and even very good) results in specific domains, especially when the topic we are dealing with is of a generic applied – or more specifically technological – nature. What was astonishing was the fact that it led to results that superseded the ones obtained by classical modelings based on traditional approaches.

This result could be taken as a support of Zadeh’s conviction that System Theory would solve some of its problems by following a completely different path, but could be equally considered as something *singular*, a specific result, without further methodological consequences, however interesting and important in itself. In the field of technology it doesn’t seem too strange to have this kind of modeling in full working order. We have already recalled previously how thermodynamics was born out of a “reality modeling”, different from Galileian mechanics.

In the present section we shall recall two further distinct aspects of the work springing from a serious evaluation of the innovative character of the notion of fuzziness, showing – indirectly – also what we intend when speaking of the “methodological flexibility” of this notion.

These two examples - in our view - show that, from one side, fuzzy notions and concepts can be perfectly embedded into pieces of traditional, classical research areas by making use of the usual demonstrative rigor (§ 7.1, below),



while from another side, they can be used to try to provide very innovative (semi-quantitative) models in completely new domains (§ 7.2, below). From an epistemological point of view, such two uses are distinct, and the latter seems to be - under some aspects - methodologically more similar to the one usually done in technological applications.

### 7.1 (Fuzzy) representation of quantum logics

It is well known that scientific exchanges between quantum logic (QL) and Fuzzy Set Theory have produced interesting and useful results along the years. However, our discussion of QL in this context will focus on a specific point of epistemological relevance and not on the question of the connection of these two fields of investigation. In particular, we shall refer to a results due to Jaroslaw Pykacz, who has been able to express QL “entirely in terms of ‘genuine’ fuzzy set operations”, to quote his own words. We avoid to go into technical details and refer to the synthesis of this interesting result provided by the author [44]. Pykacz starts from an old results of 1973 due to Maczyński and known as *Functional Representation Theorem* which shows that any QL with an ordering set of probability measures (a condition which makes them interesting from the physical point of view) can be isomorphically represented as a family of  $[0, 1]$ -valued functions satisfying some specific conditions. And, conversely, any family of  $[0, 1]$ -valued functions fulfilling the same conditions is a QL in the traditional sense [45].

This result provides a strong connection between the traditional language and formalism used in QL and a purely functional language. This is very interesting, but – as such – it is not strictly related specifically with fuzzy sets. It opens, however, the way for an easier approach to the problem of expressing a QL in the language of fuzzy set theory. This is what Pykacz was able to do in two subsequent steps (in 1987 [46] and in 1994 [47]).

The final result was that a QL with an ordering set of probability measures can be isomorphically represented by a family  $L$  of fuzzy sets satisfying some conditions expressible in terms of “genuine” fuzzy sets operations. And, conversely, any family  $L$  of fuzzy sets satisfying the same conditions is a QL in the traditional, order-theoretic, sense.

So we see that the language of fuzzy sets can be rigorously used to model situations previously represented in a more traditional language. We can obtain both an equivalence proof which fulfills all the canons of rigor traditionally required in mathematics and a full use of the innovative aspects, at the conceptual level, of the notion of fuzziness.

The representation of a QL in terms of a “pure” fuzzy sets language, in fact, opens the way to a reconsideration of many debated interpretative questions in the realm of quantum theory. The crucial point is the possibility of formally representing in an adequate language the idea “that a physical object

can possess its properties only partially”. This change of perspective allows to reconsider the well known problems of the apparent discrepancy between experimental results and their commonsense “interpretations” and, perhaps, also reinterpret in a more palatable way some of the *classical* paradoxes of quantum theory.

The same formalism of fuzzy logic can be useful in human sciences, as we shall see in the following.

## 7.2 Modeling a literary text

As a remarkable example of this kind of use of fuzzy logic, we want to cite the attempt of E. Trillas [12] to model a brief excerpt of the essay “Desde la ciudad nerviosa” by the Spanish writer E. Vila-Matas [48]. He has shown that an adequate fuzzy context-modeling also allows to appropriately represent non-trivial linguistic sentences. It is important to notice that this aim is achieved by using the very same tools made available by the fuzzy control theory. In a certain sense, it is possible to argue that fuzzy logic is effective in a similar way both in its applications and in human sciences. Let us consider Trillas’ modeling of the following sentence by Vila-Matas:

“I had always told myself that if life has no sense neither has reading, but suddenly it seemed to me that the process of reading to search for artists of the not, did have a lot of sense. Unexpectedly, I felt that the search for bartlebys gave sense to my life”<sup>3</sup>

According to Trillas, there is a hidden reasoning in this short paragraph:

*If “If life has no sense neither has reading” then “If reading has sense either has life” (1)*

or, using a more schematic, programming-like representation:

```
If
  If
    life has no sense
  then
    reading has no sense
then
  If
    reading has sense
  then
    life has sense
```

---

<sup>3</sup>Bartleby the scrivener is the subject of the homonymous short story by Herman Melville [49]. A metaphor for the progressive inactivity of man and society alike, Bartleby is famous for his mantra “I would prefer not to”, and as such a wonderful prototype and inspiration for what Vila-Matas calls “Artists of the not”.

This reasoning can be modeled in a way that neatly resembles the fuzzy control methodology. Let us start by focusing only on a fragment of (1), that is:

*“If reading has sense, either has life”*

that we now express in the more explicit form:

**If** reading has sense **then** life has sense (2)

We can immediately recognize the similarity between this short sentence and the use of fuzzy IF-THEN rules like the ones from applications quoted in Section 3.

Fuzzy logic allows to choose the (subjectively) most suitable representations not only for nouns, but also for connectives, implications and so on. In their original work, Mamdani and Assilian modeled the If-then statement through what is now known as “Mamdani conditional”, while Trillas – according to the context and its personal beliefs about the author’s style of writing – decided to model the conditional statement in (2) with a “Goguen conditional”, that is not contrasymmetrical (i.e., differentiates between “if a then b” and “if  $\neg b$  then  $\neg a$ ”), due to the fact that in (1) both “*If life has no sense neither has reading*” and “*If reading has sense either has life*” appear in the reasoning at the same time; similarly, just like “velocity” can be regarded as a dependent variable of the system that has to be controlled, Trillas considers “reading has sense” as a statement having a “big” (i.e., greater than 0.8) truth degree, again on the basis of his knowledge of the author.

Let us leave out, for the moment a more detailed account of the analysis done by Trillas which we have strongly simplified: in future occasions it would be worthwhile not only to present an accurate and complete description of the strategy used, but also to confront our interpretation with Trillas’s aims. However, a few caveats are in order. First, the similarity noted above regards only the methodological attitude in using certain tools. It has - of course - nothing to do with the intentional use of the same rules. In Control theory many of these rules behave as “orders” for correctly executing some actions. This is different in Trillas’s paper as well as in any conceivable application of fuzzy logic to human sciences. What can be then the the scope of such tools? A lot of different kinds of applications may be of course possible, but we want here to concentrate our attention to two specific aims; first: to understand better the text, especially in the case in which – like the passage of Vila-Matas interpreted by Trillas – a degree of complexity is involved. Second: to relate and connect the analyzed text to what surrounds it. More specifically, to relate the reading and interpretation of the text to a few things about the author, his preferences, the general context, the period in which the text was written, the contemporary society and so on. This is what literary criticism has already done, but in a purely “narrative”, verbal way. Now we have a tool that allows

us to do part of these things in a semi-formal, a little more quantitative, way. More than that - let us say - we can use our knowledge about all that is outside the text (a sort of enlarged “paratext”) to choose the specific tools we think are better suited for an analysis of the text itself, as Trillas did in his analysis.

Would have been possible to carry on a similar analysis through classical two-valued propositional logic? We are tempted to answer a clear and decisive: NO. A less decisive answer is that, in principle, this could have been done, but not in a natural and direct way. Not only it is easy to see that in classical propositional logic the contrasymmetrical property of implication does always hold, but we are not offered many possibilities for modelling conditional statements. So, many subtleties of natural language which are also represented implicitly by different forms of conditional statements would be lost (and with them also part of the meaning) if we try to formalize them by means of a straightforward use of classical two-valued logic. Of course we could always construct in each particular case an “ad-hoc” machinery for accounting for specific properties. It is, however, easy to forecast that such constructions would be cumbersome, for the simple fact that (classical) logic emerged in Frege, exactly from “a struggle with language” (with *natural* language) (See [50], page 270, as quoted in [51], page 97). But besides single, specific facts, it is the rigid “all-or-none machinery” (a limiting feature already stressed by von Neumann in 1951 [52]) that does not allow to introduce – in a direct and (somewhat) simpler way – many nuances of the colloquial discourse, and the general and usually partial, imprecise and revisable information we are able to gather about the subject under discussion.

We are then induced to conclude that fuzzy techniques could and can be very relevant in human sciences if they are not used as mechanical models to be applied routinely, but - before being applied - are aptly modeled on the system they aim to study. So one of the reasons why applications to human sciences have not yet been as wide as Zadeh had presumed [33] could be based on the fact that their usefulness springs out not by a simple, straightforward, mechanical application of given rules, but after a careful design, as advocated by a few researchers ([12] [13–15]).

### 7.3 A few remarks

As it should now be clear, thanks to the freedom of expression guaranteed by fuzzy logic, one is able to model situations coming from (apparently) very different domains such as literature and technology through the use of the very same methodology when the general features of questions asked are similar.

We also want to stress a further concept: what we like to call, using an amount of simplification, the “mimicking, improving and repeat” paradigm; sometimes the best approximated solution to the problem of modelization of some process existing in reality is to try and mimic the behavior of the same

fragment of reality we want to describe, entering an iterative path that eases ourselves in more and more at every iteration. This apparently simple way of doing science is all-encompassing: while executing such steps there are no more conceptually profound (or otherwise) facts to be discovered or looked for. This description can satisfy all the scientists by limiting themselves to a process of continuous refinement. At a first glance this hypothesis may seem oversimplified, even a caricature of how science is usually made, but certainly this is not a new approach: the so-called “naive physics” which has seen its heyday a few decades ago, went exactly along these lines. There have been also some scientific programs in AI which stress the fact that “the computer program” is *the* theory of a certain mental phenomenon or of an intelligent behavior which is reproduced by a successful algorithmic simulation. If such claims are taken literally, and not in a metaphorical sense, such approach can be considered a methodological peer to the one discussed above [53, 54]. To stay true to our original aim even some results (like the ones we have just briefly analysed in the previous paragraphs) in Fuzzy Sets Theory, which are noted for their ability of satisfactorily mimicking the portions of reality under investigation, could suffer the same fate. This is not, however, the only path that can be followed: the ability to imitate reality with increasing accuracy is certainly a good starting point for the understanding of real phenomena, and at the same time can be considered as a first step in focusing problems and questions, and systematizing methodologies and tools to be used. As we have already seen, the method itself is flexible in its application: iteration after iteration new results can be obtained, different strategies can be employed and more refinements can be applied. If it is seen fit, the approach can be steered toward a more classical methodology or solutions, or completely different paths altogether. Let us comment upon this last statement. The further refinements obtained by the “mimicking, improving and repeat” paradigm can lead either to a satisfactory situation or to something which is unsatisfactory for various reasons. In this last case we could decide to change methodology and also try to follow new roads in which completely different hypotheses can be made. This is, for instance, what happened with the Copernican revolution. Tolemaic system was very sophisticated and further refinements of the same technique lead to good connections with observations. However the strategy of adding new epicycles when needed became in the long run unsatisfactory from a theoretical point of view, since it was difficult to justify the reasons for them. This unsatisfactory situation was at the basis of a sudden change of paradigm, from which emerged a new hypothesis, or better, an ancient hypothesis was “rediscovered”.

## 8 Conclusions: indications from the followed path(s)

The specific aim of the present paper has been - as programmatically stated in the Introduction - a preliminary study of the (methodological) relationships existing between human sciences and technology. Although - in itself - this question does not seem specifically related to the world of fuzzy sets and soft computing, the analysis we have done has been largely, widely (and wildly) helped by ideas and suggestions coming from various evolutions and “embodiments” of the notion of fuzziness. A fact that induced us to ask whether a *necessary* connection, after all, should exist if not with specific results of soft computing as “academic discipline” at least with the *informal* notion of fuzziness.

Along this preliminary study many detours have been done. Some by necessity, others - induced by the topics meet along the way - could have been cancelled. We have preferred to follow also some of the *Holzwegewe*<sup>4</sup> we were crossing along our journey, not for the sake of losing ourselves in the wood, but exactly for the contrary reason: to test the robustness of some of our initial intuitions in front of the obscurity of the new questions to be asked.

Let us try to briefly summarize some of the points we consider potentially more interesting. There are many ways to understand the world, and many methodologies to study it. Among these we have directed our attention on two main methodologies: we have associated the first one, which shapes the surface of the phenomenon we want to model, with both human sciences and technology; the other, which programmatically strongly abstracts from the surface manifestations of the phenomena, has been paradigmatically linked to hard sciences. This is a strong and wild simplification, we are perfectly aware of this and in fact in Section 6 we began to critically discuss this point.

Along the way we have indicated that fragments of the latter methodology can also be traced in various and different aspects of human sciences (from the analyses of texts to the attempts at constructing models or theories of literature). At the same time we have pointed out how attempts at applying models of the former methodological kind to hard sciences has been present in the last decades, the most prominent example being the one of the so called “naive physics”. We have also observed, glancing at the history of science, that the emergence and development of Thermodynamics is different from the one of Mechanics and of Electromagnetic theory, preserving many aspects of a “descriptive” approach.

Along the journey we tried to observe the degree of successfulness of some of these attempts. Some of them have not shown to be very meaningful (e.g., *naive physics*), others useful (*fuzzy control*) although in a very specific niche,

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<sup>4</sup>The german term means “a path into the wood following which one can also lost himself”; it has been used by Heidegger as the title of a book collecting some of his Essays. We use the term here to stress a different use of the same concept. We can inspection the forest apparently losing ourselves, but with the aim of finding new methods, by proceeding into unknown lands

and others very promising (Trillas' analysis). We must confess our surprise in discovering that new tendencies of literary criticism seem to follow paths which appear to be consonant more with the scientific methodology of "bold" abstractions than the one of "surface" description. This *surprise* is for us a pointer to an important topic which certainly deserves a careful investigation.

The situation, then, seems to be very complex. To observe and study the problem of the similarities between human sciences and technology from the point of view of the methodological differences between a "descriptive" approach and one based on "bold hypotheses" can be - we think - very useful although it should be used with extreme care.

The analysis carried out in this paper has helped to draw a path fruitful for the authors; not a classification, but a critical trail which, by respecting the richness of the different ways the human mind has devised to understand the world in which we live, is able to re-apply each and any of them at the perusal of new problems and questions.

Future investigations along this line will show, we presume, that in every aspect of human activity, the two methodologies - in different degrees - are both present and interact (or, at least, have done so along the *historical development* of a certain field or show signs of the possibility of so doing in the future) much more than any *linnean* classification would allow. However, picking up and registering differences in the methodological attitudes can be useful for understanding the trends of development in various disciplines.

Let us now come back to the question posed a few lines above about a possible "crucial" *structural* role that fuzziness can play in this context. Is fuzziness a crucial - conceptual or technical - point of this (alleged) similarity of human sciences and technology? For what regards the specific present technical developments is hard to say. But the informal notion of fuzziness (maybe in one of its conceptual variations) is in our view absolutely central. Both human sciences and technology strongly base their developments in an environment full of a persistent and continuous presence of fuzziness and vagueness which is constantly guided and controlled but never eliminated. While hard sciences emerging "*du monde de l'à peu près*" - as keenly written by Koyrè - moved towards "*l'univers de la precision*".

Hard sciences, from a few decades, are also facing the problem of "living with" some aspects of vagueness, as we have seen when briefly discussing quantum logic. In this case, however, fuzziness must be imbedded in a scheme which has been already conceptually structured by the previous scientific tradition. In the case of technology and human sciences, fuzziness cannot be eliminated from the start without destroying meaningful features of the objects of study. This poses new and different questions, and - perhaps - is also at the basis of the methodological similarity of some of their developments as well as the necessity of using a methodology of descriptive type (at least in a phase of their development).

Let us conclude by stressing the fact that a corollary of our initial question - on the relationship existing between human sciences and technology - has been the discovery of *different* ways in which the methodology of fuzzy sets can be fruitfully used to answer some crucial questions. At the same time this analysis - starting from the discussed methodological similarity of human sciences and technology - could suggest new, different ways of using fuzzy techniques in exactly the fields Zadeh expected the methodology would have been applied in the first place, and that have been more overlooked in fuzziness history.

## References

1. D'Asaro FA, Perticone V, Tabacchi ME, Termini S: **Technology and human sciences: a dialogue to be constructed or a common thread to be rediscovered?** In *Proceedings of World Congress of International Fuzzy Societies Association (IFSA) and North American Fuzzy Information Processing Society (NAFIPS) Annual Conference 2013*. Edited by Pedrycz W, Reformat M, IEEE SMC 2013.
2. Tabacchi ME, Termini S: **Birkhoff's aesthetics, Arnheim's entropy. Some remarks on complexity and fuzzy entropy in arts.** *Preprint* 2013.
3. Tabacchi ME, Termini S: **A Few Remarks on the Roots of Fuzziness Measures.** In *Advances in Computational Intelligence, Volume 298 of Communications in Computer and Information Science*. Edited by Greco S, Bouchon-Meunier B, Coletti G, Fedrizzi M, Matarazzo B, Yager R, Springer Berlin Heidelberg 2012:62–67, [[http://dx.doi.org/10.1007/978-3-642-31715-6\\_8](http://dx.doi.org/10.1007/978-3-642-31715-6_8)].
4. Tabacchi ME, Termini S: **Measures of Fuzziness and Information: some challenges from reflections on aesthetic experience.** In *Proceedings of WConSC 2011* 2011.
5. Termini S: **Do Uncertainty and Fuzziness present themselves (and behave) in the same way in Hard and Human Sciences?** In *IPMU 2010, Volume 81 of CCIS*. Edited by Hullermeier E, Kruse R, Hoffmann F, Springer-Verlag 2010:334–343.
6. Termini S: **On Some “family resemblances” of Fuzzy Set Theory and Human Sciences.** In *Soft Computing in Humanities and Social Sciences, Volume 273 of Studies in Fuzziness and Soft Computing*. Edited by Seising R, Sanz González V, Springer Berlin Heidelberg 2012:39–54, [[http://dx.doi.org/10.1007/978-3-642-24672-2\\_2](http://dx.doi.org/10.1007/978-3-642-24672-2_2)].
7. Termini S, Tabacchi ME: **Fuzzy Set Theory as a methodological bridge between hard science and humanities.** *International Journal of Intelligent Systems* accepted 2013.
8. Tabacchi ME, Termini S: **Varieties of Vagueness, Fuzziness and a few foundational (and ontological) questions.** In *Proceedings of EusFLAT 2011*, Advances in Intelligent Systems Research, Atlantis Press 2011:578–583.
9. Tabacchi ME, Termini S: **Fuzziness and social life: informal notions, formal definitions.** In *Proc. NAFIPS* 2012.
10. Termini S: **On Explicandum versus Explicatum.** In *Soft Computing in Humanities and Social Sciences, Volume 273 of Studies in Fuzziness and Soft Computing*. Edited by Seising R, Sanz González V, Springer Berlin Heidelberg 2012:113–124, [[http://dx.doi.org/10.1007/978-3-642-24672-2\\_5](http://dx.doi.org/10.1007/978-3-642-24672-2_5)].
11. Mamdani E, Assilian S: **An experiment in linguistic synthesis with a fuzzy logic controller.** *International Journal of Man-Machine Studies* 1975, 7:1 – 13.
12. Trillas E: **Why do fuzzy representations need a careful design?** Research Report FSC 2008-6, European Centre for Soft Computing 2008, [<http://www.enriquevilamatas.com/pdf/FSC2008WhyDoFuzzy.pdf>].



13. Trillas E, Guadarrama S: **Fuzzy representations need a careful design.** *International Journal of General Systems* 2010, **39**(3):329–346, [<http://www.tandfonline.com/doi/abs/10.1080/03081070903552981>].
14. Mamdani E, Trillas E: **Correspondence between an Experimentalist and a Theoretician.** In *Combining Experimentation and Theory, Volume 271 of Studies in Fuzziness and Soft Computing*. Edited by Trillas E, Bonissone PP, Magdalena L, Kacprzyk J, Springer Berlin Heidelberg 2012:1–17, [[http://dx.doi.org/10.1007/978-3-642-24666-1\\_1](http://dx.doi.org/10.1007/978-3-642-24666-1_1)].
15. Trillas E, Moraga C: **Reasons for a Careful Design of Fuzzy Sets.** In *Proceedings of the 8th conference of the European Society for Fuzzy Logic and Technology*, Advances in Intelligent Systems Research. Edited by Ciucci D, Montero J, Pasi G, European Society for Fuzzy Logic and Technology, Atlantis Press 2013:140–145.
16. Seising R: *The Fuzzification of Systems. The Genesis of Fuzzy Set Theory and Its Initial Applications – Developments up to the 1970s.* Springer 2007.
17. Seising R (Ed): *Views on Fuzzy Sets and Systems from Different Perspectives: Philosophy and Logic, Criticisms and Applications, Volume 243.* Springer 2009.
18. Termini S: **Imagination and Rigor. Their Interaction Along the Way to Measuring Fuzziness and Doing Other Strange Things.** In *Imagination and Rigor*. Edited by Termini S, Springer Milan 2006:157–176.
19. Termini S (Ed): *Imagination and Rigor: Essays on Eduardo R. Caianiello's Scientific Heritage.* Springer 2006.
20. Montagnini L: *Le Armonie del Disordine. Norbert Wiener matematico-filosofo del Novecento, Volume XVI.* Istituto Veneto di Scienze, Lettere ed Arti 2005.
21. Wiener N: **Cybernetics: or control and communication in the animal and the machine** 1948.
22. Caianiello ER: **Outline of a theory of thought-processes and thinking machines.** *Journal of Theoretical Biology* 1961, **1**(2):204 – 235, [<http://www.sciencedirect.com/science/article/pii/0022519361900467>].
23. McCulloch WS, Pitts WH: **A logical calculus of ideas immanent in nervous activity.** *Bull. of Mathematical Biophysics* 1943, **5**:115–133.
24. Montagnini L: **Looking for “scientific” social science: The Macy Conferences on Cybernetics in Bateson's itinerary.** *Kybernetes* 2007, **36**(7/8):1012–1021.
25. Montagnini L: **L'interdisciplinarietà per Norbert Wiener ed Eduardo R. Caianiello.** In *Memoria e progetto. Un modello per il Mezzogiorno che serve a tutto il paese.* Edited by Greco P, Termini S, Edizioni GEM 2010:47–68.
26. Tamburrini G, Termini S: **Do Cybernetics, System Science and Fuzzy Sets share some epistemological problems? I. An analysis of Cybernetics.** In *Proc. of the 26th Annual Meeting Society for General Systems Research*, Washington, D.C. 1982:460–464.
27. Termini S: **Remarks on the development of Cybernetics.** *Scientiae Mathematicae japonicae* 2006, **64**(2):461–468.
28. Greco P, Termini S (Eds): *Memoria e progetto. Un modello per il Mezzogiorno che serve a tutto il paese.* ISBN 978-88-96159-31-6, Edizioni GEM 2010.
29. Readings B: *The university in ruins.* Harvard University Press 1996.
30. De Luca A, Termini S: **A definition of a nonprobabilistic entropy in the setting of fuzzy sets theory.** *Information and Control* 1972, **20**(4):301 – 312, [<http://www.sciencedirect.com/science/article/pii/S0019995872901994>].
31. De Luca A, Termini S: **Entropy and Energy Measures of a Fuzzy Set.** In *Advances in Fuzzy Set Theory and Applications.* Edited by Gupta MM, Ragade RK, Yager RR, North-Holland 1979:321–338.

32. De Luca A, Termini S: **Entropy Measures in Fuzzy Set Theory**. In *Systems and Control Encyclopedia*. Edited by Singh MG, Pergamon Press 1988:1467–1475.
33. Blair B: **Interview with Lotfi A. Zadeh**. *Azerbaijani International* 1994, 2(4):46–47, 50.
34. Winograd T: **Understanding natural language**. *Cognitive Psychology* 1972, 3:1 – 191, [<http://www.sciencedirect.com/science/article/pii/0010028572900023>].
35. Takagi T, Sugeno M: **Fuzzy identification of systems and its applications to modeling and control**. *Systems, Man and Cybernetics, IEEE Transactions on* 1985, SMC-15:116–132.
36. Tanaka K, Sugeno M: **Stability analysis and design of fuzzy control systems**. *Fuzzy Sets and Systems* 1992, 45(2):135–156.
37. Dickens C: *David Copperfield*. Classics Library, Wordsworth Editions Limited 1992.
38. Dickens C: *Oliver Twist*. Oliver Twist, Richard Bentley 1839.
39. Hugo V: *Les misérables, translated from French by Isabel F. Hapgood*. T. Y. Crowell and Company 1887.
40. Moretti F: **Conjectures on world literature**. *New Left Review* 2000, 1:54–68.
41. Moretti F: **GRAPHS, MAPS, TREES - Abstract Models for Literary History 1**. *New Left Review* 2003, 24(November December):67–94.
42. Moretti F: **GRAPHS, MAPS, TREES - Abstract Models for Literary History 2**. *New Left Review* 2004, 26:79–103.
43. Moretti F: **GRAPHS, MAPS, TREES - Abstract Models for Literary History 3**. *New Left Review* 2004, 28:43–63.
44. Pykacz J: **Fuzzy Sets in Foundations of Quantum Mechanics**. In *On Fuzziness, Volume 299 of Studies in Fuzziness and Soft Computing*. Edited by Seising R, Trillas E, Moraga C, Termini S, Springer Berlin Heidelberg 2013:553–557.
45. Maczyński M: **The orthogonality postulate in axiomatic quantum mechanics**. *International Journal of Theoretical Physics* 1973, 8(5):353–360.
46. Pykacz J: **Quantum Logics as Families of Fuzzy Subsets of the Set of Physical States**. In *Preprints of the Second IFSA Congress, Volume 2* 1987:437–440.
47. Pykacz J: **Fuzzy quantum logics and infinite-valued Lukasiewicz logic**. *International Journal of Theoretical Physics* 1994, 33(7):1403–1416, [<http://dx.doi.org/10.1007/BF00670685>].
48. Vila-Matas E: *Desde la Ciudad Nerviosa*. Santillana 2004.
49. Melville H: *The Piazza Tales*, Dix & Edwards 1856 chap. Bartleby the Scrivener.
50. Frege G: *Posthumous writings*. Hamburg 1979.
51. van Heijenoort J: *Selected Essays*, Bibliopolis 1985 chap. Frege and Vagueness.
52. von Neumann J: **The General and Logical Theory of Automata**. In *Cerebral Mechanisms in Behavior the Hixon Symposium*, J. Wiley 1951.
53. Dennett DC: *Consciousness Explained*. Penguin 1991.
54. Chomsky N: *Language and Mind*. Cambridge University Press 2006.
55. Trillas E: **On negation functions in fuzzy set theory**. In *Advances of Fuzzy Logic*. Edited by Barro S, Bugarin A, Sobrino A, Universidade de Santiago de Compostela 1998:31–43.
56. Trillas E: **Sobre funciones de negación en la teoría de conjuntos difusos**. *Stochastica* 1979, 3:47–60.
57. Bateson G: *Mind and nature: A necessary unity*. Bantam Books New York 1980.
58. Bonissone PP: **Fuzzy logic controllers: an industrial reality**. *Computational Intelligence: Imitating Life* 1994, :316–327.

59. Kovalerchuck B: **Overview of the Panel at WCCI-2012.** *Mathware and Soft Computing Magazine* 2012, **19**(2):28–30.
60. Mamdani EH: **Twenty years of fuzzy control: experiences gained and lessons learnt.** In *Fuzzy Systems, 1993., Second IEEE International Conference on*, IEEE 1993:339–344.
61. von Neumann J: **Probabilistic Logics and the Synthesis of Reliable Organisms from Unreliable Components.** In *Automata Studies*. Edited by Shannon CE, MacCarthy J, Princeton University Press 1956.
62. Termini S: **Aspects of Vagueness and Some Epistemological Problems Related to their Formalization.** In *Aspects of Vagueness, Volume 39 of Theory and Decision Library*. Edited by Skala HJ, Termini S, Trillas E, Springer Netherlands 1984:205–230, [<http://dx.doi.org/10.1007/978-94-009-6309-2..11>].
63. Termini S: **On some vagaries of vagueness and information.** *Annals of Mathematics and Artificial Intelligence* 2002, **35**:343–355.
64. Termini S: **On Fuzziness its Homeland and its Neighbour.** In *On Fuzziness – A Homage to Lotfi A. Zadeh*, Studies in Fuzziness and Soft Computing. Edited by Seising R, Trillas E, Moraga C, Termini S, Springer-Verlag 2013.
65. Termini S, Tabacchi ME: **Specificities and Vagaries of Medicine from the Viewpoint of Hard Sciences.** In *Fuzziness and Medicine: Philosophical Reflections and Application Systems in Health Care, Volume 302 of Studies in Fuzziness and Soft Computing*. Edited by Seising R, Tabacchi ME, Springer 2013:77–81, [<http://dx.doi.org/10.1007/978-3-642-36527-0.4>].
66. Zadeh LA: **Fuzzy Sets.** *Information and Control* 1965, **8**:338–353.
67. Zadeh LA: **From Computing with Numbers to Computing with Words – From Manipulation of Measurements to Manipulation of Perceptions.** *International Journal of Applied Mathematics and Computer Science* 2002, **12**:307–324.
68. Carnap R (Ed): *Logical Foundations of Probability*, Chicago University Press 1950 :461–468.
69. Seising R, Trillas E, Moraga C, Termini S (Eds): *On Fuzziness – A Homage to Lotfi A. Zadeh*. Studies in Fuzziness and Soft Computing, Springer-Verlag 2013.