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Some Ideas Concerning Fuzzy Intelligent Systems

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Abstract

This article brings together some ideas on fuzzy intelligent systems. We start from fuzzy controllers, and we reflect on the role of fuzzy logic in other domains in which, in spite of optimistic forecasts, advances made are still less significant. By way of example, we make mention of certain fields in which it is foreseeable that there will be significant advances made using fuzzy logic. Finally, we emphasise certain problems and proposals that we consider to be of interest.

1 Introduction

Although it is frequently stated that FL enables us to solve problems that would be insoluble with other types of approaches, it should be clarified to what extent this expression is true. Setting high levels of precision in the resolution of many complex problems may entail an enormous cost, in economic terms as well as developmental and computational time. Precision and semantic value evolve jointly, but in opposite directions; we should remember the principle of incompatibility between precision and relevance expressed by Zadeh:

> *"...as the complexity of a system increases, our ability to make precise and yet significant statements about its behaviour diminishes until a threshold is reached beyond which precision and significance (or relevance) become almost mutually exclusive characteristics"[20].*

Many problems do not require very precise solutions, and humans can take advantage of this, as we are capable of resolving complex problems if these allow description and processing by means of a small number of symbols or data with a high semantic content, although often with imprecise meaning. In the same manner as ourselves, FL exploits tolerance dealing with imprecision, which at a problem-solving level translates, above all, into a reduction of the cost and effort required for the design, as well as the application of the solutions provided.

It is important to stress that modelling the real world in a non soft manner also means losing valuable information about the location of their elements in the discernment classes which establishes the knowledge of this world. In a crisp set there are no mechanisms for differentiating the elements which are found close to the frontier as opposed to those which are not, and this is information which is very important in many decision-making processes.

Few technologies have undergone such a rapid and explosive advance as fuzzy technology from the moment in which its theoretical foundations were established. Apart from the intrinsic qualities of FL, in my opinion, there are a number of factors that have worked in its favour [2]. On one hand is the competence and the efforts of some researchers in the field to explain, right from the start, certain key concepts deriving from the introduction of fuzzy sets (in this sense, the case of Prof. Zadeh would seem to be paradigmatic: let us take, simply as an example, the concept of a linguistic variable), and its lucidity when suggesting potential domains and types of applications in which to project these concepts in a practical manner[1]. On the other hand, we should point out the rapid appearance of process control applications and their favourable reception and their rapid expansion in Japan [9].

Although some researchers believe that the evolution of fuzzy technology is presently leaning towards a situation of stability, one which corresponds to the typical final stage in the evolution that follows the appearance of a new technology [4], I personally am of the opinion that we are still passing through a state of over-expectation (figure 1) with regard to fuzzy technology, and which should be taken advantage of, but which should also be assimilated with a certain amount of caution.

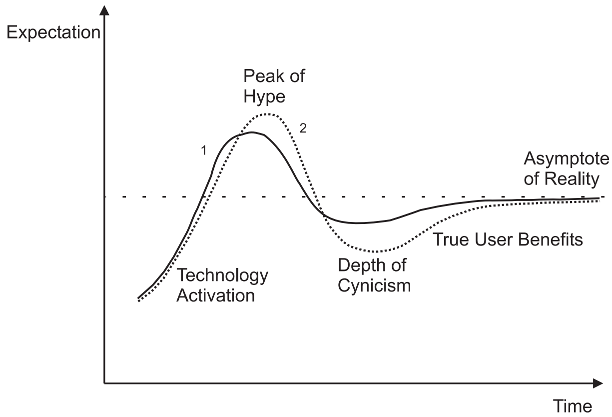

Figure 1: Evolution of fuzzy technology (1) in relation to the typical curve of the general evolution of technologies (2). Emphasis is given to quickness (due principally to the greater rapidity in the activation of the technology) and spatial compacting (the most attenuated peak of hype and depth of cynicism) which, to our way of thinking, the former has in relation to the latter.

[1]Other domains in which the "first egg" had been laid previously, have had to wait longer to see it "hatch". Such as the case, for example, of Artificial Neural Networks.

2 Fuzzy logic and process control

The initial development of the fuzzy set theory was motivated, to a good degree, by problems in pattern classification and clustering. From this came about the generalisation on the concept of the characteristic function of a set, going on to allow degrees of intermediate membership. In fact, it was not by chance that the first proposal that was aimed at the application domain was orientated towards pattern classification [3]. Nevertheless, it has been in the process control environment in which the principal practical repercussions of fuzzy logic have been obtained, and sustained, to a great degree, by the following pillars:

- Economy: in this sense, it is very clarifying to comment on the results presented by von Altrock [18] on a study relating to the experience of various European companies in the production of fuzzy-logic based designs. Out of a total of 311 companies that were consulted, in practically no instances was FL used to replace PID controllers or conventional multivariable controllers (Table 1). On the contrary, they did admit that it had served to reduce control hardware costs and, above all, with regard to sensors. Furthermore, the majority evaluated the reduction in production costs or the increase in the value of the product and its important design-time saving (in general over 50%) as being significant. These and other considerations led 303 of the 311 companies to consider the experience to be a success and to be fully in favour of repeating it.

- Opportuneness: fuzzy control appeared as an interesting response for finding alternative solutions to classic analytic control.

- Robustness: FL enables the development of systems that lose performance in a gentle, progressive manner as they move away from operational areas for which they were developed.

- Simplicity: The majority of fuzzy controllers have a very small number of rules (there are a large amount of solutions that only include between 7 and 15 rules [13]), and in these, rudimentary operational modes are assumed (Mamdani and Assilian's controller, of which we will now go on to speak, considered the 'minimum' as an implication operator linked to the application of a rule, something which is still maintained in many current fuzzy controllers).

The first fuzzy logic controller was developed by Mamdani and Assilian [12]. In this application an academic problem regarding plant control was solved, the plant being made up of a steam engine and boiler. The model of the plant used (in the words of the authors, "fuzzy controller has been derived from a fuzzy internal model of the plant identified by the human being") has two inputs: heat input to the boiler and throttle opening at the input of the engine cylinder; and two outputs: the steam pressure in the boiler and the speed of the engine. I would like to emphasise two aspects of this experiment: 1) it constituted the starting point for an alternative way to the theory of analytic control, to which neural networks and

Experience with fuzzy logic	Companies that answered in the affirmative	
	Number†	%
Solution would have been impossible to solve conventionally	0	0
Cheaper control hardware	35	11.25
Cheaper sensors	56	18.01
New functions for an existing product	130	41.80
Decrease production cost or increase product value	255	81.99
Solve the problem in less than half of any other technology	271	87.14
The company would use fuzzy logic again	303	97.43

† 311 companies were consulted.

Table 1: Data regarding the experience of certain European companies with FL [18].

genetic algorithms were added (generally, approaches known as soft computing), opening up a new front of interest and application in Artificial Intelligence (AI) (we will return to the FL-AI relationship at a later point); 2) The controller was synthesised [13] just one week after the reading and understanding of the work of Zadeh [20], which inspired the use of a fuzzy-rule based approach.

The first industrial application of fuzzy control was developed by the F.L. Smith & Co.A/S, for the control of rotary cement kilns (the first experiments in cement kilns were carried out at beginning of 1978 in a Danish cement works, using Østergaard's control rules [14]). Once again Zadeh's work [1973] appears as the main inspiration of the approach followed, but in this case there is an added aspect which it is important to stress; prior to the 1960s the cement plant operator controlled the cement kiln by looking into its hot end, the burning zone, and by watching the smoke leaving the chimney. Later temperature measurements, pressure measurements, voltage and amp indications, pen recorders alarms and other indicators were gathered in a central room. The operator no longer sat next to the hot, noisy and dusty kiln, but controlled the process by looking at instruments. This probably led to the idea of implementing a control strategy as a rough description of the manual control scheme, even before they had learnt of the fuzzy logic theory. This strategy was projected onto decision table on the oil feed exchange rate according to the error on kiln drive load and the kiln drive load trend. The incorporation of FL later served in order to better adapt the decision strategy to the human operational mode (we should bear in mind the previous comment on the opportuneness of fuzzy control).

The previous example should serve to make us reflect upon how measurement systems and instruments have been changing the type of information upon which analysis, monitoring, modelling and control, both natural and artificial, is based, permitting, with the aid of suitable theoretical, methodological and design tools, its computational projection and manipulation (figure 2), since human knowledge and modus operandi may be formulated in a more specific and comprehensible manner. FL brings together the environments of computation and cognitive models closer (an original, although often forgotten, intention of FL) as well as that of human behaviour. Both factors, pulling in opposite directions, allow the creation of meeting points. The paradigmatic case in point today is fuzzy control, although this process may extend itself to many other application domains and fields.

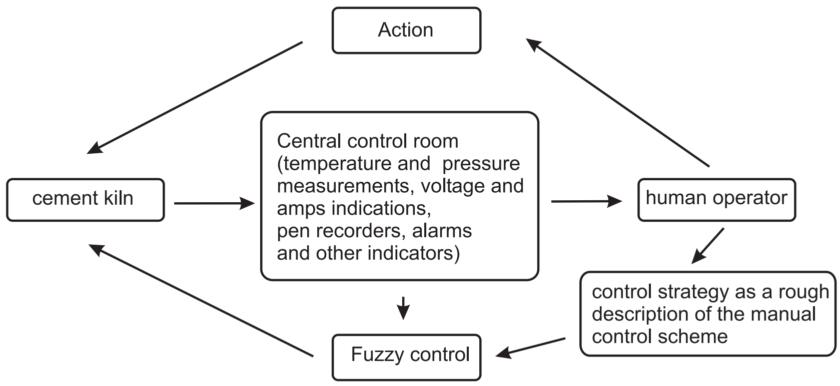

Figure 2: The introduction of systems of measurement and instrumentation makes the manual control of processes easier, but also the mimicking of it at a computational level.

3 Other application fields

It is frequently stressed that there are some application domains for FL that are more promising than those in which up until now it has had the greatest impact, such as the case of social or life sciences. Professor Zadeh has expressed this on many occasions over the years:

> *"By relying on the use of linguistic variables and fuzzy algorithms, ..., its main applications lie in economics, management science, artificial intelligence, psychology, linguistics, information retrieval, medicine, biology, and other fields in which the dominant role is played by the animate rather than inanimate behaviour of system constituents"* [20].

Although fuzzy logic and technology have already produced many important results of a practical nature in the aforementioned domains, there is an almost universal consensus of opinion that they have still not had the impact that was expected of them. It being clear that many applications of interest in these domains have a very high level of complexity, which poses problems not just for this approach but for any one that is taken, where does this special role that we predicted for fuzzy technology in these fields come from?

FL allows the handling of similarity, uncertainty and preference in a natural manner, as well as their graduation [6, 7], concepts that can be associated to the use of fuzzy sets from an eminently pragmatic point of view. The concept of similarity is closely related the idea of the prototypical character of an element in relation to a (fuzzy) set, and is directly connected with applications developed in classification processes and with fuzzy controllers. The concept of uncertainty is related to the idea of possibility distribution, and is the basis of approximated reasoning. Finally, the concept of preference refers to the acceptable solutions of a constraint that has to be satisfied, it being the optimisation process support. This triple focus is particularly interesting in those tasks that are modelled by means of "what may be uttered by a human being" or the result of which needs to be "told to a human being". In any case, be it in clarification (abstraction and structuring), retrieval or information exploitation processes, these different manners of conceptually handling fuzzy sets are principally useful in processes that aim to mimic human behaviour, knowledge and communication, and it is here where it is possible to expect the most genuine applications of fuzzy logic to be found.

On the other hand, the immense majority of current FL applications are based, albeit in an implicit manner, on the so-called fuzzy rule calculus, operating as a pseudo-language for the computational synthesis of linguistically expressed human operation. There are, of course, many more techniques of practical interest in the context of FL (fuzzy similarity relations and fuzzy orderings, etc.), but linguistic variables and fuzzy rules, along with fuzzy graphs are the ones that play a key role in which, in a broad sense, we could call "computation with words" [22] (the basis of which, is the observation that in a natural language words take on the role of labels for fuzzy granules [23]) and this is the fundamental core of fuzzy technology.

As has already been mentioned, the introduction of measurement and instrumentation systems has facilitated the development of systems through anthropomimetic approaches (we would once again reiterate that it is in this sense that FL can be seen as an especially useful tool). Nevertheless, in those domains which we referred to at the beginning of this section, this fact occurs in an irregular manner. Thus, it is notable in the case of medicine and economics, but is much more insignificant in the social sciences, linguistics or psychology, for example. In these latter domains the information involved in the resolution of the problems which are posed within them is, therefore, more difficult to deal with from a computational perspective, as it generally lacks forms of measurement of a quantitative nature. Although this does not cease to be an important drawback, it should be said in favour of fuzzy sets that, even though their origin and use have a distinct relationship with discourse universes of a numerical character (where we can exploit, for example, the potentiality of fuzzy arithmetic), for its definition it is sufficient to have an ordered set, which does not necessarily need to be numerical.

In general, I believe that we have still not seen the necessary entrance of FL into Artificial Intelligence (AI). At present, FL has created a developmental niche for itself, above all concerning its applications, and this has been simply annexed to AI, with which the latter has come to have a noteworthy presence in environments and applications where up until now this presence was merely anecdotal (we refer to consumer electronics, or, as we have already commented on, process control). Nevertheless, the set of methodologies and techniques that are grouped together under the name of soft computing has contributed to this, and not only FL.

By way of a list, and more in an attempt to provoke thought than to suggest original ideas, we now comment on some application domains in which fuzzy logic and technologies may be seen to play a special role in the coming years. The choice of these domains, amongst many others in which without any doubt there will be significant impact by FL, is based fundamentally on the interest awoken in the author of this work. Furthermore, in some cases they correspond with his own lines of research, which are either already under way or "in the pipeline".

- *Home Intelligent Medical Systems (HIMS).* HIMS gives a name to a personal prediction. The idea of a HIMS is that of a personal medical assistant. Although some futuristic visions point to some kind of global medical expert system, we believe that this vision is not a particularly realistic one, at least in a reasonable time scale, due to which we should opt for systems with much more specific tasks. We illustrate this with a very simple example. At present there are already some medical devices for personal use, the sphygmomanometer being perhaps the most well known. Nevertheless its Machine Intelligence Quotient (MIQ) [21] is almost nil. For the layman in medical aspects related with arterial pressure, its readings are of little or no value. This value, and hence its MIQ, will increase notably by "translating part of the medical knowledge of the evaluation of arterial pressure which exists today and which is shared by many individuals related with the field of medicine".

  The value of adequate control and evaluation of arterial pressure is unquestionable: hypertension is the leading risk factor of many diseases, such as renal disease or coronary artery disease, amongst others. Nevertheless, what would the interest and tasks of an HIMS-sphygmomanometer be? We will attempt to explain this with an example: If we measure our arterial pressure and we obtain values of 80mmHg of diastolic pressure and 160 mm for systolic pressure, and we use the standard classification table for blood pressure, it can be seen that these readings are normal, due to which we will happily put the sphygmomanometer away until the next time. If however the sphygmomanometer were a HIMS one, which bore in mind our age, weight, height, history of arterial hypertension in our family and many other data of interest, as well as records of previous readings, it could say something along the lines of: "systolic pressure has risen slightly over the last year, and it is a little high. Although the situation is not of grave concern, further tests should be carried out in the near future. If you wish I can programme dates for these tests and give you some advice on how to do them in order that the results be more reliable".

  In order to effect this evaluation, it is necessary to be aware of the multiple factors which may specifically influence arterial pressure: anxiety, food intake, tobacco consumption, pain, etc., as well as many others that do so in a more persistent manner: pregnancy, age, obesity, etc. Furthermore, there is a series of established criteria for the treatment of hypertension, which depend on the age of the individual in question, if he or she belongs to a high-risk group or not (those with a family history of hypertension or obesity, who use oral contraceptives, excessive consumption of alcohol, etc.) and many other factors amongst which can of course be found the arterial pressure records themselves (figure 3). These criteria range from intense monitoring over a period of time to the immediate application of a therapy.

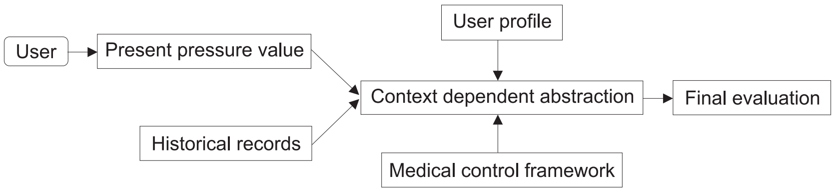

Figure 3: Basic operational scheme of a HIMS-sphygmomanometer.

- *Domotics*. In the same way as HIMS in the medical domain, many household appliances, and instrumentation typical of the home environment will reach ever greater levels of competence (who knows, perhaps we will get as far as the "sophisticated toaster" that Paniagrahi [15] puts into the words of the adviser, more specifically, a computer scientist, of a hypothetical king, and whose sophistication and, above all, software and hardware requirements, make him lose his head, and not exactly in the figurative sense. For a long time this aim has been being striven for. We should not forget that the idea that originated Java was that of enabling household appliances to "converse" and be programmed in a very flexible manner with regard to their functions, although now Java has assumed a far higher level of protagonism outside its original objectives. Be it in Java or any other technology under development, FL will almost certainly carry on being a key constituent in the progressive increase in intelligence of these machines.

- *Recovering of multimedia Web information*. We are suffering more and more from the lack of flexibility and intelligence of Web information search engines, in spite of their undeniable usefulness. In common searches we usually receive scant valuable information which is embroiled in an enormous proposal of sites of interest, with inadequate prioritisation. We are a long way, not only from being able to use natural language in the specification of our consultations, but also from doing so by means of artificial languages which, although being limited, afford us at the same time sufficient flexibility and specificity in order to describe what we are looking for. In order to do this we need to adequately deal with semantic imprecision and the contextual dependence of many terms, the identification of sounds and images with linguistic descriptions, etc. In short, we need to advance further in comparison and computation with lexical items and, once again, FL can lend a hand in this sense [11, 10].

- *Learning.* If FL facilitates "the writing of solutions", learning on a FL based support facilitates the "reading of solutions". In both cases we are approaching the expert in the domain, the designer of the system, and its user. In recent years important advances have been made in sub-symbolic learning techniques (neural networks, genetic algorithms, reinforcement learning, etc.). The usefulness of these methods is unquestionable in the resolution of multiple practical problems in the most varied domains, but the sub-symbolic support itself onto which all that is learned is projected, poses problems to their interpretation, explication and reutilization. On the other hand, the real world, and hence the "worlds" which the learning processes encounter, usually have poorly defined borders in their classes, non-linearity in their behaviour, a great deal of both structural and functional complexity, which requires them to be simplified for it to be possible to use them, etc. Learning, therefore, should lead to knowledge capable of "reproducing" these aspects. Soft computational techniques, and amongst these, FL, are capable of doing so, at least partially.

4 Some problems and proposals

Real applications of FL that are genuinely novel and significant do not abound in the journals and congresses of the field. A comment made by Zimmermann [24], although in this case fundamentally referring to industrial applications, can be understood within the setting of certain justifications that we can say are of an "optimistic nature":

> *"Practitioners normally are not writers. Their objective function calls for solving problems with techniques that are as safe, as inexpensive, and as efficient as possible, not for the publication of a new approach. In addition, attractive real-world applications are rather complex when explained in detail. Therefore, such applications are not necessarily suited for publication in a journal. Furthermore, competitive considerations often prevent the publication of attractive applications before the patenting of novel technology used in the application".*

I feel that it is necessary to add to this consideration the fact that some of the most valuable results are published in places belonging to the application domain to which they are aimed (journals of the different branches of engineering, for example, and less frequently in medicine or economics) and not in those usually used for the publication of results relating to FL. In any case, I fear that there is presently a certain amount of apathy in the fuzzy technological environment, which is reflected by the low level of truly original contributions in the habitual forums for the presentation and discussion of results (in contrast to the previous one, it could be said that this justification is of a "pessimistic nature").

In the area of theoretical contributions, I feel that many papers published are, from a mathematical point of view, relevant exercises, but they do not provide, at least in a sufficiently clear manner, novel or transcendent concepts. Of course, purely theoretical works are positive, but all too often no effort is made to clear up any doubts as to the interest of their content, which could be a little confusing to anyone approaching the field in search of new ways of solving their problems, or inspiration for advancement in methodologies and the tools for constructing these solutions. In the words of Dubois and Prade [6]:

> *"there exists a very nice and mathematically sound framework for combining fuzzy sets, but it is often presented without casting it into an interpretative framework".*

On the other hand, there is an almost obsessive tendency to take any precise concept (C), be it abstract or real, and make it fuzzy (fuzzy C), leaving aside the relative reflection on it sense or direct or potential usefulness. This is taken as if it fuzzifying everything were a challenge, or fashion. Here we should remember something that Zadeh often reiterates, although with a different intention, and which goes more or less as follows: "to he who only has a hammer, everything looks like nails". We should be aware that in many cases FL may not be the most suitable design option. Furthermore, in the majority of complex applications it is not advisable to approach a solution that is structured on the basis of the exclusive use of FL. From a practical point of view complex projects need to combine different design approaches, based on heterogeneous and hybrid architectures.

Practically all software tools for the design of fuzzy systems [5, 16] differ in their interaction with the user (editing of rules, knowledge base analysis and debugging possibilities, etc.) or with regard to the system supporting the application (admitting source or assembler code generation, for example) but they basically adhere to the same knowledge and reasoning representation model as the first fuzzy controllers. They need much more sophisticated and powerful tools, with a greater emphasis on improved flexibility and expressiveness in the representation of fuzzy knowledge [17], on the reasoning mechanisms employed (the excellent adaptation of FL to the reasoning based on cases [6, 19] is widely recognised) or in integration into other systems design strategies (neural networks, genetic algorithms, etc.). Clearly, the development of these software tools requires theoretical and methodological contributions to lend them support, but, curiously, little effort is being made along these lines, whilst the design of ad-hoc hardware for the execution of fuzzy systems, for example, is distracting a great deal of human effort and material resources, in spite of the fact that today this is difficult to justify from a perspective of end profitability. Although the availability of this hardware may eliminate problems derived from the execution load of a fuzzy system in complex applications with high demands with regard to the reduction of response time, the enormous advance in the performance of more general purpose hardware (such as the case of microcontrollers, which are widely used in fuzzy control applications) in the majority of cases allows us to disregard execution time as an important conditioner in the design and implementation process of fuzzy systems.

Finally I would like to point out the protagonism that I believe FL will have in modelling of common reasoning, something that is crucial for the design of intelligent systems. FL is both sufficiently formal and flexible to be considered as a cornerstone of the modelling of common sense. There are two principal axes in the configuration of Common Sense (CS): Common Knowledge (CK) and Common Reasoning (CR). The equation for common sense, CS=CK+CR, takes the contribution of CK as being the practical knowledge used by individuals in many frequent real-life situations (huge knowledge bases, dependent on the most common experiences, on cultural and social aspects, and even on dogmas of faith, for example) and that of CR, as being the practical reasoning applied by individuals in those real-life situations (supported by multiple abilities, strategies and criteria of reasoning, based on logical reasoning, pattern matching, rules of thumb, etc.). Human reasoning is plagued with aspects belonging to this common reasoning, which do not, by any stretch of the imagination, fit into a single model of reasoning. Nevertheless, this is not assumed in the majority of intelligent systems that are developed. Fuzzy Logic is a very good way of connecting symbols and concepts, for dealing with semantics for representing and comparing concepts, for constraining them, extending them, compressing them, generalising them, particularising them, etc., as humans do. In this sense, FL has already given us a good set of conceptual, methodological and design tools for dealing with forms that are typical of common reasoning: linguistic variable, fuzzy quantification, fuzzification and defuzzification, predicate modification, truth qualification, the extension principle, the compositional rule of inference, interpolate reasoning, etc. This is also the case with the concept of generalised constraints, a starting point in the "fuzzy information granulation" theory; in the same manner as there are multiple types of constraint (related to possibilistic, veristic and probabilistic values, etc. [23]), which are capable of being adapted to the representation of concepts and the semantic plurality typical of the real world and natural language, there also exist transformation mechanisms for these restrictions which may be considered as list of reasoning processes, and which, as has already been stated, on of the fundamental parts of common sense.

5 Final Reflections

At present we are witnessing saturation of technology in the fields of information and communications which affects practically all application domains. Thus, the improvements in system is fundamentally going hand in hand with advances in hardware. Nevertheless, it is not very probable that this situation will be maintained indefinitely, whilst the introduction of more intelligence through knowledge technologies, or 'know ware', will assume increasing protagonism as a driving force for the design of ever more complex systems with more competence in their operation domains. In this setting of strengthening of knowledge technologies, FL will have, and is already having, a prominent role. In fact, if we specifically defined how to obtain the intelligence quotient of a machine (MIQ), and we calculated it for some examples of well known, popular current appliances (such as video cameras, washing machines, air-conditioning systems, etc.), it would turn out that many of them with the highest MIQs would make use of "fuzzy intelligence". Nevertheless, we should bear it clearly in mind that the meaning of the adjective intelligent, above all when applied to a machine, will be dynamic. Initially, almost any microcontroller based system could immediately be labelled intelligent. Today we are more demanding, and not even the washing machine, that autonomously chooses the drying programme according to the water and level of dirtiness of the clothes now seems to be overly intelligent to us. Thus, we should not expect that the solutions that are currently being used in the environment of fuzzy control should give us unlimited growth in the intelligence of our appliances.

Although FL cannot be considered as a panacea for any one application domain, there is no doubt that it is fundamental and a theoretical, methodological and design tool in those applications in which no precise information or knowledge is available. Moreover, although it is possible to achieve it, we must insist that precision is indissolubly linked to increased cost. As Zadeh [23] pointed out so well, FL plays its best role when it is a matter of "exploiting the tolerance for imprecision, uncertainty and partial truth to achieve tractability, robustness, low solution cost and a better rapport with reality". Added to this, the possibility of dealing with many problems on the basis of a certain degree of mimicry with regard to knowledge and/or the human problem solving method, confers an important added value to FL. In this sense there is still a strong need for theoretical and methodological contributions and tools that will enable us to represent and manipulate knowledge in more flexible and expressive ways, which need to go hand in hand with greater homogeneity of perspectives and approaches in the design of intelligent systems. The design of a controller may be focused solely on FL, but this is unlikely for patient supervision systems, nuclear powerstation monitoring or the total control of a helicopter.

In the same way that, sooner or later, physics theories are demonstrated to be insufficient, too simplistic with regard to reality, erroneous in certain suppositions, or are simply displaced by newer and better theories, those most typical of the computation environment, with the reservation that its object of study and research is not the so-called real world, are subjected to strong fluctuations. What remains of these theories when this happens? In some cases, no more than the memory of it for the posterity of science, in other cases the recognition of having served as a bridge between the even earlier ones and the current ones. Nevertheless, the sediment are often more specific, and they form part of the technological advances that have been made possible on the basis of this theory, even though it was flawed, incomplete or simplistic concerning the reality under study. It is possible that FL ends up being transformed, reformed, reconverted of absorbed by a new theory, but meanwhile, fuzzy technology is improving our lives, and in order that it should continue to do so, we should bear in mind that FL does not have to change our way of thinking, rather that of machines [1].

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