Language, Thinking, Meaning – and Fuzzy Logic

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Abstract

In this paper we associate the three concepts of language, thinking, and meaning with Fuzzy Sets and Systems and Fuzzy Logic. We present some developments in 20th century history of science and of humanities that show deep links between these concepts and we give a proposal for a fuzzy theoretical interpretation of what is meaning.

Keywords: Language, thinking, meaning, perception, fuzzy sets, family resemblance

1. Introduction

With this paper we give an introduction to the special session on "Language – Thinking – Meaning" of the EUSFLAT – LFA 2011 conference. This special session is intended to intensify discussions on the non-technical applications of the theories of Fuzzy Sets and Systems (FSS) and Fuzzy Logic (FL) in the communities of humanities and social sciences.

Four years after his seminal papers "Fuzzy Sets" [1] and "Fuzzy Sets and Systems" [2], and once again two years later, Lotfi A. Zadeh, the founder of this mathematical theory notified that he did not expect the incorporation of fuzzy sets and systems (FSS) into the fields of hard sciences and technology: "What we still lack, and lack rather acutely, are methods for dealing with systems which are too complex or too ill-defined to admit of precise analysis. Such systems pervade life sciences, social sciences, philosophy, economics, psychology and many other "soft" fields." [3, 4]

On the contrary, he intended to open the field of applications of his new theory of FSS to humanities and social sciences. Reading an interview that was printed in the *Azerbaijan International*, in 1994, we can improve this view: when Zadeh was asked, "How did you think Fuzzy Logic would be used at first?" his retrospective answer was: "In many, many fields. 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.

Instead, Fuzzy Logic was first embraced by engineers and used in industrial process controls and in "smart" consumer products such as hand-held camcorders that cancel out jittering and microwaves that cook your food perfectly at the touch of a single button. I didn't expect it to play out this way back in 1965." [5]

Zadeh's first efforts to use his fuzzy sets in linguistics led to an interdisciplinary scientific exchange on the campus of the University of California at Berkeley between him and the mathematician Joseph Goguen (1941-2006) on the one hand and between the psychologist Eleanor Rosch (born 1938) and the linguist George Lakoff (born 1941) on the other.

Zadeh had served as first reviewer for Goguens's Ph.D. thesis "Categories of Fuzzy Sets" [6] and Hans-Joachim Bremermann (1926-1996), his Berkeley-colleague, who was then in the mathematics department, served as the second. In this work, Goguen generalized the fuzzy sets to so-called "*L*-sets". An *L*-set is a function that maps the fuzzy set carrier X into a partially ordered set L: A: $X \rightarrow$ L. The partially ordered set L Goguen called the "truth set" of A. The elements of L can thus be interpreted as "truth values"; in this respect, Goguen then also referred to a "Logic of Inexact Concepts" [7].

Since Zadeh's earlier definition had established this truth set as the unit interval, Fuzzy Set Theory was very soon associated with the two multi-valued logics or with probability logic, as well. Goguen's generalization of the set of values to a set L for which the only condition was to be partially ordered cleared up these misunderstandings.

Goguen's work was laid out in terms of logical algebra and category theory, and his proof of a representation theorem for L-sets within category theory justified Fuzzy Set Theory as an expansion of set theory [8].

In these times, Eleonor Rosch developed her prototype theory on the basis of empirical studies. This theory assumes that people perceive objects in the real world by comparing them to prototypes and then ordering them accordingly. In this way, according to Rosch, word meanings are formed from prototypical details and scenes and then incorporated into lexical contexts depending on the context or situation. It could therefore be assumed that different societies process perceptions differently depending on how they go about solving problems [9]. When Lakoff heard about Rosch's experiments, he was working at the Center for Advanced Study in Behavioral Sciences at Stanford. During a discussion about prototype theory, someone there mentioned Zadeh's name and his idea of linking English words to membership functions and establishing fuzzy categories in this way. Lakoff and Zadeh met in 1971/72 at Stanford to discuss this idea and also the idea of idea of fuzzy logic, after which Lakoff wrote his paper "Hedges: A Study in Meaning Criteria and the Logic of Fuzzy Concepts" [10]. In this work, Lakoff employed "hedges" (meaning barriers) to categorize linguistic expressions and he invented the term "fuzzy logic" whereas Goguen had used "logic of inexact concepts".

Based on his later research, however, Lakoff came to find that fuzzy logic was not an appropriate logic for linguistics: In an interview he said: "It doesn't work for real natural languages, in traditional computer systems it works that way."[11] But: "Inspired and influenced by many discussions with Professor G. Lakoff concerning the meaning of hedges and their interpretation in terms of fuzzy sets," Zadeh had also written an article in 1972 in which he contemplated "linguistic operators", which he called "hedges": "A Fuzzy Set-Theoretic Interpretation of Hedges". Here he wrote: "A basic idea suggested in this paper in that a linguistic hedge such as *very*, *more*, *more or less*, *much*, *essentially*, *slightly* etc. may be viewed as an operator which acts on the fuzzy set representing the meaning of its operand [12].

After this short period to use the theory of Fuzzy Sets, however, a multitude of other developments has arisen in the field of control engineering to Fuzzy Control. In the year 1973 Abe Mamdani (1942-2010) and his Ph. D. student Sedrak Assilian designed the first real fuzzy application when they controlled the system by a fuzzy rule base system [13]. In 1974, Assilian completed his Ph.D. thesis on this first fuzzy control system [14]. This steam engine heralded the Fuzzy boom that started in the 1980s in Japan and later pervaded the Western hemisphere. Many fuzzy applications, such as domestic appliances, cameras and other devices appeared in the last two decades of the 20th century. Of greater significance, however, was the development of fuzzy process controllers and fuzzy expert systems that served as trailblazers for scientific and technological advancements of fuzzy sets and systems.

At the end of the 20th century Zadeh came back to his early intention to use FSS and FL in non-technical areas when he proposed the method of "Computing with Words" (CW). In 1996 he had published the article *Fuzzy Logic = Computing with Words* [15] where he proposed CW based on the theories of FSS and FL instead of exact Computing with numbers (CN). He argued that "the main contribution of fuzzy logic is a methodology for computing with words. No other methodology serves this purpose" ([16], p. 103.) and for the new century (millennium) Zadeh published his proposal *A New Direction in AI. Toward a Computational Theory of Perceptions* [17]. Once again he clarified here that this "Computational theory of perceptions" (CTP) was inspired by the remarkable human capability to operate on, and reason with, perception-based information. Zadeh wrote: "Humans have a remarkable capability to perform a wide variety of physical and mental tasks without any measurements and any computations. Everyday examples of such tasks are parking a car, driving in city traffic, playing golf, cooking a meal, and summarizing a story. In performing such tasks, for example, driving in city traffic, humans base whatever decisions have to be made on information that, for the most part, is perception, rather than measurement, based." He assumed "that progress has been, and continues to be, slow in those areas where a methodology is needed in which the objects of computation are perceptions—perceptions of time, distance, form, and other attributes of physical and mental objects." ([17], p. 73)

Since that time, many scientists work hard to contribute with mathematical and logical thinking to establish theories in the areas of CW and CTP. In my view, this research lacks the contribution from humanities and social sciences. CW and CTP cannot arise without the fundamentals in these non-technical fields and on the other hand: they cannot lead to new developments in the humanities, such as in linguistics, philosophy or economics. Therefore, we have to inspire philosophers, psychologists, linguists, sociologists and also thinkers in the fields of arts and music.[1] This special session will give a new view on associations in these fields with the concepts of FSS. It will concern the relations between Logics, Linguistics, Cognitive Science, Psychology, Philosophy and other Humanities and Social Sciences on the one hand and the methodologies of Fuzzy Sets and Systems on the other hand. Especially in this introductory paper we associate the three concepts of *language*, *thinking*, and *meaning* with some historical paths in humanities and non-technical sciences at one hand and in science and technology in the 20th century from Computing to Soft Computing at the other hand.

2. Language

In the second decade oft he 20th century the Austrian-British philosopher Ludwig Wittgenstein (1889-1951), wrote the *Tractatus logico-philosophicus* [18] that was published − in German in 1921 and one year later in a bilingual edition (German and English). He and his work were supported by Bertrand Russell (1872-1970), who wrote an introduction to it where he tried to explain Wittgenstein's thinking: "A picture", he says, "is a model of the reality, and to the objects in the reality correspond the elements of the picture: the picture itself is the fact. The fact that things have a certain relation to each other is represented by the fact that in the picture its elements have a certain relation to one another. "In the picture and the pictured there must be something identical in order that the one can be a picture of the other at all. What the picture must have in common with reality in order to be able to represent it after its manner − rightly or falsely − is its form of representation." (2.161, 2.17) ([21], p. 10)

In the *Tractatus*, Wittgenstein wrote that the world consists of facts. Facts may or may not contain smaller parts. If a fact has no smaller parts, he calls it an "atom-

[1] See the already published book [18] and also the coming book [19] and the special issue [20].

ic fact." If we know all atomic facts, we can describe the world completely by corresponding "atomic propositions." He proposed that "the logical picture of the facts is the thought" and that "the thought is the significant proposition". Finally: "The totality of propositions is language." ([21], prop. 4.001)

Of course, Wittgenstein argued that sentences in colloquial language are very complex. He conceded that there is a "silent adjustment to understand colloquial language" but it is "enormously complicated." Therefore it is "humanly impossible to gather immediately the logic of language." ([21], prop. 4.002) This is the task of philosophy: "All philosophy is «Critique of language.»" ([21]. prop. 4.0031)

Wittgenstein knew that common linguistic usage is vague, but at the time when he wrote Tractatus, he tried to solve this problem by constructing a precise language – an exact logical language that gives a unique picture of the real world – and he influenced any philosophers in the era before the Second World War, e.g. most of the members in the Vienna Circle and first of all Rudolf Carnap (1891-1970) the author of *Der logische Aufbau der Welt* (*The Logical Structure of the World.*) [22]. Therefore, in the years before the Second World War Wittgenstein and many philosophers thought that the Tractatus solved all philosophical problems!

After the Second World War many of the scientific-technological achievements that were developed in research projects during the war became generally known by the public. In this initiating period of the "Age of intelligent systems" the American mathematician and science administrator Warren Weaver (1894-1978) wrote three important papers:

- The article "Science and Complexity" [23] based upon material for Weaver's introductory contribution to a series of radio talks, presenting aspects of modern science by 97 scientists, given as intermission programs during broadcasts of the New York Philharmonic-Symphonies. Weaver edited the written contributions in the book The Scientists Speak [24] and one year later "Science and Complexity", which arose from the book's first chapter, was published in the American Scientist.
- The text "Translation" was a memorandum that circulated to some twenty or thirty acquaintances, which was to stimulate the beginnings of research on machine translation in the United States. In 1955, this text appeared in a Collection of essays on Machine translation of Language, see [25].
- The article "The Mathematics of Communication" [26] was a re-interpretation of the article "A Mathematical Theory of Communication" [27] by the electronic engineer and mathematician Claude Elwood Shannon (1916-2001) for broader scientific audiences. Later, Weaver modified and accentuated this text with the new title "Recent Contributions to the Mathematical Theory of Communication" that was published together with Shannon's paper in the book The Mathematical Theory of Communication. [28]

In the first article Weaver identified a "region" of problems "which science has as yet [1947/1948] little explored or conquered". These problems, he wrote, can neither be reduced to a simple formula nor can they be solved with methods of probability theory. To solve such problems he pinned his hope on the power of computers and on interdisciplinary collaborating "mixed teams" [23].[2]

In the second paper, Weaver brooded whether it is unthinkable to design digital computers which would translate documents between natural human languages, Weaver speculated "that the way to translate from Chinese to Arabic, or from Russian to Portuguese, is not to attempt the direct route […]. Perhaps the way is to descend, from each language, down to the common base of human communication – the real but as yet undiscovered universal language – and – then re-emerge by whatever particular route is convenient." [28]

Weaver was looking for "invariant properties which are, not precisely but to some statistically useful degree, common to all languages": "All languages – at least all the ones under consideration here – were invented and developed by *men*, whether Bantu or Greek, Islandic or Peruvian, have essentially the same equipment to bring to bear on this problem. They have vocal organs capable of producing about the same set of sounds (with minor exceptions, such as the glottal click of the African native). Their brains are of the same general order of potential complexity. The elementary demands for language must have emerged in closely similar ways in different places and perhaps at different times. One would expect wide superficial differences; but it seems very reasonable to expect that certain basic, and probably very nonobvious, aspects are common to all the developments." [28]

This idea, "to descend from each language, down to the common base of human communication – the real but as yet undiscovered universal language –" seems similar to Zadeh's concept of "precisiated natural language" (PNL) that "was employed as a basis for computation with perceptions" and that is still "in its initial stages of development" ([29], p. 74).

The third article Weaver wrote to put Shannon's "Mathematical Theory of Communication" across to a general and scientific interested public. Moreover, Weaver considered this theory in a philosophically way: ''In communication there seem to be problems at three levels: (1) technical, (2) semantic, and (3) influential. The technical problems are concerned with the accuracy of transference of information from sender to receiver. They are inherent in all forms of communication, whether by sets of discrete symbols (written speech), or by a varying two-dimensional pattern (television). The semantic problems are concerned with the interpretation of meaning by the receiver, as compared with the intended meaning of the sender. This is a very deep and involved situation, even when one deals only with the relatively simple problems of communicating through speech. [...] The problems of influence or effectiveness are concerned with the success with which the meaning

[2] For more details see [30].

conveyed to the receiver leads to the desired conduct on his part. It may seem at the first glance undesirable narrow to imply that the purpose of all communication is to influence the conduct of the receiver. But with any reasonably broad definition of conduct, it is clear that communication either affects conduct or is without any discernible and provable effect at all." ([26], p. 11)

Weaver argued that Shannon's "Mathematical Theory of Communication" did not even touch upon any of the semantic and effectiveness or pragmatic problems, but that the concepts of information and communication therefore must not be identified with the "meaning" of the symbols. Then he wrote "The theory goes further. Though ostensibly applicable only to problems at the technical level, it is helpful and suggestive at the levels of semantics and effectiveness as well."

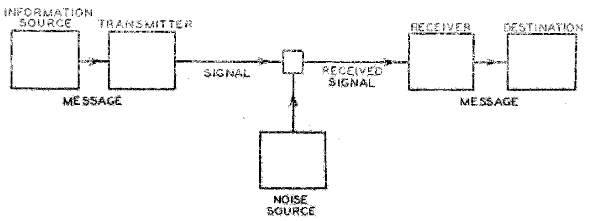

Fig. 1: Shannon's diagram of communication ([27], p. 381).

He stated, that Shannon's formal diagram of a communication system (Fig. 1) ''can, in all likelihood, be extended to include the central issues of meaning and effectiveness. [...] One can imagine, as an addition to the diagram, another box labelled ''Semantic Receiver" interposed between the engineering receiver (which changes signals to messages) and the destination. This semantic receiver subjects the message to a second decoding the demand on this one being that it must match the statistical semantic characteristics of the message to the statistical semantic capacities of the totality of receivers, or of that subset of receivers which constitutes the audience one wishes to affect. Similarly one can imagine another box in the diagram which inserted between the information source and the transmitter, would be labelled ''Semantic Noise" (not to be confused with ''engineering noise"). This would represent distortions of meaning introduced by the information source, such as a speaker, which are not intentional but nevertheless affect the destination, or listener. And the problem of semantic decoding must take this semantic noise into account. It is also possible to think of a treatment or adjustment of the original message that would make the sum of message meaning plus semantic noise equal to the desired total message meaning at the destination. ([23], [25], p. 13)[3]

Weaver's midcentury expectations on the progress in science and technology seem to be anticipating important topics in the field of FSS and FL: vague, fuzzy or approximate reasoning, the meaning of concepts. However, there is no direct relation between the work of Weaver and Zadeh[4] but these aspects make it worth to study Weavers writings in this context, to compare it with more recent scientific theories, to intensify discussions and to push interdisciplinary work between hard and soft and social scientist, researchers in humanities and actors in arts, music and literature.

3. Thinking

As we mentioned already in the last section, after the Second World War, computers – next to the atomic bomb the most famous technical product of war research – became popular as "electronic brains" or "thinking machines". This "era of computers" started already with MIT Differential Analyzer of Vannevar Bush (1890-1974) that was not a digital but an analogue machine and then the war products ENIAC (Electronic Numerical Integrator and Computer) and EDVAC (Electronic Discrete Variable Computer), both designed by J. P. Eckert (1919-1995) and J. W. Mauchly (1907-1980).

In the spring of 1945 the mathematician John von Neumann (1903-1957) was asked to prepare a report on the logical principles of the EDVAC, since the ENIAC had not had any such description and it had been sorely missed. In this report [33] he adopted the neuron model from a paper of Warren Sturgis McCulloch (1898-1968) and Walter H. Pitts (1924-1959) [34] that explained the brain and nervous system to a logical computer and drew the inverse conclusion. The similarity between neurons and electric switching elements was apparently so clear to him that he did not thoroughly question it. When the British mathematician Alan M. Turing (1912-1954) published in 1950 his famous article "Computing Machinery and Intelligence" [35] in the journal *Mind* the answer of the following question was very popular and also of philosophical interest: "Can machines think?" – Turing proposed the well-known imitation game, now called the "Turing test", to decide whether a computer or a program could think like a human being or not.

In those days a young Lotfi Zadeh was interested in the new computing machines. In 1949 he had obtained a position at Columbia University in New York as an instructor responsible for teaching the theories of circuits and electromagnetism but after this year, when he had received his Ph. D., he turned his attention to the problems of computers. Inspired by a lecture of Claude E. Shannon in New York in 1946, two years before his "Mathematical Theory of Communication" would be published [26], and also by Norbert Wiener's famous book *Cybernetics* [36], Zadeh served as a moderator at a debate on digital computers at Columbia University between Shannon, Edmund C. Berkeley (1909-1988), the author of the book *Giant Brains or Machines That Think* published in 1949 [37], and Francis J. Murray (1911-1996), a mathematician and consultant to IBM.

[3] For more details see [31].

[4] In a personal message Zadeh answered to the author's question whether he was familiar with Weaver's papers in the 1940s and 1950s that he did not read the papers [23-25, 27, 28]. He also wrote: "It may well be the case that most people near the center [of the "world of information theory and communication" in that time] did not appreciate what he [Weaver] had to say. In a sense, he may have been ahead of his time." [32]

Then, unaware of Turing's philosophical article, Zadeh wrote the paper "Thinking Machines – A New Field in Electrical Engineering", which appeared in the student journal *The Columbia Engineering Quarterly* in New York City in 1950 [38]. Here, Zadeh put up for discussion the questions "How will 'electronic brains' or 'thinking machines' affect our way of living?" and "What is the role played by electrical engineers in the design of these devices?" ([38], p. 12.]

He was looking for "the principles and organization of machines which behave like a human brain. Such machines were then variously referred to as "thinking machines", "electronic brains", "thinking robots", and similar names. He mentioned that the "same names are frequently ascribed to devices which are not "thinking machines" in the sense used in this article", therefore he separated as follows: "The distinguishing characteristic of thinking machines is the ability to make logical decisions and to follow these, if necessary, by executive action." ([38], p. 12.) He stated: "More generally, it can be said, that a thinking machine is a device which arrives at a certain decision or answer through the process of evaluation and selection." With this definition he decided that the MIT Differential Analyzer is not a thinking machine, but both then built large-scale digital computers, UNIVAC (Universal Automatic Computer) and BINAC (Binary Automatic Computer), are thinking machines because they both were able to make non-trivial decisions. ([38], p. 13.) Zadeh explained in this article "how a thinking machine works" (Figure 1) and he claimed, "the box labeled Decision Maker is the most important part of the thinking machine".

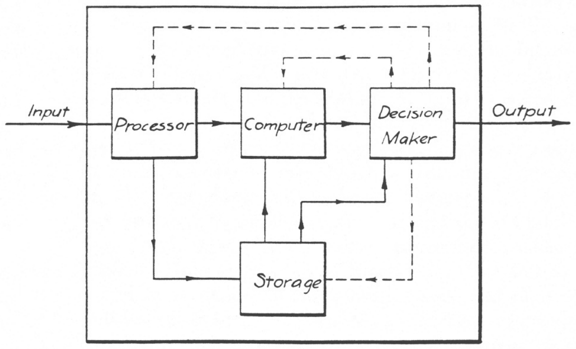

Fig. 2: Zadeh's chart for the basic elements of a "Thinking Machine" [38], p. 13.

Zadeh illustrated his argumentation by peering forward into the year 1965, which was then 15 years in the future. Three years earlier, in this version of the future, the administration at Columbia University had decided, for reasons of economy and efficiency, to close the admissions office and install in its place a thinking machine called the "Electronic Admissions Director". The construction and design of this machine had been entrusted to the electrical engineering department, which completed the installation in 1964. Since then, the "director" has been functioning perfectly and enjoying the unqualified support of the administration, departments and students. This thinking machine functions as follows:

1. Human secretaries convert the information from the list of applicants into series of numbers $a_1, a_2, a_3, \dots, a_n$; each number represents a characteristic, e. g. a_1 could stand for the applicant's IQ, a_2 for personal character, and so on.
2. The lists coded thusly are provided to the processor, which processes them and then relays some of the data to the computer and another part of the data to storage. On the basis of applicant data as well as university data, the computer calculates the probabilities of various events, such as the probability that a student will fail after the first five years. This information and the saved data are sent to the decision maker to come to final decision on whether to accept the applicant. The decision is then made based on directives, such as these two:
   - accept if the probability of earning the Bachelor's degree is greater than 60%;
   - reject if the probability that the applicant will not pass the first year of college is greater than 20%.

Zadeh didn't consider the machine sketched out here to be as fanciful as student readers (and surely others, as well) may have thought: Machines such as this could be commonplace in 10 or 20 years and it is already absolutely certain that thinking machines will play an important role in armed conflicts that may arise in the future. ([38], p. 30) Now, in the year 1950, though, there was still much to be done so that these or similar scenarios of the future could become reality.

"Thinking Machines are essentially electrical devices. But unlike most other electrical devices, they are the brain children of mathematicians and not of electrical engineers. Even at the present time most of the advanced work on Thinking Machines is being done by mathematicians. This situation will last until electrical engineers become more proficient in those fields of mathematics which form the theoretical basis for the design of Thinking Machines. The most important of these fields is that of symbolic logic." ([38], p. 31)

The fundamental principles of thinking machines, Zadeh stressed, were developed by mathematicians, but today, after more than 50 years of *Artificial Intelligence* (AI) – a research program that was lounched in 1959, that spread to many scientific and technological communities throughout the world and that includes a number of successes – we know that AI has lagged behind expectations. AI became a field of research aimed at developing computers and computer programs that act "intelligently" even though no human being controls these systems. AI methods became methods of computing with numbers and finding exact solutions. As well, humans are able to resolve such tasks very well, as Zadeh mentioned very often over the last decades. In conclusion, Zadeh stated that "thinking machines" do not think as humans do.

In the 1970s, he distinguished between mechanic (or inanimate or man-made) systems at one hand and humanistic systems at the other hand and he saw the following state of the art in computer technology: „Unquestionably, computers have proved to be highly effective in dealing with mechanistic systems, that is, with inanimate systems whose behaviour is governed by the laws of mechanics, physics, chemistry and electromagnetism. Unfortunately, the same cannot be said about humanistic systems, which – so far at least – have proved to be rather impervious to mathematical analysis and computer simulation." He explained that a "humanistic system" be "a system whose behaviour is strongly influenced by human judgement, perception or emotions. Examples of humanistic systems are: economic systems, political systems, legal systems, educational systems, etc. A single individual and his thought processes may also be viewed as a humanistic system." ([39], p. 200) To summarize, he argued, "that the use of computers has not shed much light on the basic issues arising in philosophy, literature, law, politics, sociology and other human-oriented fields. Nor have computers added significantly to our understanding of human thought processes—excepting, perhaps, some examples to the contrary that can be drawn from artificial intelligence and related fields." ([39], p. 200)

Computers have been very successful in mechanic systems but they could not be that successful humanistic systems in the field of non-exact sciences. Zadeh argued that this is the case because of his so-called *Principle of Incompatibility* that he established in 1973 for the concepts of exactness and complexity: „The closer one looks at a 'real world´ problem, the fuzzier becomes its solution." [40][5] With this principle there is a difference between system analysis and simulations that base on precise number computing at one hand and analysis and simulations of humanistic systems at the other hand. Zadeh conjectured that precise quantitative analysis of the behaviour of humanistic systems are not meaningful for „real-world societal, political, economic, and other types of problems which involve humans either as individuals or in groups." ([40], p. 28)

From the mid-1980s he focused on "Making Computers Think like People". [41] For this purpose, the machine's ability to "compute with numbers" was supplemented by an additional ability that was similar to human thinking. The "remarkable human capability [of humans] to perform a wide variety of physical and mental tasks without any measurements and any computations" inspired him and he has given everyday examples of such tasks in many papers: parking a car, playing golf, deciphering sloppy handwriting, and summarizing a story. Underlying this, is the human ability to reason with perceptions – "perceptions of time, distance, speed, force, direction, shape, intent, likelihood, truth and other attributes of physical and mental objects." ([42], p. 903).

Already in the 1990s he presented perception-based system modeling: "A system, S, is assumed to be associated with temporal sequences of input X_1, X_2, …; output Y_1, Y_2, …; and states S_1, S_2, … S_2 is defined by state-transition function f with $S_{t+1} = f(S_t, X_t)$, and output function g *with* $Y_t = g(S_t, X_t)$, for $t = 0,1,2,\dots$. In perception-based system modelling, inputs, outputs and states are assumed to be perceptions, as state-transition function, f, and output function, g." ([43], p. 77.)

[5] More explicitly: "Stated informally, the essence of this principle is, that 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." [39]

This view on future artificial perception-based systems – CW-systems and therefore systems to reasoning with perceptions – is the goal of CTP. This view is closely linked by regarding the human brain as a fundamentally fuzzy system. Only in very few situations does people reason in binary terms, as machines classically do. This human characteristic is reflected in all natural languages, in which very few terms are absolute. The use of language is dependent on specific situations and is very seldom 100% certain. For example, the word "thin" cannot be defined in terms of numbers and there is no measurement at which this term suddenly stops being applicable. Human thinking, language and reasoning can thus indeed be called fuzzy. The theory of fuzzy sets has created a logical system far closer to the functionality of the human mind than any previous logical system.

FSS and FL enable computers and human beings to communicate in terms that enable them to express uncertainty regarding measurements, diagnostics, evaluations, etc. In theory, this should put the methods of communication used by machines and human beings on levels that are much closer to each other.

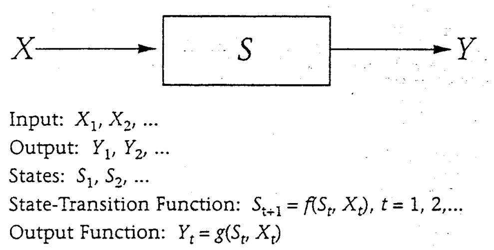

Fig. 4: Perception-based system modelling, [43].

4. Meaning

In his late philosophy Wittgenstein turned away from the epistemological system in the *Tractatus* with its ideal mapping between the things in reality and a logical precise language. If we are not able to find such an exact logical language then we have to accept the fact that for all languages there is a vague lingual usage. Then, the images, models, and theories that we build with words and propositions of our languages to communicate on them are and will be vague (or fuzzy).

Already in his so-called *Blue Book*, that is a collection of Wittgenstein's lecture manuscripts in 1933/34, we find the following paragraph: "This is a very one-sided way of looking at language. In practice we very rarely use language as such a calculus. For not only do we not think of the rules of usage – of definitions, etc. – while using language, but when we are asked to give such rules, in most cases we aren't able to do so. We are unable clearly to circumscribe the concepts we use; not because we don't know their real definition, but because there is no real 'definition' to them. To suppose that there must be would be like supposing that whenever children play with a ball they play a game according to strict rules." ([44], p. 49)

Wittgenstein's new philosophy of language and meaning is more detailed presented in *Philosophical Investigations* which appeared two years after his death in a book translated and edited by Wittgenstein's former student and Cambridge professor Gertrude Elisabeth Marie Anscomb (1919 - 2001). Here, he wrote, "Instead of producing something common to all that we call language, I am saying that these phenomena have no one thing in common which makes us use the same word for all, – but that they are related to one another in many different ways. And it is because of this relationship, or these relationships, that we call them all »language«." ([45], § 65) He explained it, keeping the concept of a game: "Consider for example the proceedings that we call »games«. I mean board-games, card-games, ball-games, Olympic games, and so on. What is common to them all? – Don't say: »There must be something common, or they would not be called »games« «– but look and see whether there is anything common to all. – For if you look at them you will not see something that is common to all, but similarities, relationships, and a whole series of them at that. To repeat: don't think, but look! – Look for example at board-games, with their multifarious relationships.

Now pass to card-games; here you find many correspondences with the first group, but many common features drop out, and others appear. When we pass next to ball-games, much that is common is retained, but much is lost. – Are they all »amusing«? Compare chess with noughts and crosses. Or is there always winning and losing, or competition between players? Think of patience. In ball games there is winning and losing; but when a child throws his ball at the wall and catches it again, this feature has disappeared. Look at the parts played by skill and luck; and at the difference between skill in chess and skill in tennis. Think now of games like ring-a-ring-a-roses; here is the element of amusement, but how many other characteristic features have disappeared! sometimes similarities of detail. And we can go through the many, many other groups of games in the same way; can see how similarities crop up and disappear. And the result of this examination is: we see a complicated network of similarities overlapping and criss-crossing: sometimes overall similarities." ([45], § 66)

In the next paragraph Wittgenstein creates a new concept to describe this new epistemological system:

"I can think of no better expression to characterize these similarities than »family resemblances«; for the various resemblances between members of a family: build, features, colour of eyes, gait, temperament, etc. etc. overlap and cries-cross in the same way. – And I shall say: »games« form a family." ([45], § 67)

Concepts and their families have no sharp boundaries as he wrote in the following paragraph: "One might say that the concept »game« is a concept with blurred edges. – »But is a blurred concept a concept at all? « – Is an indistinct photograph a picture of a person at all? Is it even always an advantage to replace an indistinct picture by a sharp one? Isn't the indistinct one often exactly what we need? Frege compares a concept to an area and says that an area with vague boundaries cannot be called an area at all. This presumably means that we cannot do anything with it. – But is it senseless to say: »Stand roughly there«?" ([45], § 71)

5. Concluding proposal

As we have seen in the previous sections, our perceptions and conceptions of external things or objects are entities without sharp borders. They are fuzzy entities! They are fuzzy because they are hypotheses, i.e. we do not know whether they are true or false. Therefore, we will attach these hypotheses by a membership function. In our model we characterize a percept y as a result of interplays between

- past experiences, including one's culture,
- and the interpretation of the perceived.

Let's identify our old ideas (from past experience) by $x_1, x_2, x_3, \ldots \in X$, where X is a set of ideas.

What is the fuzzy concept of our percept y? It is a hypothesis: $y = x_i \in X$ with the membership function $\mu_X(y) \in [0,1]$.

How can we identify the *meaning* of the perception of percept y? This *meaning* is the hypothesis that the new idea y is equal to one of our old ideas $x_i \in X$. However, there are different meanings of our perception of y and thus various hypotheses:

- hypothesis that y is equal to the old idea $x_i \in X$,
- hypothesis that y is equal to the old idea $z_i \in Z$,
- hypothesis that y is equal to the old idea $r_i \in R$, etc …, where X, Z, R are sets of ideas.

Therefore we have to consider different hypotheses to capture the meaning of a percept y, e.g.

- hypothesis: $y = x_i \in X$ with $\mu_X(y) \in [0,1]$,
- hypothesis: $y = z_i \in Z$ with $\mu_Z(y) \in [0,1]$,
- hypothesis: $y = r_i \in R$ with $\mu_R(y) \in [0,1]$, etc …

To this end we create a *meanings vector* of the perception of y: $\boldsymbol{m}(y) = \{(y, \mu_X(y)), (y, \mu_Z(y)), (y, \mu_R(y)), \ldots\}$.

This vector of meanings of an idea's (percept's) perception collects all its possible meanings and associates them with their membership values to be a well-known idea.

(to be continued)

References

[1] L. A. Zadeh, "Fuzzy Sets", *Information and Control*, 8, 1965, pp. 338-353.

[2] L. A. Zadeh, "Fuzzy Sets and Systems". In: Fox, J. (ed.): *System Theory*, New York: Polytechnic Press 1965, pp. 29-37.

[3] L. A. Zadeh, "Toward a Theory of Fuzzy Systems", Electronic Research Laboratory, University of California, Berkeley 94720, Report ERL-69-2, 6, 1969.

[4] L. A. Zadeh, "Towards a theory of fuzzy systems". In: R.E. Kalman, N. DeClaris, (eds.): *Aspects of Network and System Theory*, New York: Holt, Rinehart and Winston, 1971, pp. 469-490.

[5] L. A. Zadeh: *Interview with Lotfi Zadeh, Creator of Fuzzy Logic* by Betty Blair, *Azerbaijada International*, winter 1994 (2.4): http://www.azer.com /aiweb/categories/magazine/24_folder/24_articles/24_fuzzylogic.html.

[6] J. Goguen: Categories of Fuzzy Sets: Applications of a Non-Cantorian Set Theory. Ph.D. Thesis. University of California at Berkeley, June 1968.

[7] J. Goguen: The Logic of Inexact Concepts, *Synthese*, 19, pp. 325-373, 1969.

[8] J. Goguen: L-Fuzzy Sets, *Journal of Mathematical Analysis and Applications*, 18, pp. 145-174, 1967.

[9] E. Rosch: Natural Categories, *Cognitive Psychology*, 4, pp. 328-350, 1973.

[10] G. Lakoff: Hedges: A Study in Meaning Criteria and the Logic of Fuzzy Concepts, *Journal of Philosophical Logic*, 2, pp. 458-508, 1973.

[11] R.: Interview with George Lakoff (6.8. 2002), University of California, Berkeley, (unpublished).

[12] L.A. Zadeh: A Fuzzy-Set-Theoretic Interpretation of Linguistic Hedges, *Journal of Cybernetics*, vol. 2, pp. 4-34, 1972.

[13] E. H. Mamdani and S. Assilian: An experiment in linguistic synthesis with a fuzzy logic controller, *International Journal of Man-Machine Studies*, 7 (1), 1975, pp. 1-13.

[14] S. Assilian: *Artificial intelligence in the control of real dynamic systems*, Ph.D. Thesis, No. DX193553, University London, August 1974.

[15] L.A. Zadeh: Fuzzy Logic = Computing with Words, *IEEE Transactions on Fuzzy Systems*, vol. 4, no. 2, 1996, pp. 103-111.

[16] L.A. Zadeh: From Computing with Numbers to Computing with Words – From Manipulation of Measurements to Manipulation of Perceptions, *IEEE Transaction on Circuits And Systems-I*, vol. 45, no. 1, Jan. 1999, pp. 105-119.

[17] L.A. Zadeh: A New Direction in AI. Toward a Computational Theory of Perceptions, *AI-Magazine*, vol. 22, no. 1, 2001, pp. 73-84.

[18] R. Seising: *Views on Fuzzy Sets and Systems from Different Perspectives*, Berlin: Springer 2009.

[19] R. Seising and V. Sanz (eds.): *Soft Computing in Humanities and Social Sciences,* Springer 2011.

[20] Special Issue "Soft Computing in Humanities and Social Sciences", Fuzzy Sets and Systems (Guest eds.): R. Seising and V. Sanz, to appear in 2012.

[21] B. Russell: Introduction. In: Wittgenstein, L.: *Tractatus logico-philosophicus*. Routledge & Kegan Paul, London 1922.

[22] R. Carnap: *Der logische Aufbau der Welt*. Berlin-Schlachtensee: Weltkreis Verlag, 1928.

[23] W. Weaver: *Science and Complexity*. American Scientist, 36, 1948, pp. 536-544.

[24] W. Weaver: *The Scientists Speak*, Boni & Gaer Inc., 1947.

[25] W. Weaver, *Translation*. In: W. N. Locke, A. D. Booth (eds.): *Machine translation of Languages: fourteen essays*, Cambridge, Mass., Technology Press of the MIT, 1955, pp. 15-23.

[26] W. Weaver: The Mathematics of Communication, *Scientific American*, 181, 1948, pp. 11-15.

[27] C. E. Shannon, A Mathematical Theory of Communication, *The Bell System Technical Journal*, 27, pp. 379-423 & 623-656, 1948.

[28] C. E. Shannon and W. Weaver: *The Mathematical Theory of Communication*, Univ. Ill. Press, 1949.

[29] L. A. Zadeh, Precisiated Natural Language (PNL), *AI Magazine*, vol 25, no. 3, 2004, pp. 74-92.

[30] R. Seising: What is Soft Computing? – Bridging Gaps for the 21st Century Science! *International Journal of Computational Intelligent Systems*, vol. 3 (2), 2010, S. 160-175.

[31] R. Seising: Cybernetics, System(s) Theory, Information Theory and Fuzzy Sets and Systems in the 1950s and 1960, *Information Sciences*, 180, 2010, S. 459-476.

[32] L. A. Zadeh, e-mail to the R. Seising, (23.5. 2009).

[33] W. S. McCulloch and W. H. Pitts: A Logical Calculus of the Ideas Immanent in Nervous Activity, *Bulletin of Mathematical Biophysics*, vol. 5, pp. 115-133, 1943.

[34] J. von Neumann: First Draft of a Report on the EDVAC: http://www.alt.ldv.ei.tum.de/lehre/pent /skript/VonNeumann.pdf.

[35] A. M. Turing.: Computing Machinery and Intelligence. In: *Mind*, vol. LIX, 1950, pp. 433-460.

[36] N. Wiener*: Cybernetics or Control and Communications in the Animal and the Machine*. Cambridge, Massachusetts: MIT Press, 1948.

[37] E. C. Berkeley: *Giant Brains or Machines that Think*, New York,: John Wiley & Sons, 1949.

[38] L. A. Zadeh, Thinking machines – a new field in electrical engineering, *Columbia Engineering Quarterly*, January 1950, pp. 12-13, 30-31.

[39] L. A. Zadeh: The Concept of a Linguistic Variable and its Application to Approximate Reasoning – I, *Information Science*, 8, 1975, S. 199-249: 200.

[40] L. A. Zadeh: Outline of a new approach to the analysis of complex systems and decision processes, *IEEE Trans. On Systems, Man, and Cybernetics*, SMC-3 (1), January, 1973, pp. 28-44.

[41] L. A. Zadeh: Making Computers Think like People, *IEEE Spectrum*, 8, 1984, pp. 26-32.

[42] L. A. Zadeh, The Birth and Evolution of Fuzzy Logic – A Personal Perspective, *Journal of Japan Society for Fuzzy Theory and Systems*, vol. 11, No. 6, 1999, pp. 891-905.

[43] L. A. Zadeh: Fuzzy Logic, Neural Networks, and Soft Computing, *Communications of the ACM*, vol. 37, no. 3, 1994, pp. 77-84.

[44] Wittgenstein, L.: *Das Blaue Buch*. Frankfurt/M.: Suhrkamp, Werkausgabe, Bd. 5, 1984.

[45] Wittgenstein, L.: *Philosophical Investigations*. Blackwell Publishing, Oxford 1953.