Human-Inspired—Zadeh—Sets and Logic

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***Abstract*—In 2015 fuzzy sets and fuzzy logic celebrated their golden anniversary, but (arguably) unfortunately they have not been and are not being used or considered by most technical people outside of the fuzzy community. I believe that this is, arguably, to a large extent due to the negative connotation of the name *fuzzy* and believe that it is time for a replacement of that word. *Fuzzy* may be okay to describe a soft teddy bear, a cuddly pet, or a peach but for it to be used for mathematics and its applications is a red flag. In this article I propose *Zadeh set/logic* as replacements of *Fuzzy set/logic*. After 55 years, it is time to honor Prof. Zadeh by using his name as a proper adjective. Replacing *fuzzy* by *Zadeh* is universal in that it needs no translation in any language, whereas *fuzzy* does. This article also illustrates how the use of these replacement terms will provide everyone with a way to describe what they are working on when they are in different situations, without encountering the derision or worse that frequently occurs when *fuzzy* is used.**

Keywords—fuzzy sets, human-inspired sets, Zadeh sets, Zadeh logic

I. Prologue

Fuzzy sets and fuzzy logic celebrated their golden anniversary in 2015 but (arguably) unfortunately they have not been and are not being considered or used by most technical people outside of the fuzzy community. I believe that this is, arguably, to a large extent due to the negative connotation of the name "fuzzy" and believe that it is time for a replacement of that word when explaining what we do to people who are outside of this community. For those of us who are active in this community such a replacement is not necessary, although I will argue below that even for us in this community a name change would be very timely and appropriate.

I must acknowledge from the onset that I approach the word "fuzzy" as an English speaking and writing author, and so the opinions that I express below must be taken within this context. I mention this because in other languages "fuzzy" may have been translated into another word (e.g., "flou") that has a more technical-like meaning (e.g., hazy), or the word may not have existed in that language, and so it was and has been viewed positively.

This article may be viewed by some readers as very controversial, or by some others as an attack on Prof. Zadeh (it is most certainly not). It is authored by someone who has worked in the fuzzy field for close to 35 years and is a Fuzzy Systems Pioneer of the IEEE Computational Intelligence Society (I only mention these facts to establish some author- credibility for writing this article). It is meant to open up a dialog within the fuzzy community and should be read in that light.

The rest of this paper includes a familiar dialogue (Section II), proposals for a name change (Section III), a new dialog (Section IV), observations (Section V), example conversations (Section VI), discussions (Section VII) and conclusions (Section VIII).

II. Familiar Dialog

Question from a relative or friend or colleague (who know nothing about fuzzy sets or logic): "Hey, what do you work on?"

Answer[1]: "Oh I work on fuzzy sets."

Reaction: Derisive smile, laugh, snicker or snide remark.

Feeling: "This is not starting out right. Why oh why does what I love and work on have to be called 'fuzzy' anything? Now instead of explaining more about what I do, I have to first explain why it's called 'fuzzy.' I want to crawl into a hole."

I'll bet many of you have been in this situation at least once and probably more than once. I have, and in all honesty I don't like it. What I work on is as important as what anyone else works on; but as soon as I use the word "fuzzy" I'm put on the defensive just because of this word. Yeah, I've been told: "It's just me, and get over it," but I don't believe it's just me; it's just about all of us. It's downright demeaning to be working in a field whose name has a very negative connotation. "Fuzzy" may be okay to describe a soft teddy bear, a cuddly pet, or a peach but for it to be used for mathematics and its applications is a red flag. As a result of using "fuzzy" people take umbrage[2] to what we are doing and don't respect us right off the bat because

[1] This Answer is very abbreviated so that it reaches the word "fuzzy" as quickly as possible. A more realistic dialog, one that I have frequently used, is: "I work in an area called computational intelligence, that's a collection of biologically and linguistically motivated computational methods. My work falls mainly in the linguistically motivated part of this area and uses *fuzzy* sets as models for words."

[2] Offense, annoyance, displeasure, suspicion, doubt, hostility or the like.

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of that name. They easily wave us off (this is also called "dissing") to others with some sort of cute (to them) or downright nasty comment. It goes downhill from there.

How many Ph.D. students would use the word "fuzzy" in the title of their dissertation[3]? Today, to do so would be tantamount to a disaster when looking for a job in the United States, because a prospective employer might not even read the abstract of the dissertation due to that word and their prejudice about it. So, instead, the student conceals what they have been doing by using a dissertation title that hopefully stands a chance for them to get an interview. Some of my students have called it "non-linear signal processing" or "computational intelligence."

Okay, okay, I can hear the wave of purists saying everything from: "This is the name given to our field by its founder for reasons he felt were appropriate, and it would be offensive to him to change the name". Or, "The name is an accurate description of the field, and so we should not tamper with it." Or "The name's been around too long to change it; we just have to live with it." Or, as Shakespeare's Juliet said: "What's in a name?" Any more?

Others may argue that more time is needed for "fuzzy" to become accepted; look how long it took for "probability" to become widely accepted and used. To that I counter that the word "probability" flows quite naturally from the word "probable," a word used and understood by people even in the 17th century, and, as a result, people don't scoff at or mock the word "probability." What does "fuzzy" flow from?

These arguments don't change the painful fact that our work is often/usually ridiculed by those outside of our field because "fuzzy" is attached to it. Paraphrasing Howard Beale, in the 1976 movie "Network," I'm fed up and don't want to take it any more!

III. Proposals for a Name Change

When Lotfi Zadeh [6] invented a fuzzy set in 1965 (according to the many times I heard him talk and interacted with him) I don't believe he was thinking of engineering applications for it; he was thinking about applications that involve human beings. Humans are the only ones to use words[4], and from the very first example in his first seminal paper [6] he proposed to use a fuzzy set as a mathematical model for a word. It was very inspirational for Zadeh to model a human word by a fuzzy set. So, *my first proposal* is that "fuzzy" be replaced by "**human-inspired**." We would then have *human-inspired set* (HIS) and *human-inspired logic* (HIL).

Of course, now that I've made this suggestion, the natural inclination for technical people like us is to analyze the phrase and all of its possible meanings, and to seek alternatives. For starters, some people have told me that "human-inspired" is two words, whereas "fuzzy" is one word, so it's too long. Counter-examples to this already exist in computational intelligence, such as Ant Colony Optimization, Particle Swarm Optimization, Computing With Words, Radial Basis Function Network, etc.

"Human-inspired" was not my original choice for a word to replace "fuzzy." My first inclination was to suggest the use of "humanistic," which is only one word, but when I checked for its definition I found "of pertaining to humanity, as humanistic devotion," and, although I'm a somewhat religious person, this sounded too religious to me. So, the last thing we need to do is to replace one negative-sounding word with another one.

I then was inclined to use "human-centered". I learned[5] that "human-centered" was introduced first in [2], and found that it is already used in "human-centered design," "human-centered design and engineering," "human-centered computing," "human-centered information processing" [1], [4], etc. The University of Washington even offers BS, MS and Ph.D. programs in human centered design and engineering. I could find no mention of fuzzy sets, fuzzy systems, etc. connected with those programs. How sad, since what we do is so relevant to anything that is human-centered. But, it's no wonder that what we do is not a part of such programs, because the name "fuzzy" has no direct connection to such programs and activities.

I sent early (and later) drafts of this article to 22 of my former Ph. D. students and colleagues (acknowledgements are given at the end of this article), and 20 of them replied back to me. Some of them suggested that "fuzzy" could be replaced by "natural", "robust", "human-based", or "human-like." Prof. Ligang Zhou explained that: "'Natural' means caused by nature not by human kind, and is entirely unrelated to fuzzy theory; 'Robust' means strong and healthy or vigorous, which is also irrelevant to fuzzy; 'Human', relating to people or human being, does not emphasize the inherent characteristic of human language using fuzzy theory." So, none of these proposed replacements for "fuzzy" seemed to fit the bill. Prof. Zhou even discussed the different alternatives to "fuzzy" with six professors in different universities who use "fuzzy" in their research or applications. They were unanimous that "if we can not have a better [word], human-centered is the best." This endorsement of "human-centered" sounded too much like a compromise to me. Additionally, one of them felt that in human-centered the word "centered" is too vague.

Then Prof. Li-Xin Wang suggested "smart" or "intelligent" as a replacement for "fuzzy." He explained that: "The classical set is in-or-out, 0-or-1, which is too simple, too naïve, and exhibits no intelligence whatsoever. 'Smart set' is smart, which tells you how to determine a degree of belonging, giving one flexibility and more control. 'Smart logic' is smart, like a human, who is not black-and-white, who has feelings (a continuous variable), and 'smart logic' gives you a collection of scientific/engineering principles and means to reason, to control, and to make decisions in an intelligent, human-like manner."

[3] Professor Frank Rhee informed me that the word "Fuzzy" has been removed from the name of the Korea Fuzzy Logic and Intelligent Systems Society; it is now called the Korean Institute of Intelligent Systems.

[4] Some animals (dolphins, whales, dogs, chimpanzees, etc.) can communicate using sounds or maybe other cues, but only humans communicate using words.

[5] This was pointed out to me by Ms. Raquel Ureña Pérez, a former Ph. D. student at the University of Granada, Spain, who spent three months at USC in Fall 2014.

In the 1960's I lived through the era of so-called "modern control." This phrase was used very widely by the new state-space advocates; however, it greatly offended the "older generation," because, by implication what they had been or were working on, by not being "modern", was now viewed as "old fashioned." This caused a large division in the Controls community that took a long time to heal. Putting "smart" or "intelligent" in front of "set" or "system" would, in my opinion have a similar effect, since an antonym of "smart" is "dumb" and an antonym of "intelligent" is "stupid."

Prof. Qilian Liang suggested "human-inspired" for "fuzzy." Each of the two words is understandable. All of the words that could be preceded by it (set, logic, system, logic system, reasoning, control) sounded okay. On the Internet, I found that "human-inspired" has already been used in "human-inspired robots," "human-inspired walking", "human-inspired granular computing", etc. So, a precedent already exists for using "human-inspired".

It was called to the attention of this author that in 1957 Karl Menger translated into English the French 'ensemble flou', which he coined, to 'hazy set.' I initially thought that replacing "fuzzy" by "hazy" could work since "hazy" does not have the same negative technical connotation that "fuzzy" does. To show you how complicated languages can be, I went on-line to a French into English dictionary

(http://www.larousse.com/en/dictionaries/french-english/flou/34185)

and found "hazy" was an English translation of "flou." I then went on-line to an English dictionary

(http://www.thesaurus.com/browse/hazy)

and found that a synonym for "hazy" is "fuzzy", but when I then looked for a synonym of "fuzzy"

(http://www.thesaurus.com/browse/fuzzy?s=t)

it did not list "hazy". Based on this, I rejected "hazy" as a replacement for "fuzzy."

Another person suggested using "gradual" set since Prof. Zadeh sometimes explains that a fuzzy set is set whose membership is gradual rather than abrupt. A reviewer of this paper suggested something very similar (see Section VII).

So many possible replacements for "fuzzy"! Here's one more: Prof. Fred Aminzadeh proposed to me that "fuzzy" could be replaced by "Zadeh." After thinking about this for a while his proposal started to really resonate with me, and so *my second proposal* is that "fuzzy" be replaced by "**Zadeh**", which would be analogous to using Hilbert, Borel, Bayes, Einstein, etc., We would then have: a Zadeh set (ZS) and Zadeh logic (ZL). Note, also, that a proper adjective is used *as is* in *all* languages, and so by using Zadeh set and Zadeh logic we will have created *universal designations* for both of them. This is very important because even "human-inspired" could be translated into a different phrase in different languages, whereas "Zadeh set" and "Zadeh logic" would not be.

It is well known that Prof. Zadeh was a very modest and humble man, and would not have wanted to see his name used in the ways that I have proposed, certainly not during his lifetime; however, Prof. Zadeh passed away in 2017, and it seems to me that after 55 years, his name should be attached to at least *set* and *logic*.

IV. A New Dialog

My third and final proposal is to use both "human inspired" and "Zadeh," each when appropriate, but both when appropriate even in the same conversation, e.g. here's how the earlier conversation might go:

Question from a relative or friend or colleague (who know nothing about fuzzy sets or logic): "Hey, what do you work on?"

Answer: Oh, I work in an area called computational intelligence, that's a collection of biologically and linguistically motivated computational methods. My work falls mainly in the linguistically motivated part of this area and uses mathematical models for words. Because only humans communicate using words, you could say that I use "human-inspired" mathematics.

Reaction: Happy smile followed by "interesting." And a follow-up question, such as: "But, what is human-inspired mathematics?"

Feeling: "This is great. Now I can continue."

Further Explanation: "For most humans nothing is always black and white—right? (your relative, friend or colleague is now shaking their head in agreement, giving you confidence to go on). So human-inspired mathematics is mathematics that lets us fill in all of the shades of grey between black and white, just as we humans do. And it does this as rigorously as all other mathematics, like arithmetic or algebra and even probability. This mathematics was introduced in 1965 by UC Berkeley Professor Lotfi Zadeh, and is now referred to as Zadeh sets and Zadeh logic, which let us go very smoothly from black to white through shades of grey, and have paid off in a lot of practical applications where smooth transitions are needed, such as in automobile braking and transmission systems. Zadeh sets even let us model words so that we can compute with words. Because things are no longer black or white for such sets, but are shades of grey, you might say they are no longer 'crisp', so they are also called, for want of a better name, 'fuzzy'."

Feeling: Wow! By using "human-inspired" and "Zadeh" I was actually able to explain what I do and no one snickered or made a derisive comment. What a great feeling!

V. Observations

Some may be thinking that what I am proposing is akin to historical revisionism. It's not! We have a great product, and just like other products (e.g., automobiles, televisions, mobile phones) it is in competition with other technical products, but unfortunately it has not been and is not being used or considered by most people outside of the fuzzy community. I believe, as I stated in Section I that this is

(arguably) due to the negative connotation of its name, so let's replace (rebrand) the name and watch what happens.

Some will still say: "It's not the name, it's the product that I don't like," to which we should reply: "Why is that?" After the answer is given, we should then be able to provide counter-arguments, as many have done in the past, but now for "Zadeh sets" or "Zadeh logic". Now there's an idea for another article!

Others may argue that there is no difference between fuzzy sets/logic and subjective probability. This argument was dispelled decades ago[6], but is still used by some die-hard Bayesians. Since our field has thrived successfully for more than 50 years, this confusion should be disappearing.

Finally, some may also say that the name "human-inspired set" should include other things than a fuzzy set, e.g., rough set, grey set, shadowed set, intuitionistic set, hesitant set, etc. Maybe it should, but all of these other kinds of sets originated after Zadeh introduced a fuzzy set in 1965 [6], and it is right after the publication of this seminal paper that derisive smiles, laughs, snickers or snide remarks began (as well as technical attacks). I don't think that "rough," "grey," "shadowed," "intuitionistic" or "hesitant" have received the same negative reactions from people because of their names as did "fuzzy," so to me there is no problem in using those terms as is. However, even if a "human-inspired set" was to be used as an umbrella term for all of these different kinds of sets, by using "Zadeh" instead of "fuzzy", to distinguish among the constituents of human-inspired sets, the name problem would be avoided.

Of course, we must be able to connect back to the 55 years of technical works that use "fuzzy", so I also propose that we always include a footnote to "Zadeh set/logic" such as: "Zadeh set/logic" is a replacement of 'fuzzy set/logic'; Zadeh set/logic has the property of fuzziness[7], and so are also known as 'fuzzy set/logic'." By doing this we will pay respect to the founder and to the many contributors from the past.

VI. Example Conversatons

Here are how some conversations might take place when the world is partitioned into three groups:

- **Group 1:** Friends, relatives, acquaintances and all others, who we either know or suspect are non-technical, and to who we want to (or are asked to) tell what we work on.

  Example: See Section IV.

- **Group 2:** Friends, relatives, acquaintances and all others who we either know or suspect are technical but don't know anything about fuzzy sets or systems, and to who we want to (or are asked to) tell what we work on.

  Example: You win a best publication award for a paper about fuzzy logic control and your campus newspaper wants to report on it, so they send a student reporter to interview you. By using "human-inspired" and "Zadeh" the interview will proceed (I predict) smoothly and without the usual initial barrier. Of course, the reporter will probably ask "What's the connection between human-inspired and that title of your paper," to which I would reply: "Our controller uses Zadeh sets and logic that are human-inspired; such sets have the mathematical property of fuzziness and are also known as fuzzy sets," and then go on to explain what this means as I have done in this article.

- **Group 3:** Technical colleagues, friends, relatives, acquaintances and all others, who we know are knowledgeable about fuzzy sets and systems, and to whom we want to (or are asked to) explain what we are working on.

  Example: Hey Jim, I'm now working on networks that use fuzzy sets, and instead of calling them "fuzzy networks" I prefer to call them "human-inspired networks" because "fuzzy" has too negative a connotation for these networks and for my work. Of course, these networks enjoy the mathematical property of fuzziness, so I'm not going to abandon "fuzzy" altogether, but I'm going to downgrade it to a mathematical property rather than as a designation for my work.

  Example: If I'm in a conversation with a technical control system colleague, my conversation could go as follows: "Hello. I work on "human-inspired control" that uses Zadeh sets and Zadeh logic that have the mathematical property of fuzziness, in which things are not always black or white, but can assume shades of grey, which is why this is also called "fuzzy logic control".

  Example: Anyone who is a member of the IEEE Computational Intelligence Society and has to explain what CI is about could state: "CI has three main pillars, neural networks, evolutionary computing and fuzzy systems. Neural networks are biologically inspired, evolutionary computing is nature inspired, and fuzzy systems are human inspired."

VII. Discussion

Additional terms and their recommended usage (by this author) both within and outside of the fuzzy community

[6] See, e.g. vol. 2, no. 1 of the *IEEE Trans. on Fuzzy Systems,* in which there are 10 articles devoted to this.

[7] According to Zadeh [6], fuzziness occurs [i.e., is a property of a fuzzy set] when the "transition between membership and non-membership is gradual rather than abrupt." Mathematical descriptions of fuzziness (and there are more than one) can be found, e.g., in [5], [3, pp. 254–258].

TABLE I
SOME TERMS AND THE AUTHOR'S RECOMMENDED USAGE BOTH WITHIN AND OUTSIDE OF THE FUZZY COMMUNITY

Term	Fuzzy Community	Outside of the Fuzzy Community
Fuzzy set	Zadeh set	Zadeh set that has the property of fuzziness and is therefore often called a fuzzy set
Fuzzy logic	Zadeh logic	Zadeh logic that uses Zadeh sets which have the property of fuzziness, and is therefore often called fuzzy logic
Fuzzy (logic) system	Fuzzy (logic) system	A non-linear system that uses Zadeh sets and Zadeh logic, commonly called a fuzzy system
Fuzzy logic control	Fuzzy logic control	Non-linear control, that uses Zadeh sets and Zadeh logic, commonly called fuzzy logic control
Fuzzy c-means clustering	Fuzzy c-means clustering	Clustering that uses Zadeh sets, commonly called fuzzy clustering, fuzzy c-means clustering, etc.

are given in Table I. Observe that I am not proposing any name changes for applications (derivative terms) that use Zadeh sets or Zadeh logic within the fuzzy community. However, I am proposing that these derivative terms be explained using terms that are more widely used outside of the fuzzy community.

I initially thought about renaming "Fuzzy logic system" a "Zadeh system", but then thought that doing this would be going too far, e.g. would we then call "fuzzy logic control" "Zadeh control" and "FCM" "ZCM"? Doing this would give Zadeh too much credit. So I decided to drill down into the fact that a Zadeh set has the property of fuzziness and to then retain all existing names since they use Zadeh sets or Zadeh logic and therefore they all possess "fuzziness".

A reviewer of this paper proposed that instead of "Zadeh set" and "Zadeh logic" one should use "Zadeh extended set" and "Zadeh extended logic" or "Zadeh graded set" and "Zadeh graded logic." These proposals suffer from some of the same difficulties already explained, i.e., "extended" and "graded" are properties of Zadeh sets and Zadeh logic, and should be treated as such; and, "extended" and "graded" are not universal terms, i.e. they may be translated differently in different languages.

VIII. CONCLUSIONS

Although I have tried to inject some humor into this article, its subject is not funny at all. It's time for a replacement of the word "fuzzy" by a word or term that does not engender derision or worse, and so I have proposed that "fuzzy set/logic" be replaced by "Zadeh set/logic" *After 55 years, it is now the right moment to honor Prof. Zadeh by using his name as a proper adjective*.

I have also proposed that we use the phrase "human-inspired" to help explain what we do, and that we always include a footnote to "Zadeh set/logic" such as: "Zadeh set/logic is a replacement of fuzzy set/logic," so as to connect back to the 55 years of technical works that use "fuzzy".

Accepting these proposals will provide everyone with a way to describe what they are working on when they are in different situations without encountering derision or worse.

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