Truth, American Culture, and Fuzzy Logic

Dan Simon

Department of Electrical and Computer Engineering
Cleveland State University
Cleveland, Ohio, USA

d.j.simon@csuohio.edu

***Abstract* – This paper examines the history, relationships, and influences that act between concepts of truth, American culture, and fuzzy logic. We see that postmodernism is largely a reaction against the Western overemphasis on crisp mathematics. This overemphasis started with ancient Greece, but became solidified in Western culture with the Renaissance. At first glance, fuzzy logic seems to tie in nicely with postmodernism. But a closer look reveals that fuzzy logic is actually more similar to modernism, because it is based on rigorous mathematics. However, fuzzy logic does make some concessions to postmodernism by acknowledging the possibility of ambiguity, at least to some extent. Fuzzy logic therefore provides a balance in the cultural war between modernism and postmodernism. In order for fuzzy logic to take advantage of this unique position, the fuzzy logic community needs to pursue three objectives: (1) it must acknowledge its own limitations and avoid overselling itself; (2) it must develop a wider perspective on its role in modern-day culture; and (3) it must be more proactive in defining its role.**

I. INTRODUCTION

Modernism is the world view that absolute truth exists. Postmodernism is the world view that there are no absolutes. Fuzzy logic seems to fit in the middle. It allows for absolutes (membership values equal to 0 or 1), but also allows degrees of membership. This places fuzzy logic in a unique position midway between modernism and postmodernism. This allows fuzzy logic to combat the extremes of both modernism and postmodernism, and thus prove a benefit to society in ways far beyond those envisioned by most fuzzy logic researchers.

Section II summarizes the relationship between modernism and postmodernism to set the stage for the rest of the paper. Section III looks at the history of math, and views of mathematical truth. Some cultures viewed mathematical truth as absolute (Greece), while others viewed it as more applied (China and Islam). Again, fuzzy logic lies in the middle, with both theoretical rigor and practical roots. Section IV explores various concepts of truth and how they might relate to fuzzy logic. We see that our view of truth (which is related to our modernist/postmodernist bent) could have a strong influence on the way we perform fuzzy research. Section V discusses the mathematical emphasis that reigned in the West beginning with the Renaissance. This resulted in depersonalizing effects, which postmodernism reacted against in the 1960s. Fuzzy logic provides a balance between this over-emphasis on math, and the relativism of postmodernism, by relying on mathematical rigor while still allowing for ambiguity. Section VI presents some conclusions and proposes some future work.

II. MODERNISM AND POSTMODERNISM

Modernism is the world view that absolute truth exists, that is possible for individuals to discover that truth, and that individual discovery of truth improves society. The rise of modernism is often traced to the French philosopher Rene Descartes in the early 1600s. The fall of modernism is often traced to Thomas Kuhn's publication in 1962 of *The Structure of Scientific Revolutions*. Kuhn claimed that scientific truth is not absolute, and scientific discovery is shaped by human psychology and culture.[1]

There are a number of ways to characterize modernism and postmodernism. A simplified view of the differences between the two can be summarized as follows:

- Modernism: truth is objective and eternal.
  Postmodernism: truth is subjective and temporal.
- Modernism: truth is good and can be attained by humans.
  Postmodernism: truth is not intrinsically good (since it can be misused), and human understanding of it is uncertain.
- Modernism: truth can be reliably learned via science.
  Postmodernism: truth can be learned by intuition.
- Modernism: individuals can learn and make progress.
  Postmodernism: the community provides the only context within which learning and progress can occur.

The influence of modernism and postmodernism on views of fuzzy logic can be deduced from the above list as follows:

- Modernism: fuzzy logic works because it is true.
  Postmodernism: fuzzy logic is true only if it works.
- Modernism: fuzzy logic is valuable in-and-of itself.
  Postmodernism: fuzzy logic is valuable only in so far as it benefits society.
- Modernism: fuzzy logic must be firmly grounded in math.
  Postmodernism: fuzzy logic is intuitive.
- Modernism: individuals can make objective contributions to fuzzy logic theory.
  Postmodernism: individual contributions to fuzzy logic theory are valid only insofar as they are accepted by the wider fuzzy logic community, or by society in general.

Fuzzy logic researchers will surely be divided on modernism versus premodernism as related to fuzzy logic. Of course, the dividing line between the two world views is not necessarily

[1] It should be noted that with such broad classifications as modernism and postmodernism, many other demarcations have been proposed. For example, some date the period of modernity from the French revolution in 1789 until the fall of the Berlin Wall in 1989 [Ode95].

crisp; it more of a fuzzy distinction, and many researchers may tend toward modernism in one area and postmodernism in another. For example, many fuzzy researchers will probably believe that fuzzy logic should be mathematically rigorous (modernism). However, most researchers will believe that more than one type of defuzzification could be used in a fuzzy logic system, depending on the context (postmodernism).

III. The History of Math

As we look at the history of math, we see evidence for both modernist and postmodernist views of the truth of fuzzy logic. Ancient Greek and Moslem approaches to math differed, supporting the view that mathematical truth is culture-dependent. On the other hand, the mathematics of ancient China and the West involved different approaches, cultures, and emphases, but gave rise to similar results. This supports the view that mathematical truth is independent of culture. In this section I emphasize the contributions of Greece (600-200 BC), Islam (700-1300 AD), and China (100 BC-300 AD).[2]

Greece made history's first major contributions in math, from about 600 BC until 200 BC. Greece placed a strong emphasis on theory, as typified by Euclid's *Elements* (300 BC), which contains 465 propositions that cover topics such as algebra and geometry. Greeks believed that numbers rule the universe. This implies that numbers exist independently of a creator. Numbers were almost like a god to the Greeks. The Greeks had many gods in their mythology, but their gods did not exist apart from the universe. Numbers, however, did exist apart from the universe, and governed the behavior of the universe. The Greek emphasis on precision (and scorn of approximation) is typified by Aristotle's Law of the Excluded Middle, which states that a given proposition is either true or false; there are no degrees of truth or falsehood [1].

After Greece, the next major contributors to math were Moslems. Islam was founded in the 700s AD, and within a few decades became the dominant religion/culture of much of civilization. In Islam, *religious science* included such studies as theology, law, literature, and language. *Foreign science* included such things as math, physics, and medicine. In the foreign sciences it was recognized that other cultures had much to offer. Islam had a friendly relationship with secular science. Foreign sciences not only expressed truth about Allah's world, but could offer tools for religious service.

In Islam we see a reduction in the glory of math from ancient Greece. Greeks believed that math was holy, while Moslems believed that math was holy only insofar as it could be brought under religious rule. For Moslems math should be useful, while for Greeks math was an end in itself. Moslems took Greek math and made it more practical. Numerical and approximation methods developed by Moslems would have been horrifying to Greeks. Trigonometric methods developed by Moslems to solve problems related to religious rituals would have been considered profane by Greeks. Fuzzy logic would have been welcomed by Moslems but shunned by Greeks. Moslems were rigorous in their math, but their math was driven by a culture of religion and practice, whereas Greek math was driven by idealism (a religion in its own way). Moslems would not look at a mathematical theorem and categorize it as true or untrue; they would view it as useful or not useful. *We see that culture affects math, which supports a postmodern view of mathematical truth.*

Next we turn to the far East. The philosophies of ancient China (Confucianism, Taoism, and Buddhism) emphasized harmony, balance, and paradox. Paradox and ambiguity are not to be avoided but to be embraced. Exclusive, rigorous, closed theories about the world are viewed as limiting and corrupted by human thought. Ancient Chinese math boasts an impressive array of accomplishments, including the binomial theorem, solutions of polynomial equations, combinatorial analysis, Gaussian elimination, and interpolation methods. Chinese math was characterized by the following [2]:

- Begin with specific examples and then generalize.
- Draw conclusions about one area of math by comparing it with other areas of math.
- Use induction rather than deduction to obtain proofs.
- Use experiment rather than analysis.
- Use heuristics rather than rigorous analysis.
- Use non-linguistic proof methods (e.g., visual constructs).

These approaches all contrast with Greek math. Chinese math resulted in many techniques that were later reproduced by the West. However, ancient China worked from a much different culture than the West. *We see that culture does not affect math, which supports a modernist view of mathematical truth.*

IV. The Truth of Fuzzy Logic

Is fuzzy logic true? Modernism holds that truth is absolute and impersonal. Postmodernism holds that truth is relative and personal. A modernist will assert that fuzzy logic is true outside of human experience; that is, fuzzy logic was true before it was discovered. A postmodernist, however, will assert that fuzzy logic only *became* true when it was first invented in the 1960s.

Why is fuzzy logic true? This questions can be asked of mathematics in general (or any other discipline), but it seems to be more applicable to fuzzy logic because of its recent development. Such a question can be answered in a variety of ways, including the following [2]:

1. Fuzzy logic is true because God created it.
2. Fuzzy logic is true because it is logical.
3. Fuzzy logic is true because it reflects the reality of the world in which we live.
4. Fuzzy logic is true because it is an expression of man's intuitive knowledge.
5. Fuzzy logic is true because man created it.
6. Fuzzy logic is true because it has been proven.
7. Fuzzy logic is true because the fuzzy systems community has come to a general consensus about it.

[2] This is not to say that other cultures and time periods are not mathematically important. For example, Indian mathematics was quite productive from 500-1100 AD, and there were significant Chinese mathematical advances after 300 AD. But I chose the three cultures and time periods that I did in order to illustrate the main point of this section.

8. Fuzzy logic is true because it is useful.
9. Fuzzy logic is not true; it is only a human invention.
10. Fuzzy logic is not true because truth does not exist.

Over time, cultural views of truth have shifted from the earlier answers in the above list (modernism) toward the latter answers (postmodernism). It is not realistic to expect fuzzy logic researchers to come to a consensus on the nature of truth, but it is reasonable to strive for a consensus on a general program of fuzzy logic research that respects a variety of viewpoints regarding the truth of our discipline.

Our view of the truth of fuzzy logic will have a strong influence on our research and practice. If we view truth as more objective (e.g., answers 1–3 above) we may have a more exalted view of our work, believe that it is valid as an end in itself, and be less concerned for practical applications. If we view truth as more subjective (e.g., answers 8-10 above) we may have a more practical, service-oriented view of our work, and be more concerned with application.

Beyond the truth of fuzzy logic, we can discuss the value of fuzzy logic. What gives fuzzy logic its value? The West would say that logical rigor is valuable in that it uncovers ultimate reality; it is the mathematical rigor of fuzzy logic that bestows its value. The East would say that practical use is valuable; it is the practical benefits of fuzzy logic in engineering systems that bestow its value. The West would consider the Eastern viewpoint and respond, "Yes, it works, but so what? Is it theoretically rigorous?" The East would consider the Western viewpoint and respond, "Yes, it is theoretically rigorous, but so what? What use is it?"

The difficulty with trying to determine the value of fuzzy logic is that we judge its merit from within our own value system, which necessarily lies outside of fuzzy logic. The call to the fuzzy logic community is to broaden its perspective and determine what it is that makes fuzzy logic research valuable.

V. Mathematics and Culture

A. *Mathematization*

The permeation of mathematics into every aspect of daily life can be called the *mathematization* of culture [2]. Mathematization really began with Greek philosophy, which asserted that the entire universe was governed by numbers. Other cultures also exalted math, but it was really the Greeks that first emphasized math in a thorough and systematic way.

Greek mathematics was very active from about 600-200 BC, but after that there were no major Western contributions to math for about 1200 years. This was due to social and economic instability, and later to Christian resistance to secular knowledge. The general approach to life in the West was to take special care to worship the creator (God) rather than the created (math, science, etc.). There was a strong division between the sacred and the secular.

In the later middle ages, secular learning resurfaced in the West, largely due to increasing influence from other cultures. Arabic and ancient Greek texts began to be translated into Latin and taught in schools. Thomas Aquinas (13th century) and other Christian philosophers began to merge ancient Greek philosophy with Christian thought. Christian intellectuals such as Roger Bacon, the 13th century British philosopher, began to exalt math as the means by which God governed the world. In the 14th century math gained an influence on other areas of life, such as music, finance, navigation, and the military. Copernicus developed his heliocentric view of the solar system in 1543 because of its mathematical simplicity.

Math began influencing everyday life in the 1600s. Math found applications in such areas as politics, economics, business, ethics, and art. Math became revered as the knowledge that could solve all problems. There was a backlash against this emphasis with the Romanticists in the 1700s, but mathematicians won the day. This can be seen in the still-popular quote by William Kelvin in 1891: "When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind" [3, p. 225]. Bernard de Fontenelle, a French scientist, earlier expressed this idea in his essay "On the usefulness of mathematics and physics" (1699), where he asserted that *any* field will be better if it uses math. Literature, art, and poetry was forced into a more rigid mold. Dictionaries and grammar books were written to lend more structure to language. Popular culture believed that anything worth knowing was quantifiable.

Math and science began replacing religion as the ultimate source of reliable knowledge about the world. Since math and science could completely describe the universe, religious belief began to decrease, especially among the educated. This is typified by Pierre Laplace's quote after being questioned by Napoleon (early 1800s) about where God fit into his theory about the formation of the solar system. Laplace replied, "Sir, I have no need for that hypothesis" [4, p. 538].

The mathematization of Western culture has continued in large part to the present day, especially among the more educated. Only 40% of US scientists believe in God, compared with 93% of the general population [5].

B. *The Effects of Mathematization*

Math has enabled us to control our world and (arguably) make it a better place to live. Some mundane benefits of math include the ability to measure recipes, prepare food, and build houses. More sophisticated examples include the ability to use telephones, drive cars, and use computers. However, some results of math are not so beneficial. Math tends to depersonalize its subject. It allows us to make life-and-death decisions without regard to personal issues.

Governments and organizations rely on quantitative data to make decisions, not personal judgments. Math inherently introduces norms. For example, IQ testing reduces intelligence to a single number, which ignores the complexities of human intelligence. IQ testing is one notable example of the depersonalizing effects of mathematization. At the beginning of the 20th century, 16 American states passed laws that required the sterilization of those with low IQs.

Mathematization is also seen in sports. Math and science allow us to precisely determine if a football player made a first down, or if a baseball pitch was a ball or strike. We don't need to rely as much on the vagaries of human judgment with the advent of instant replay. Although balls and strikes are still determined by umpires, computers are now used to grade umpires. Eventually balls and strikes will be determined entirely by computer. Traditionalists lament the days when officials were more a part of the game, but most sports fans are glad that humans can be removed from the equation and that technology can assure us of "getting the call right."

The use of math to study a problem shapes our perception of that problem. A scientist who studies a problem must use math to obtain and report research results, otherwise it will not be published or funded. There are some advantages to this. Research can more easily be replicated, and math helps remove personal bias. But certain aspects of problems are not easily condensed into math (e.g., personal issues). Math-based research must therefore ignore those problems that are not amenable to mathematization.

Math tends to oversimplify complexity. How can economic well-being be quantified? It can be approximated by income, debt, etc., but shouldn't it also be linked to contentment? We forget the limits of math, and since we use only math to measure things, our perception of them is shaped by our assumptions. It is the appearance of objectivity that increases the difficulties associated with mathematization. Since math is neutral, we assume that it is value-free. But in reality, the exclusion of moral and social values from math is itself the value of math. Math implicitly values measurables but gives the impression of neutrality. If we recognized the values implicit in math this would not be such a problem.

Fuzzy logic can help in some of these areas, although fuzzy math still relies on objective measures and is therefore susceptible to the same type of oversimplification as crisp math (although not to as great an extent). But fuzzy logic can measure things like contentment, friendship, satisfaction, and values, without imposing as much structure. The challenge for fuzzy logic is to strengthen its connection with linguistics in order to balance the mathematization of modern culture.

C. *The Backlash Against Mathematization (Postmodernism)*

Is it true that mathematical knowledge is superior to other forms of knowledge? Is the proof of a mathematical theorem better than intuition? If so, in what sense is it better? It is clear that the definition of "better" must come from outside of math itself, otherwise statements about the superiority of math will be circular.[3] Consider the mathematization of time, and the value judgments inherent in it. Before mathematical methods for keeping time, appointments were kept with less precision. Now that we have the ability to be precise, it is understood that the more precise the concept of time, the better. Time that is linked to everyday experience (sunrise, sunset, etc.) is devalued in our culture because we have technology that makes those types of benchmarks unnecessary.

The backlash against mathematization began in earnest with postmodernism in the 1960s. Postmodernism de-emphasizes crisp numbers and values, and instead embraces things like paradox and ambiguity. Postmodernism reacts against the over-reliance on math and reminds us that the use of math must be directed by principles that lie outside of math. Postmodernism has over-reacted (denial of objective truth, over-emphasis on intuition and emotional ways of reasoning), so that the pendulum has swung to the other extreme (see Fig. 1). The over-reaction is understandable in view of the arrogance of modernism and its abuses (think government bureaucracy). But fuzzy logic can provide a balance because it accepts both mathematical rigor and ambiguity.

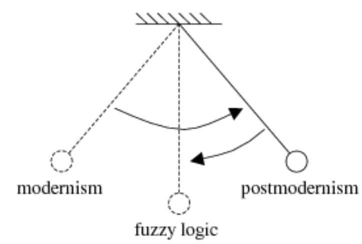

Fig. 1 Fuzzy logic provides a balance between modernism and postmodernism

D. *Fuzzy Logic and Mathematization*

Perhaps not coincidentally, fuzzy logic was developed about the same time as the start of popular postmodernism.[4] Fuzzy logic became popular in engineering because of its ability to deal with real-world, ambiguous problems. Fuzzy logic is heavily mathematical, but at the same time emphasizes ambiguity and uncertainty. Its popularity is due to its practicality, not its mathematical rigor. It was developed to address practical problems, and the math came later. Fuzzy logic arose in an atmosphere of application. Zadeh did not pursue fuzzy logic because it was true, but because it was practical. Fuzzy logic was conceived in a milieu of practice, but since then it has become "Westernized" in a way. It has become mathematical, with many fuzzy logic research papers now showing little (if any) connection to practice.[5]

There is a positive-feedback relationship between culture and fuzzy logic. Postmodernism helped give fuzzy logic respectability in culture, and now fuzzy logic is increasing the acceptability of postmodern thinking. Culture had an impact on the development of fuzzy logic, and now fuzzy logic is having an impact on culture. Fuzzy logic balances the over-

[3] Think about the logic circularity of the following argument: "This mathematical theorem is more true than my intuition because it has been proven mathematically. I know this because truth is defined by mathematics."

[4] Perhaps the first hint of fuzzy logic in its present-day form was in a 1962 paper by Lotfi Zadeh when he wrote, "…we need a radically different kind of mathematics, the mathematics of fuzzy or cloudy quantities…" [6]. This was the same year that Thomas Kuhn wrote *The Structure of Scientific Revolutions*, which is often cited as the beginning of postmodernism.

[5] It would be interested to survey early papers on fuzzy logic and see how many dealt with practical problems, then survey more recent papers on fuzzy logic for the same purpose, and compare the two. This remains as a task for future research.

reliance of modernism on crispness, but it also balances the irrationality of postmodernism with mathematical rigor.

Consider the mathematization of intelligence via the crispness of IQ scores. Fuzzy logic can help with this by allowing, for example, a student with an IQ of 90 to be considered in the "medium" range, and another student who reads 1/2 grade level lower than average to also be considered in the "medium" range. There are many other similar examples (university rankings, standards of living, etc.).

E. The Crispness of Fuzzy Logic

Fuzzy logic can strike a balance between rigorous math and postmodernism by retaining its "fuzziness" while still emphasizing its mathematical foundations. After all, fuzzy logic is not fuzzy in itself. As Erwin Schrodinger wrote, "There is a difference between a shaky or out-of-focus photograph and a snapshot of clouds and fog banks" [7]. This quote refers to quantum mechanics, but it also applies to fuzzy logic. Just as quantum mechanics involves indeterminacy, fuzzy logic involves ambiguity. However, just as quantum mechanics is a precise science, fuzzy logic is precise mathematics. Fuzzy logic has often been wrongly criticized as being equivalent to fuzzy thinking. This is understandable, especially in view of the unfortunate use of the word "fuzzy."

The term "fuzzy" has resulted in a lot of publicity, so the advantages of its name may outweigh the disadvantages.[6] On the other hand, does the average consumer really want his antilock brake system controlled by something that is "fuzzy?" We can look at the history of fuzzy logic in Japan to see the tension between its effectiveness and the negative connotation of its name. The acceptance of fuzzy logic in Japan was difficult at first due to the negative con-notation of the term "fuzzy." When the Japanese replaced the Japanese word for "fuzzy" with the new word "faaji" (a transliteration of the American word "fuzzy"), sales soared [8, p. 135].

There are many examples of the confusion of fuzzy logic with mathematical imprecision. For instance, in 1972 Rudolph Kalman said, "No doubt Professor Zadeh's enthusiasm for fuzziness has been reinforced by the prevailing political climate in the U.S. – one of unprecedented permissiveness" [8, p. 46]. William Kahan said in 1975, "The danger of fuzzy theory is that it will encourage the sort of imprecise thinking that has brought us so much trouble" [8, p. 47]. Fuzzy logic has always been mistaken for fuzzy thinking, and now it is also mistaken for postmodernism. We as fuzzy logicians need to make an effort to combat this perception and reinforce the (objective) truth that fuzzy logic is based on precise, rigorous mathematics. It can deal with ambiguity, but that does not mean that it is ambiguous, any more than a medical doctor who deals with cancer is himself cancerous.

Fuzzy logic does not preclude the idea of absolutes – after all, membership functions can be equal to 0 or 1. Fuzzy logic rather adds to the idea of absolutes more levels of belonging. This is in contrast to postmodernism, which rejects the possibility of absolutes. A postmodern view of fuzzy logic would insist that membership functions cannot be equal to 0 or 1, but must rather lie between, say, 0.1 and 0.9. (The exact values here are just a guess. I wonder what thresholds postmodern fuzzy theorists would pick, and how they would come to such a decision.) Contrary to prevailing opinion [9], there is actually more difference between postmodernism and fuzzy logic than there is commonality.

As an example, suppose a control system error is "medium high," as shown in Fig. 2. This is not the same as saying it is partly true that it is "high," and partly true that it is "medium." It is 100% true that it is "medium high." To say that it is "high" is 100% false. However, to say that it is "30% high" is 100% true. To say that it is "35% high" is 100% false, although it is closer to the truth than saying that it is "high."[7]

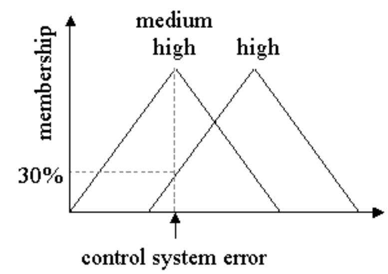

Fig. 2 Fuzzy logic is crisp; here we see that the control system error is *exactly* 100% medium high, and *exactly* 30% high.

VI. CONCLUSION

It should be noted that the perspectives of this paper are those of the author alone. Although I have benefited greatly from a number of sources (as seen in the references section of this paper), there are many other perspectives on this material that deserve to be heard and studied. Other perspectives are widely held with regards to the history of math, the philosophy of truth, the relationship between modernism and postmodernism, and the nature of fuzzy logic.

After discussing these issues, there are some conclusions that can be made. The first deals with the limitations of fuzzy logic. The second conclusion deals with the need of the fuzzy logic community to gain a wider perspective of its role in modern culture. The third conclusion deals with the need of the fuzzy logic community to more actively set its own research agenda. Finally we propose some directions for future research.

A. Fuzzy Logic Limitations

We need to recognize the limitations of fuzzy logic. Fuzzy logic cannot solve all of our problems, and if we oversell it then our efforts become counterproductive. We have seen similar problems in some of the extremes of the mathematization of culture. The use IQ testing to "weed out"

[6] Which book is more likely to be a popular best-seller: one with the name "Fuzzy logic" or one with the name "Continuous set theory"?

[7] Even Aristotle recognized the practicality of this type of fuzziness, when he said that someone who thinks that 4=5 is "more correct" than someone who thinks that 4=1,000 [1].

undesirables in the first part of the 20th century is a notable example of over-mathematization. Postmodernism is, in part, a reaction to the over-mathematization of culture. Extreme postmodernists, however, overreact by throwing out the baby (crispness) with the bathwater (over-mathematization). Math is good, but too much of a good thing is bad.

Fuzzy logic, like crisp math, could fall prey to its own success and provoke a backlash. For example, Bart Kosko resolves the abortion issue by claiming that life is fuzzy [10]. A fetus's degree of membership in the human class is 0% at conception, gradually increases as time passes, and reaches 100% nine months after conception. This over-reach of fuzzy logic will be offensive to many. Even if fuzzy logic applies to the beginning of life, can it be extended to end-of-life issues? Perhaps an old person's degree of membership in the human class begins to decrease as he continues to age (after all, he is getting closer to death). To what degree am I human when I am 90 years old? What about handicapped persons? Does a person's degree of membership in the human class decrease as handicaps become more severe? We see that fuzzy logic, like any technology, can be misused. To prevent misuse we need to be modest in our claims and clear in our explanations.

Another claim that Kosko makes is that fuzzy decision makers could eventually distill the wisdom of vast quantities of documentation to make expert decisions in areas such as social policy and politics [8, p. 13]. But this claim ignores the fact that there are no closed systems, so any fuzzy decision maker needs to be seeded with values and priorities from outside itself. Such extravagant claims are counterproductive in that they damage the credibility of fuzzy logic, and reduce its chances of acceptance by thinking people. The bring about a lot of hype, excitement, and popularity in the short term, but are counterproductive in the long term.

B. Fuzzy Logic and Modern Culture

The fuzzy logic community needs to develop a wider, well-thought-out perspective on its own role in the history of math and its role in modern culture. Fuzzy logic's emphasis on mathematical rigor should not be lessened; it should retain its modernist agenda in that regards. However, in agreement with postmodernism, fuzzy logic should strive to be socially connected and serve society. Fuzzy logic is well-placed to bring the analytical nature of math in contact with practical cultural challenges, but it will not happen by accident.

In order for fuzzy logic to expand its influence on culture, it needs to be made available to a wider audience. This may require more opportunities for undergraduates in science and engineering to study fuzzy logic. Since these students are presumably inundated with postmodernist viewpoints in their general elective courses, it makes sense to show them the firm mathematical foundation of fuzzy logic so that they can see how precise fuzzy logic really is.

C. The Fuzzy Logic Research Agenda

Fuzzy logic, like any discipline, needs to set its own agenda, and this will happen either purposefully or accidentally. The challenge for fuzzy logic is to set its own agenda in a purposeful, thoughtful way. Some questions that need to be discussed include: What problems are important? What approaches are likely to be most fruitful? What constitutes good research? What is the value of fuzzy logic? Does its value derive from practice, or from some intrinsic worth? If it derives from practice, how much emphasis should be placed on current practice rather than potential future benefits? How should current practice (vs. potential future practice) be weighted when considering the value of fuzzy logic research? Is a fuzzy logic application to missile navigation just as valuable as a fuzzy logic application to biomedical control?

D. Future Work

Further research that could follow on from this paper includes relationships between language and fuzzy logic. Language is inherently imprecise, which corresponds nicely with fuzzy logic. But rules for understanding language, constructing grammars, and the like, can be stated quite precisely, which also corresponds with fuzzy logic. There may be some deeper connection between fuzzy logic and human language that could be explored.

The relationship of various aspects of philosophy with fuzzy logic also bears further investigation. Does truth mean the same thing for fuzzy logic as it does for crisp math? What ethical issues should guide the fuzzy logic community as we work on issues that directly effect humans? What purposes should guide fuzzy research – application, discovery, or other purposes? What contributions can fuzzy logic make to our understanding of the nature of other areas of math, science, and engineering (pick your own favorite area: ecology, biology, theology, civil engineering, etc.)? As fuzzy logic continues to increase in popularity in engineering and in modern culture, there will be many opportunities to more crisply define the role that it can play in society.

References

[1] Aristotle and H. Lawson-Tancred, *The Metaphysics*, New York: Penguin Books, 1999.

[2] R. Howell and W. Bradley (eds.), *Mathematics in a Postmodern Age*, Grand Rapids, Michigan: Wm. B. Eerdmans Publishing Co., 2001.

[3] A. Crosby, *The measure of reality: Quantification and western society, 1260-1600*, New York: Cambridge University Press, 1997.

[4] C. Boyer, *A History of Mathematics,* New York: Wiley, 1968.

[5] E. Larson and L. Witham, "Scientists are still keeping the faith," *Nature*, vol. 386, pp. 435-436, April 3, 1997.

[6] L. Zadeh, "From Circuit Theory to System Theory," *Proceedings of the Institute of Radio Engineers*, vol. 50, pp. 856-865, May 1962.

[7] E. Schrodinger, "Die gegenwartige Situation in der Quantenmechanik," *Naturwissenschaftern*, vol. 23, pp. 807-812, 823-823, 844-849, 1935. English translation: John D. Trimmer, *Proceedings of the American Philosophical Society*, vol. 124, pp. 323-38, 1980.

[8] D. McNeill and P. Freiberger, *Fuzzy Logic*, New York: Simon & Schuster, 1993.

[9] T. Ligorio, "Postmodernism and fuzzy systems," Kybernetes, vol. 33, no. 8, pp. 1312-1319, 2004.

[10] B. Kosko, *Fuzzy Thinking*, New York: Hyperion, 1993.