Ruspoinin comments
I agree mainly with your points but I believe that we need to be careful about Axiom 4. In my reply I advanced some reasons for its inclusion (I believe, at any rate, that GAines could have been a bit more careful --- I fully expected Kosko not to be).

Also I think that your draft needs a bit of English editing.

I am not sure what is the status of my supposed comments to IEEE Expert so I am not positive that I should appear on your list but I do not see any problem with it provided we change a few minor things as indicated above.

added by Rudolf
From the viewpoint of logic - at least in the relatively narrow sense of Elkan - to require the relation (*) is very unusual. Indeed, in such approaches like probabilistic logic, where the (classical) logical system is endowed with an additional probabilistic structure, it is reasonable to assume that logically equivalent formulae are assigned the same probabilities. But neither in the model theory of classical logic, intuitionistic logic nor Lukasiewicz logic (which is most adequate for fuzzy logic) there is such a presupposition like the relation (*). The truth values are assigned only on the basis of valuation functions for logical connectives. In each of these logics, (*) is obtained as a CONSEQUENCE if logical equivalence is interpreted w.r.t. the syntax of the corresponding logic.

added by Rudolf
It is even refuted for most propositions.

t(red(x)) = 0.5, meaning that x is somewhat red) and a degree of certainty (like for the watermelon, where 0.8 means that x may be something different from a watermelon). Uncertainty management differs from the handling of vague or gradual properties in logical expressions. Only the latter is allowed to be fully compositional with respect to negation, conjuntion and disjunction.

As a consequence, the way the author considers probability is as wrong. The major flaw is that the author again forgets the respective meanings of a degree of partial truth as opposed to a degree of probability. He has a strictly syntactical approach and seems to ignore the semantic that underlies the numbers. Probabilily deals with a unknown object for which we have some belief that it belongs to some well defined sets. Partial truth deals with assertions that contain vague predicates.

Suppose now that watermelon is a fuzzy predicate. The author is then right when observing that the minimum operator has no reinforcing effect while such an effect may look natural here. This remark just shows that a blind application of the minimum rule can be misleading, not that fuzzy logic is wrong.

3. Fuzzy logic in control

The author mainly insists on the simplicity of fuzzy controllers where the number of rules is small and where there is no chaining between rules because rules directly relate sensor observations to control decisions. He fails to understand the difference between fuzzy controllers and certainty-factor-based techniques in expert systems.

The key issue in fuzzy control is that the use of fuzzy predicates supplies the basis of an interpolation mechanism between typical decisions. Fuzzy predicates enable the controller to estimate the similarity of the current situation to the prototypical ones described in the rules. The procedure results in a precise decision where no uncertainty is involved.The small number of rules is an appealing feature of the fuzzy approach where rules can cover large classes of situations owing to the interpolation. On the contrary, in expert systems we are interested in estimating the certainty of plausible conclusions.

Conclusions.

Elkan's paper is a typical example of the so-called rebuttal papers. Unfortunately, the author falls in a classical trap. He considers a theory, presents HIS interpretation, shows the inadequacy of the conclusions derived from HIS interpretation, and concludes to the inadequacy of the theory. He forgets that the inadequacy might reside in HIS interpretation as it was the case in the present analyze of fuzzy logic. Indeed, the relation (*) in his definition is not required in fuzzy logic.

The problem with such papers is that casual readers will use them to criticize and maybe stop future fundings for research on the topic just as it was the case with the famous British report that killed artificial intelligence for a decade in Great-Britain. Acceptance and publication of negative papers that claim to "prove" that a theory is wrong should be made with more care. Non-sense leads to non-sense ... but might kill good work by giving it a bad reputation even when completely unjustified.

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A reply to 'The Paradoxical Success of Fuzzy Logic' of Ch. Elkan.

Charles Elkan has presented at AAAI'93 a paper entitled "The Paradoxical Success of Fuzzy Logic" where he tries to show that fuzzy logic collapses formally to two-valued logic and, further, that it is empirically not adequate for reasoning in expert systems.

If the contents of the paper had been correct, a casual reader could come to share the author's opinion about fuzzy logic and conclude negatively about the interest of such a theory. Fortunately for fuzzy logic (and unfortunately for the ill-adviced author), his argument is fallacious. It is based on wrong assumptions and on a lack of understanding of what fuzzy logic is about. A reply to the author's comments seems to be necessary in order to stop potentially deleterious effects of such a paper and to avoid further propagation of such fallacies in the scientific community. The fact that such a paper was accepted by the Scientific Committee of AAAI is realy not in favor of the reviewer's work! Their selection desreves a greater care.

We will analyze successively the three major errors developed in that paper.

1. Fuzzy logic collapses into binary logic.

Fuzzy logic is defined as a logic where assertions receive a degree of truth. The author claims that the truth assignment t satisfies:

t(A and B) = min(t(A), t(B))
t(A or B) = max(t(A), t(B))
t(not A) = 1-t(A)
t(A) = t(B) if A and B are logically equivalent. (*)

where A and B are two assertions. Under such assumptions, the author proves that t(A) can take only two values (what of course would trivialize fuzzy logic). This is a well known and very old result. But the defining properties are not those required for a correct definition of fuzzy logic. Relation (*) is not required in fuzzy logic.

The author fails to acknowledge that, by definition, classical logical equivalence does not apply to fuzzy assertions. The author seems to ignore that fuzzy logic deals not only with crisp assertions (those encountered in classical logic) but also with fuzzy ones, i.e., assertions where vague terms are involved like in 'John is tall'....

The author's proof is relevant only for crisp propositions for which (*) indeed holds. The proof is based on the claim that "not(A and not B)"and "(notA and notB) or B" should be logically equivalent in fuzzy logic. It is true when both A and B are crisp assertions, not when they are fuzzy, in which case Elkan's proof collapses, not fuzzy set theory. Even more strikingly, assumption (*) implies that for all A t(A and not A) = min(t(A), 1-t(A)) = t(contradiction), t(A or not A) = max(t(A), 1-t(A)) = t(tautology) two postulates that are rejected by fuzzy logic and that even more obviously trivialize Elkan system. Lastly there is no hope that Elkan's axioms be compatible with intuitionistic logic since he assumes that negation is involutive.

2. The red water melon example.

To criticize fuzzy logic, the author introduces two predicates "red" and "watermelon" and proposes that for some object x, t(watermelon(x)) = 0.8 and t(red(x)) = 0.5. What is the meaning of 0.8 and 0.5 in such statements. Is "watermelon" a crisp predicate or is it a vague predicate?

Assume "watermelon" is crisp. Then 0.8 cannot be a degree of truth. The trouble comes from Elkan's confusion between the degree of truth of a vague proposition (like in