WHY FUZZY REASONING ?

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1 Background

The topics of "fuzzy logic" and "fuzzy reasoning" are not clear-cut subject areas with well-defined results and track records. Instead they represent a wealth of recent activity on an international front that may be seen to have its technical roots in philosophical and mathematical studies of "multi-valued logics" (Rescher 1969) and "vague reasoning" (Machina 1974), but which owes much of its present impetus to engineering interest from those concerned with "information systems" (see Sanford 1975 for some wry comments on this "engineering interest" in a philosophical journal).

Much of the current literature on fuzzy logic is neither precise in its objectives nor accurate in its conclusions. Much of the current effort duplicates activities taking place, or having taken place, elsewhere. However, this is of the nature of a fast growing subject area - it makes it difficult, however, for the newcomer to assimilate the (literally hundreds) of papers of recent years and assess the results, neither dismissing them because of his contact with the trivial, nor believing the exaggerated claims of enthusiasts.

This seminar is intended to introduce this area, relate it to other subject areas concerned with reasoning and decision-making, and give pointers to the most useful literature and areas of development.

These notes are complementary to those on "Multi-Valued Logic and Fuzzy Reasoning" for the AISB Summer School (Gaines 1975), which gives a technical summary and literature references. I will only emphasize again that it is worthwhile commencing with Zadeh's papers and the more "philosophical" and "linguistic" literature that emphasizes the motivation behind the study of fuzzy reasoning rather than the more technical aspects of "fuzzy logic".

2 Basic Problems of Knowledge and Prediction

Because of the fuzzy nature of the subject area I feel one should go back to some fundamental considerations. These have massive and ancient philosophical roots. However, they are also of direct practical relevance - whenever we attempt to implement, for example, a management information system that does more than store and reproduce the data fed to it, to make inferences or estimate trends, we are involved in basic problems of knowledge whose "solution" entails assumptions - if we become concerned with the nature and reasonableness of these assumptions then we very rapidly come to face problems that have been the subject of philosophical debate for all recorded time.

However, our own attitudes to these problems have probably been formed in the light of the past century of the growth of science and the success of technology based on it. This places great emphasis on precise physical laws framed in terms of relations between numeric quantities. It has little use for human opinion and belief, and its development through verbal qualitative reasoning. Thus, when faced with problems of aiding the manager in decision-making we automatically fall back on probability theory based on measure theory and the observation of frequencies. This is not necessarily a natural tool in which to formulate the decision processes used by human beings. Work on fuzzy reasoning is best seen as stimulated by the quest for more natural tools in which to develop information systems that interface naturally with the human reasoning process.

2.1 Induction and Prediction

The purpose of reasoning is to draw inferences from established premises. It used to be thought meaningful to make a clear distinction between deductive reasoning in which the conclusions were logically derivable from the premises (and hence had no more content than them, were in essence a re-formulation), and inductive reasoning in which the conclusions involved an alogical inductive "leap" or generalization - the former was mathematically rigorous and the latter metaphysically dubious. This distinction attained its strongest form with Hume's (Popper 1972) (irrefutable) proof that the process of inductive reasoning cannot itself be proven valid.

This result may be seen as undermining any possible foundations of "science", and has naturally generated an immense effort among philosophers of science (such as Carnap (Carnap and Jeffrey 1971), Popper (1972), Lakatos (Lakatos and Musgrave 1970), Feyerabend (1975), Hesse (1974) and Gellner (1974)) to determine what are the foundations of science and to give them whatever lesser rigour Hume's result still permits. The relevant literature on the problem of induction (Katz 1962), confirmation theory (Swinburne 1973, Rescher 1973) and scientific inference (Hesse 1974) is important to anyone developping information systems. However, they will be disappointed at the strength of the negative results and the paucity of positive methodology.

More recently doubt has been thrown on the strength of deductive inference (Dummett 1973). Firstly, the whole concept of an established premise is extremely dubious. Even "raw observation" seems always to entail inductive reasoning - we cannot perceive or measure without unverifiable assumptions. Secondly, the uniqueness and absoluteness of classical logics (propositional and predicate calculi) has been increasingly challenged with increasing success (Haack 1974). In recent years the rigorous development of modal logics (Snyder 1971), the weakness of the classical logical foundations of quantum physics (Mehra 1973), the success of alternative logical calculi as foundations of mathematics (Mostowski 1966), and, probably also, the obvious poverty and weakness of our whole knowledge of knowledge, its acquisition and use, as demonstrated by the attempts to use it operationally in artificial intelligence systems - all have weakened the position of classical deductive reasoning.

3 Human Reasoning

Once we realize that any form of predictive inference involves alogical and unverifiable assumptions, that all premises have inherent vagueness if not some element of falsity, and that our process of reasoning, having papered over these basic flaws, is itself somewhat arbitrary, we must begin to wonder how anything is possible (or decide that in fact anything *is* possible - a perfectly tenable position if somewhat devastating for systems engineering!).

One natural way out is a form of pragmatism - "valid reasoning is what works". This is the argument that Hume proved circular - however, as Katz (1962) has argued, there is a difference between (logical) validation and (pragmatic) vindication. We may, for example, give various evolutionary arguments as to why creatures with brains whose reasoning is like our own have survived in this physical environment (what we cannot justify is the supposition that they will continue to do so - however, it seems reasonable to act as if this were so - at the utmost level of despair permitted to a working engineer one may operate under the motto of William the Silent, "It is not necessary to hope in order to act, or to succeed in order to persevere" !).

In the light of these strong undercurrents mining away the philosophical and methodological foundations of science, it is not surprising that one of the main pragmatic models of successful reasoning that is being examined is man himself. The last hundred years of scientific and commercial success of physical and mechanist science gave great hopes that such science would lead to a complete account of biological processes, including all aspects of the human brain and its reasoning capabilities. One would not look to the human mind as a model of inference processes - the precision and exactness of formal logical deduction are foreign to the forgetful, inexact, wandering human mind. Perhaps, conversely, creative and original thought was foreign to the precision of the digital computer, but the judicious introduction of "noise" might achieve it without necessarily introducing the basic weaknesses of the brain.

We would not nowadays wish to return to a position where the brain was regarded as having a vitalist component beyond our knowledge, nor the computer regarded as pre-programmed in every respect and thus incapable of the emulation of "creativity". We are making too much progress in understanding, emulating and collaborating with human reasoning to feel the need to invoke magic, and no-one who has retrieved interactively from a natural language data base system which has also interacted with other users (and contains data resulting from those interactions) could deny the creativity of some computer systems (constructive novelty is essentially always relative to the percipient - we are the ones who recognize innovation and what it is reflects upon both observer and observed).

However, there is an increasingly healthy respect for human reasoning that begins to recognize the problems of inferencing from unreliable, inconsistent and vague premises to conclusions that form the basis for action.

Perhaps forgetting, inexactness, and search for analogies, are not defects of a weak deductive system but instead essential features of a powerful inductive system (those who see this as the obvious position anyway should introspect a little more deeply and ask even if they believe it superficially do they actually act on it in systems engineering - we have been indoctrinated to believe in the superiority of numbers and exact operations to names and qualitative operations - this affects many design decisions - for example, we generally require far more precision of expression by the computer user than is necessary - we are surprised that alphabetic names can just as well be entered on a 10-key telephone dialler (with 2.6 to 1 vagueness) as on a teleprinter - we trust numerical approximations to reality and our manipulations of them far more than any direct verbal logic).

An interest in human (verbal) reasoning processes is not new - Plato and Aristotle had a lot to say that is still very fresh today. The modal logicians studying our use of terms such as "possible" and "necessary" (Snyder 1971), "sometimes" and "always" (Prior 1967), "a few" and "many" (Altham 1971), and so on have essentially modelled the reasoning processes of which these terms are major components. Both modal logic and linguistics have made great progress in this direction in recent years (Creswell 1973, Fillmore and Langendoen 1971, Hockney, Harper and Freed 1975). The technical development of fuzzy logic and fuzzy reasoning may be seen as providing enhanced mathematical tools for the study and emulation of human verbal reasoning, logics which carry both factual information are estimates of its reliability. Probably more important than any single technical development however is the motivation behind the surge of engineering interest in such logics - it has brought together many workers on diverse forms of information systems in the common realization that there are substantial gaps in our knowledge of knowledge that are being filled ad hoc in many practical systems and which need, and can sustain, far greater coherent development.

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