FUZZY SET THEORY IN MEDICINE (Part I)

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ABSTRACT:

All real world knowledge is characterized by incompleteness, imprecision and inconsistency.

Fuzzy set theory provides the possibility of defining inexact medical entities as fuzzy sets. It offers a linguistic concept with excellent approximation to texts. In addition, fuzzy logic presents powerful reasoning methods capable of handling approximate inferences.

These facts make fuzzy set theory highly suitable for the development of computer-based diagnostic and treatment-recommendation systems.

The medical expert system CADIAG-2 provides evidence for fuzzy set theory as a mathematical tool to formalize medical processes.

Keywords: Uncertainty, Medicine, Fuzzy Set Theory,
          Computer-Assisted Diagnosis, CADIAG-2.

The 2nd Part of this paper , devoted to a presentation of the system CADIAG-2 , will appear in BUSEFAL n° 18 (April 1984) .

1. INTRODUCTION

Uncertainty of knowledge about the patient and about medical relationships is generally accepted and considered to be an inherent concept in medicine. The physician, however, is quite capable of drawing conclusions from this information. Naturally, these conclusions are approximate rather than precise.

In medicine, the principle of "Measuring everything measurable and trying to make measurable that which has not been measurable so far" (G. GALILEI) still exists but its limitations have become obvious in this century.

In fact, all real world knowledge is characterized by
- incompleteness hence the human process of cognition is infinite
- imprecision as indicated by HEISENBERG's Uncertainty Principle
- inconsistency anticipated by GÖDEL's Theorem.

Fuzzy set theory developed by ZADEH [1] provides the possibility of defining inexact medical entities as fuzzy sets. It offers a linguistic concept (ZADEH [2], ZADEH [3])with excellent approximation to medical texts. In addition, fuzzy logic (ZADEH [4], BELLMAN and ZADEH [5]) presents powerful reasoning methods that can handle approximate inferences. These facts make fuzzy set theory highly suitable for the development of a computer-based diagnostic and treatment-recommendation system [6].

The medical expert system CADIAG-2 [7,8,9] provides evidence for fuzzy set theory as a mathematical tool to formalize medical processes.

2. REAL WORLD KNOWLEDGE

Precision exists only through abstraction. Abstraction is the ability of human beings to recognize and single out relevant properties of real world phenomena and objects.

Intellective models are then established defining and terming abstract classes of phenomena and objects. In fact, every real world phenomenon and object is unique.

Abstract models of real world phenomena and objects such as mathematical structures (circle, point, etc.), equalities $(a=b+c)$, propositions(yes, no) are artificial constructs. They represent ideal structures, ideal equalities and ideal propositions.

But abstraction forms the basis of human thought, and human knowledge is its result.

2.1. Incompleteness

Abstraction, however, does not remain in a static state. The process of abstraction is being continued and will achieve new results. Additional or other properties of real world phenomena and objects are considered. Knowledge is therefore always and necessarily incomplete.

2.2. Imprecision

Unlimited precision is impossible in the real world. What is called "precise" can only be considered as "precise to a certain extent".

Maximizing of precision is still a valuable aim in science. G. GALILEI, who passes of the inventor of the quantitative experiment in science, is certainly right with his stipulation of "Measuring everything measurable and trying to make measurable that which has not been measured so far" although its limitations ought to be recognized.

HEISENBERG's Uncertainty Principle [10] shows these limitations of accuracy very clearly. Of course the principle applies only to the world of microphenomena and microobjects but its philosophical implications go further. It shows that nature is fundamentally indeterministic. And it seems meaningless to ask whether nature inherently lacks determinism or whether uncertainty stems only from experimentation.

2.3. Inconsistency

Abstraction does not always lead to the same results and is not always accepted in the same way. Knowledge cannot be considered to be a final instance. It may differ according to nation, culture, religion, social status, education, etc. Therefore it will be inconsistent. To eliminate inconsistency from the knowledge system is only possible in limited systems. GÖDEL's Theorem [11] clearly demonstrates that contradictions within a system cannot be eliminated by using means of the system itself.

3. MEDICAL KNOWLEDGE

In medicine, one does not have to deal with microphenomena and microobjects, etc. to run into the problems of incompleteness, uncertainty and inconsistency. Lack and imprecision of knowledge as well as contradictory knowledge are by far more obvious in medicine than in sciences such as mathematics, physics, chemistry, etc.

These aspects are familiar to every physician and have to be considered in daily medical routine, in every medical decision where they may have important, even vital consequences for the object of medical activity, the patient.

3.1. Knowledge about the patient

Patient data can be divided into different categories that are all characterized by an inherent lack of accuracy.
- patient's history

  The patient's history is given by the patient himself. It is a highly subjective part of the patient data and may include simulated, dissimulated, exaggerated or understated symptoms. Ignorance of previous diseases in himself or his family, repression of previous operations and general failure in remembering make a patient's history often questionable for the physician. On the other hand, however,

very often the most important information that leads to the correct diagnosis is found in patient's history.

-- physical examination

The physician submits the patient to a physical examination from which he obtains more or less objective data. But of course, physicians can make mistakes, overlook important signs or make an incomplete examination. Furthermore, they may attribute wrong meanings to other signs because of the undefined transition from normal to pathological.

- lab test results

Lab test results are considered to be objective patient data. But failures in measurements, transmission failures or improper behaviour of patients prior to examinations can lead to imprecise and even totally incorrect data. In general, pathological boundaries are not strict. There are always borderline values that are neither normal nor pathological.

- findings obtained by histological, X-ray, ultrasonic examinations, etc.

These results again require correct interpretation by medical or paramedical staff. Such findings are often very crucial because of their pathognomonicity inasmuch as they frequently indicate invasive therapy. Obviously, uncertainty is often part of the evaluation results, occurring with for example cell counts, cell determination, picture analysis, etc.

3.2. Knowledge about medical relationships

Medical knowledge thus consists of medical descriptions and assertions that are incomplete and uncertain. Historically, medical knowledge has built up step by step. It has become a system based partly on theoretic foundations (anatomy, physiology) and partly determined by almost purely empirical behaviour (internal medicine, surgery). It incorporates knowledge about theoretically founded causal relationships,

statistical knowledge, pure definitions and judgments , etc.

To add further difficulties, quantities in medical rela-
tionships change in place and time, vary in different medical
schools or have not even been studied.

3.3. Medical inference process

The medical inference process describes the process of
inferring from patient's symptoms, signs and test results to
diagnosis by means of medical knowledge. This is a complex
and almost uninvestigated process in which the physician is
obviously able to work with uncertain and imprecise sets of
knowledge. To some extent, it is a subconcious activity which
is why it is often called an art.

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