# AN EXPERT SYSTEM BASED ON FUZZY LOGIC AS A SUPPORT TO THE MEDICAL DIAGNOSIS

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ABSTRACT.

The fuzzy sets and their logic enable us to match decision problems when the date and concepts deal with fuzziness. The work wants to investigate the use of such not traditional logics for making an expert system secure knowledge-base in medical area. The main topic of this work,consists in an expert system making, based on the fuzzy logic,digestive organs desease diagnosis. The language used is Prolog. . The strategy which the system is based on is "backward channing", upon which the system searches the property to shawn for getting a conclusion.Also, the system was realized with the production system theory, appropriately modified to use the fuzzy logic. To present the fuzziness we need. to associate a fuzziness measure to every logic rule and define some appropriated composition operation by means of which the fuzziness grows from the data to the conclusions.

INTRODUCTION.

In clinical medicine a very important step is that of diagnosis. Its intellectual mechanism is a very complicate problem since there all our culture, experience, immagination and inductive capacity converge.
Having in mind that even if clinical medicine is essentially an inferencial activity, even though the physician has difficulties in keeping control of all events occurring inside the organism, several facts run off his hands and as a consequence he can only satisfy himself of the indirect symptoms he can reveal. We can not even neglect the fuzziness of the symptoms and the "thoughts" of the patient. The physician thus faces a vast field of knowledge and a more or less vague information and must,therefore, use a correct methodology. For the above reasons he needs a tool having the following functionalities:
-to treat a big volume of knowledge,
-to link data and information,
-to extract the hypothesis driving certain phenomena.
Until recently, the use of computers in diagnosis has been based on recording information and statistical mathematical models. A more complex level has been reached recently with higher success, that is, to work with concepts, on cause-effect relations and to organize them among themselves. This new approach is based on Artificial Intelligence, which collects and integrates salient aspects of mathematics, psychology and informatics.
The programs developed in such a way take the name of Expert Systems, since they are informatic systems which mimic human reasoning.
Expert Systems are based on the "black-box" criterion, in which the user is not conscious of the inner functioning of the instrument, but only of the external aspects. Due to the expert system capacity to make understand his reasoning (in fact, he can supply explanations which are understandable of how and why he is lead to conclusions) he can be used by physicians without needing of knowing specific information abaut its functioning.

FUZZY LOGIC.

The multiplicity uses of the algebric characteristics of fuzzy sets, has lead us to verify if its use can give a meaninful contribution in the field of decision taking in particular for a better construction of a knowledge basis of an expert system. It has been observed in such analysis that a logic built on such sets resulted particularly optimal in the scientifically oriented medical research and automatic medical diagnosis.
These sentences came out from the following considerations:
1)A pathology is linked not only to the presence or absence of particular symptoms, but to the intensity degree of the symptoms themselves.
2)Often the correspondence existing between symptoms and illness (or symptoms and diagnosis) assumes an "imprecition" character (the "fuzziness").
The concept of fuzziness is thus at the basis of the construction of many methodologies for the development of automatic diagnosis. Starting from fuzzy set theory, which allow us to rappresent the gradual membership of an element to a given set, it is then possible to build a logic which well adapts to the problems given above. In such a study came out several approaches to the diagnosis problem. In the following we discuss some of them and then we will describe that, which according to us, can better mimic our goals.

DIAGNOSIS PROBLEM: SEVERAL APPROACHES.

The first one is based on the properties of possibility distributions, reaching the performance of a program in C language for the diagnosis of the myotonia group of sickness. The second one is based on cluster analysis and through a well-known case and articulated study it has been obtained a way to formulate diagnosis of particulate heart diseases illness. The third approach is that of the Expert System, which is central part of the work presen-

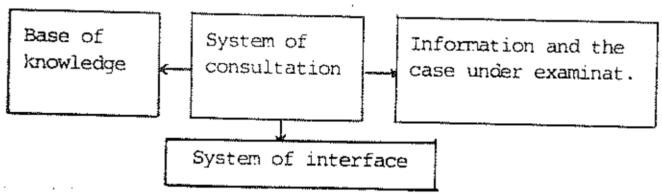
ted here. It has been developed, actually, an expert system based on fuzzy logic to diagnose digestive apparatus illness. The language use was the Prolog.
The first method shows a structure too rigid to be applied successfully to the diagnostic practice. Moreover, the dialogue structure is at a very primitive stage in the trame of a predetermined questionnaire being the same for every clinical case.
A second approach to the diagnostic problem could be that one based on the fuzzy cluster analysis. Information about the patient's illness can be set out as follows:
i)patient's past life,
ii)patient's symptoms,
iii)warks associated to the physical exam,
iv)clinical and diagnostic tests results.
This information is memorized in fuzzy matrices, which are considered in the four stages of the diagnostic process:
a)medical hypothesis,
b)preliminary and initial diagnosis,
c)other preliminary diagnosis,
d)final diagnosis.
The method aim is to assign a patient to a disease or to a group of diseases. The first preliminary diagnosis try to select a group of likely diseases and to eliminate illnesses from those considered already. The successive diagnosis goals are to identify a single disease or at least a very narrow number of them. For several of each diagnosis, the matrices with information on the patient must be compared with similar matrices for likely diagnosis: the patient is thus "clustered" with the illness which is "more similar" to his/her true symptoms. Thanks to this model we go further as concerning the model performance and completeness respect to the model based on "possibility" measures. But most of the numerical factors in the schedules are deduced in some way from physicians criteria, are a kind of hindrance rather difficult to remove in the creation of general models applicable in any diagnostic area. Furthermore, the same medical-informatic interation is difficult because of the wide gap between this kind of diagnostic methodology and the one used in its every day practice. Since we are taking into consideration the analysis of informatic means that make use of human knowledge to assist the clinical physician in his work, it worthes to use diagnostic methodologies close to these ones used by experts to grant facilities to the above mentioned medical-informatic interaction.
For such a motivation we will consider now expert systems and, in particular, that of a diagnostic expert system.
Garry has suggested that expert systems of help to decision taking must contain, in addition to its advise, three qualities:
- the possibility of keeping and handling a set of symbolic concepts rather than simple numbers
- the possibility of communicating with the physician with a language close to the natural one
- the possibility of making explicit the process of reasoning used.

On the basis of such a problematic the MEDEX project has been started. Its main goal is that of performing an informatic system which allows to help the physician facing the problem of diagnosing digestive apparatus diseases and showing similar symptomatologies.
The system has been conceived independently from its applications, that is, to support the diagnostic decision with the diagnostic base goals:
- the knowledge of which the system must make it able to give a comparable opinion with that of an expert
- the dialogue with the machine must be a clear language and as close as possible to the natural one. It must save the user from learning a particular language or code.
- the system must have the possibility of advise the explanations supplying the elements on which its reasoning is based.

It must be able to initiate the action when it is supposed to be useful, rather than being reactive and handled by the user as it happens about traditional systems.
The MEDEXP system is based on the "backward channing", through which the system finds the properties that is enough to demonstrate in order to obtain the conclusion wanted.
The MEDEXP system has been entirely performed by using the system theory output, which has been changed a bit in order to deal with information having a certain grade of trustwortiness with numerical factors stating the grade of membership of the correct information of facts.
As a matter of facts, a suitable model of expert reasoning must take into consideration the uncertainty and inaccuracy that characterizes the introductory statements and conclusions coming out.

MEDEXP ARCHITECTURE.

The general architecture of the MEDEXP system is shown in the following picture:




The dialogue with the specialist is performed by the system of consultation. The system of interface gives explanations about the conclusions reached. The base of knowledge is composed of the rules about the dominion of hepatic diseases. The information about the case under examination is memorized during the consultation session.
The system base of knowledge is composed of rules which include the introductory statements and actions, as, for instance, the following case:

if 1) yellowish complexion color of the patient
2) the liver has swollen.

There is a strong belief saying that the sickness is hepatitis.
The concept of "strong evidence" is expressed by a numerical factor 0.8 which is a measure of the confidence grade of the rule about the expert, with values included in the [0,1] interval. If we consider the rule mentioned before, for example, we can see that both the preliminary statements are satsfied, that is, if both confidential factors are above 0.2, to the conclusion that the diagnosis is a hepatitis then it is associated a numerical factor equal to Fact multiplied by 0.8, where Fact is the lower of the factors of certainty of the preliminary statements. The numerical factors associated to the preliminary statements can be given directly to the user or extracted through the application of the rules of the system.

PROLOG IMPLEMENTATION.

The language adopted for the implementation was PROLOG, which, as a descriptive language, is composed by a fuzzy set describing relations. The representation of fuzzy data is not a natural concept in PROLOG, and the attempt to in-

clude it, may cause discrepancies against the elegance of the language. A possible solution would be that of considering the PROLOG on a fuzzy logic instead of the traditional two-valued logic: we would obtain a more general system of which Prolog is a standard where all the statements and data are absolutely true, an it is a special fuzzy Prolog. For example, given a set of facts about a patient whose liver has swollen and his yellowish complexion, we can define a predicate "infere (hepatitis,chi)" which is true if the patient presents liver increased and yellow color.
Clearly, the "increased volume of the liver" and "yellow color" are fuzzy predicates, which can be satisfied at several levels.
In Prolog we can write

```
Infere(hepatitis,chi) : -liver (increased,chil),
                         color(yellowish,chi2),
                         combine(chil,chi2,chi)
```

where chil expresses the degree with which the anomalous liver satisfies "increased volume", chi2 gives the degree of yellowish color of x, while chi represents the value of truth of the obtained result from the combined chil and chi2.
As we have said before, the basis of knowledge of the system is constructed from a set of production rules; for example, the rule showed above has the following form:

```
infere(9,hepatitis,800,Fact):-
       value(liver,increased volume,CF1),!,
       value(colour,yellowish,CF2),!,
       min([CF1,CF2] ,Fact).
```

The predicate "value", in the preliminary statement of the rules, verifies if an object has certain attributes.
To the rule a fuzziness factor is associated (800 in the example), expressed in a value scale from 0 to 1000, while the certainty factor is the value calculated as the number of certainty factors of each preliminary statement. The certainty value of the rules and the value of the Fact variables, are used to calculate the certainty factor in the results.
The predicate value is successful if the certainty value calculated has a value higher than 200. It is defined as:

```
value(Attribute,Val,CF9):-
          Find(Attribute,Val,CF),!,
          CF > 200
```

where "Find" gets the CF value.
In the chapter of "single case information" are contained observations in which we take care of the deduction results obtained during the consultation; they have the following form:

info( <attribute> , <object-list> )

where <object-list> is composed by couples of the type
obj( <value> , <numerical factor> ).
For example:

```
info(diagnosis,[obj(cholera,950),obj(hepatitis,800)])
info(colour,[obj(yellowish,1000)]).
```

A fundamental part of MEDEX is the procedure "abduction", which determines the value of a given attribute: "abduction" works in backward mode, as the name states. To determine the value of the attribute first looks for it in the knowledge base at short term, otherwise tries to deduce it from well-known facts applying the production rules and, at last, if this is not possible, then a precise user request is executed explicitly. Abduction is thus defined as follows:

```
Abduction(attribute,list):-
(info(attribute,list);obtain(attribute,list);
question(attribute,list).
```

The procedure "obtain" gets its value from a clinical parameter and records it under the name "information on the case", which is defined as:

```
obtain (attribute,list):-
      setof(obj(Val,CF),
            getinfere(attribute,Val,CF),
            Listval),
      reduce(Listval,List),
      assert(info(attribute,List)).
```

The getinfere procedure is given instead by:

```
getinfere(attribute,Val,CF):-
         infere(N,attribute,Val,CF,Fact),
         mult(C,Fact,CF)
```

The procedure setof is a system procedure that invokes all the rules regarding a certain attribute, while the procedure reduce associates to a conclusion all the certainty obtained by invoking several rules.
The procedure mult executes the multiplication between a numerical factor associated to a rule with that associated to the preliminary statement of the rule in the following way:

$$CF = (C * Fact)/1000$$

The procedure Find gets the numerical factor associated to a certain value through the use of abduction. It is defined by:

```
find(attribute,Val,Maxcf):-
     abduction(attribute,object),
     reduce(object,Val,reduction),
     result(reduction,Maxcf).
```

The procedure reduce supplies the factor associated to the variable reduction.
The main call of the abduction procedure is
abduction(diagnosis,res).
During the consultation, when the system needs additional information, the requests are formulated to the user through the procedure question defined as follows:

```
question(attribute,Val,CF):-
        ask(attribute),
        answer(answer,num),
        isaquestion(answer,num,A,B),
        asserta(info(attribute,obj(Val,CF)).
```

in which ask formulates the question to the user, answer collects the answer and the relative factor, isaquestion checks if the user has not made a specific request of the type "rule" in order to have an explanation about the rule used.
The explanation is activated through the procedure isaquestion which is defined in the following way:

```
isaquestion(answer,num,A,B):-
       answer = rule,
       write('the involved rule is'),
       identify(rule),
       translate(rule),
       answer(A,B)

isaquestion(A,B,A,B).
```

The other procedures are so defined:

```
identify(rule):-actualrule(num),
                reg(num,rule)

translate(rule):-clause(rule,consequent),
                 traduce(rule,consequent)
```

where actualrule identifies the number of the present rule, reg looks for it, translate divides it into a body and a head and traduce expresses it in natural language.

RESUME.

The work presented here wants to be, essentially, a methodological tool. We have started with the idea of using fuzzy logic in medical decision problems. There came out three different approaches. The first two are only survayed due to space and interest limitations. They have been however, developed and their limits of application underlined. Both of these approaches are of statistical nature in the sense that the consultation is guided by the user, while the diagnostic system is passive, being able only of changing the data obtained by the user. Last, a new system called MEDEXP has been developed, as we see from the context presented here. During the knowledge acquisition phase, we have worked very tightly with a group of physicians.
The several rules of MEDEXP derive from interview sessions with those physicians: we have tried to understand the language they use in order to diagnostic a given illness, which were the signs and symptoms we wanted to underline and how much "weight" they had in order to arrive to a certain conclusion. Furthermore, we have studied the clinical schedules of patients affected by the mentioned illnesses and their diagnosis. The last phase of such an interaction with these physicians has been that of verifying the system. There were proposed several clinical cases documented by clinical schedules and several diseases observed. We underlined the discrepancies exixting between the system and that of the expert.
We have made corrections to the knowledge base by adding new rules and modifying those previously existing.
A successive improve work has lead us to a better performance of our system.
The language choosen for the implementation was Prolog (Arity/Prolog) due to its semplicity and elegance.
We must reveal some pitfall in the interface with the user, which in an expert system, must be the most "user-friendly" possible. Still, Prolog has a lot of interpreters and compilers hosts, which make it more easy to transport into other systems making use of such language.
To conclude we must recall the ethic problems posed by expert systems. A physician's activity is decomposed schematically in four moments: the examen of the patient, the elaboration of the diagnosis, the therapeutic prescription and the following of the illness evolution. Certainly, Expert Systems help the physician in many of these periods, but never as concerning the axam of the patient which is the most human aspect of the physician activity.
There is no way of substituting a man, a physician by a machine. The attitude of physician evolve and the use of informatics in medicine will certainly influence this evolution. It stands to them, to absob and use the new available methods and to be aware of them.
The critical point of view of physician will fall not less with regards to informatic systems until they will finally enter into their costumes as a book does.

REFERENCES.

|1|Debois-Prade, Fuzzy sets and systems:theory and applications, Academic Press, 1980
|2| Zadeh-Takana, Fuzzy sets and their applications to cognitive and decision processes, Academic Press, 1975
|3| Vila-Delgado, "On medical diagnosis using possibility measures", Fuzzy sets and Systems,vol.10,1983
|4| Esogbue-Elder, "Fuzzy sets and the modelling of physician decision processes" part 1 and part 2, Fuzzy sets and Systems, vol.2,1979, vol.3,1980
|5| Esogbue-Elder, "Measurement and valuation of a fuzzy mathematical model for medical diagnosis" Fuzzy sets and systems, Vol.10,1983
|6| Rosaia, "L'incertezza nella medicina", Le Scienze, Vol.209,1986
|7| Croft, "Is computerized diagnosis possible?" Computer and biomedical research, vol.5,1972, pp 351-367
|8| Szolovits, Artificial Intelligence in Medicine, Westview Press Boulden, Colorado, 1972
|9| Hayes-Roth, Building Expert Systems, Addison Wesley
|10|Weis-Kulikowski, A pratical guide to designing Expert Systems, Rauman & Allouheld Pubbl.,1984
|11|Clocksin-Mellish, Programming in Prolog, Springer-Verlag,1981
|12|Arity Corporation, An Introduction to Arity/Prolog. The Arity/Prolog programming language, 1986
|13|Martin-Baldwin, "The implementation of FProlog. A Fuzzy Prolog interpreter" Fuzzy sets and systems, vol.23 n.1,1987, pp 119-129
|14|Zadeh, "Fuzzy sets as a basis for a theory of possibility" Fuzzy sets and systems, n.1, 1978, pp 3-28
|15|Zadeh, "A theory of approximate reasoning", Machine Intelligence, vol.9,1979 pp 149-194