Diagnosis by Fuzzy Constraints in Attribute Model

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Abstract: In the paper the problem of diagnostics in the terms of fuzzy attribute model is considered, where the problem domain is described by a number of attributes and their values. The diagnostic knowledge about the problem domain is thought of as fuzzy constraints on the possible combinations of the values of attributes in the corresponding attribute model. The search for the diagnosis turns into finding the maximal constraints on the goal attribute by means of logical inference on the knowledge and source data. This approach is implemented in the knowledge manager EDIP under MS-Windows and may be used to create concrete diagnostic systems.

I. Introduction

In the given paper an approach to the problem of diagnostics based on the notion of fuzzy attribute model of the problem domain is considered. We suppose that the system being diagnosed can be described at the syntactic level by a finite number of attributes and the values, and at the semantic level (using the given syntax) by fuzzy constraints on the possible combinations of the values of attributes.

The representation with the help of attribute model means that each state of the problem domain has its description in the form of the concrete collection of the values of attributes. Thus the Cartesian product of the values of attributes forms the space of state descriptions of the object being diagnosed or the universe.

In fact, since each object has an infinite number of properties, each combination of the values of attributes is assigned an infinite number of real states which in the given attribute model are indiscernible, i.e. they are mapped into the only point of the universe. However this property is not considered in the paper (see, e.g., [1]). It will be supposed that an expert and knowledge engineer are responsible for the correct selection of attributes and the values, when all states which should be distinguished have different descriptions. As one way for forming the attribute model an analogue of the repertory grids technique may be proposed [2] in which syntactic and semantic parts of the attribute model are acquired simultaneously and interdependently.

By knowledge in attribute model we mean only the semantic part of the description, i.e., fuzzy constraints on the universe. They say us which states are enabled and which states are disabled.

To solve the problem of diagnostics it is necessary to select one or more goal attributes, the values (or combinations of values) of which represent diagnoses. The rest of the attributes are viewed as the premises. Diagnosis of the problem consists in that the facts being observed are input as fuzzy constraints on the values of particular attributes (premises). Then logical inference is carried out and all constraints (both knowledge and data) are propagated on the goal attributes.

The notion of the attribute model was introduced in [3]. In the paper [4] it was generalized on the fuzzy case. On the basis of this formalism the expert system shell EDIP for MS-DOS [5] and the knowledge manager EDIP for MS-Windows were developed.

II. Diagnosis by Fuzzy Constraints

Let the object being diagnosed be described by a set of attributes $x_1, x_2, \ldots, x_n$ taking its values in finite sets $A_1, A_2, \ldots, A_n$ called domains respectively. Each set A_i $(i = 1, 2, \ldots, n)$ consists of n_i values $a_{i1}, a_{i2}, \ldots, a_{in_i}$.

The Cartesian product of all sets of the values forms the universe or the object states space:

$$\Omega = A_1 \times A_2 \times \ldots \times A_n = \{\omega = \langle x_1, x_2, \ldots, x_n \rangle | x_i \in A_i\}$$

where ω is the particular state.

Let $\pi : \Omega \to [0, 1]$ be fuzzy constraints on the possible states of the object being diagnosed, then the triple

$$\langle X, A, \pi \rangle$$

where $X = \{x_1, x_2, \ldots, x_n\}$ and $A = \{A_1, A_2, \ldots, A_n\}$ is referred to as fuzzy attribute model of the problem domain. Attributes and values represent the syntactic part of the attribute model while the fuzzy constraints reflect the semantics of the problem domain or knowledge.

For example, let the problem domain be described by the following three attributes (in the EDIP notation):

DEPENDENCE = {Psychical, Psychico-physical, Physical}
LOSS OF SELF-CONTROL = {Quantitative, Situational}
ALCOHOLISM STAGE = {First, Second, Third}

States space of this model consists of 18 points. If in addition to attributes and values we also gave degrees of possibility for each state, then it means complete description of the problem domain in terms of attribute model.

For example, if nobody has ever seen anything like the object

$$\langle \text{Psychical, Quantitative, Third} \rangle$$

then it means that the corresponding state is fully disabled, i.e.,

$$\pi\ (\ \langle \text{Psychical, Quantitative, Third} \rangle\ ) = 0$$

If the degree of confidence in this fact is not so large, then its degree of possibility is increased.

Let us note the following characteristic features of the attribute model. First, both the domains and the universe are crisp sets. It reflects our belief that the problem domain is always in one state — it may not be at the same time in several states, between states, beyond states or somewhere else. Consequently, all sets of the values of attributes must be chosen so that any attribute took one and only one value in any real state which the problem domain may be in.

For example, if the attribute TRAFFIC LIGHTS takes values from the set {Green, Red}, then it is obvious that the state exists (yellow) for which there is no value in the domain. Hence the attribute will not take any value.

In fact the issue is more complex. It is seen from the following example. If the domain is equal to {Green, Yellow, Red}, then, nevertheless, there are states which are not reflected in the domain, e.g., Broken or Moon Fell on the Earth. It says that either each domain must be appended by a special value responsible for the rest of the states (called, e.g., the Rest or Unknown) or, more realistically, unlikely and unrelevant situations (such as Nuclear War Began) should not be considered at all.

The second side of this issue is that attributes may not take several values. It is especially important for the problems of diagnostics where different diagnoses and symptoms may combine. For example, the attribute SYMPTOM with the values from {..., High Temperature, Cough, ...} is not permissible because it is clear that two its values maybe present simultaneously. In such cases the values have to be devided into groups, e.g., TEMPERATURE = {Low, Normal, High}, COUGH = {No, Yes}.

Semantics in the attribute model has a prohibitive character. It means that the knowledge expresses that may not be. We may not say 'it is the case that...'. Instead we have to say 'it is not the case that...'.

It is clear that for real problems it not possible simply to enumerate the values of the possibility distribution π for all points from the universe — to do this, we need some *intensive* technique. As such one can use the method based on the fuzzy propositional logic [6]. In this case semantics is formed from fuzzy propositions, each of them being disjunction of elementary propositions. The elementary proposition is that about the values of one attribute, i.e., fuzzy constraints on the values of attribute.

In fact, for the problems of diagnostics it is more convenient to use implicative propositions which by negating the left part are transformed into the disjunct.

Here is an example of the fuzzy knowledge base consisting of two implications:

DEPENDENCE = {PSYCHICAL : 1, PSYCHICO-PHYSICAL : 0, PHYSICAL : 0} &
LOSS OF SELF-CONTROL = {QUANTITATIVE : 1, SITUATIONAL : 0} →
ALCOHOLISM STAGE = {FIRST : 1, SECOND : 0.2, THIRD : 0}

DEPENDENCE = {PSYCHICAL : 0, PSYCHICO-PHYSICAL : 1, PHYSICAL : 0} →
ALCOHOLISM STAGE = {FIRST : 0, SECOND : 1, THIRD : 0.1}

Having the knowledge base defining fuzzy constraints on the possible combinations of the values of attributes, we can use it to diagnose the object. For this, some initial data must be entered, i.e., fuzzy constraints on the possible combinations of premises. The diagnosis is thought of as *maximal* fuzzy constraints on the goal attribute given data and knowledge. Maximality means that if they are some more increased, then the diagnosis is not a consequence of data and knowledge. Formally, the diagnosis is a projection of knowledge π and data on the goal attribute.

To obtain the diagnosis it is necessary to carry out logical inference. There are many different inference techniques. One of them is extensive and consists in that the diagnosis is found by explicitly projecting the possibility distribution (intersection of knowledge and data) on the goal attribute. Clear that this technique is too difficult. Another inference technique which is based on the operation of fuzzy resolution and is implemented in the knowledge manager EDIP.

III. Knowledge Manager EDIP

The knowledge manager (KM) EDIP is an interactive environment running under MS-Windows and providing means for accessing the knowledge base and logical inference. KM EDIP is based on the library of functions called the logical kernel (LK) EDIP.

The knowledge manager EDIP allows opening four classes of windows: structure window, knowledge window, data window and conclusion window. In each window one can fulfill a corresponding set of actions. Structure and knowledge windows are intended for editing the knowledge base, i.e., for changing the syntactic structure and semantics of the problem domain. Data and conclusion windows are intended for carrying out consultations.

Finding a conclusion consists in preliminary compilation of the knowledge base and its transformation into a new form with the help of fuzzy resolution operation. Compiled knowledge base is composed of a number of fuzzy disjuncts. The compilation depth may be regulated. If the compilation depth is equal to zero, then the knowledge base obtained is not changed, i.e., it consists just of the source disjuncts. Completely compiled knowledge base contains all fuzzy prime disjuncts.

When carrying out logical inference and obtaining the diagnosis fuzzy constraints on separate attributes from data window are put on each disjunct in the knowledge base, after that a projection of each disjunct on the goal attributes from conclusion window is found.

Note that the knowledge manager EDIP is realized so that any attribute may be inserted into the data and conclusion windows, therefore one is free to choose the goal of the diagnosis and its succession.

III. Conclusions

In the given paper one approach to the problem of diagnostics is described. Its characteristic features are the following:

- using qualitative information (attribute model);
- clear semantics of fuzzy constraints;
- effective inference technique for constraint propagation;
- equality of attributes.

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