

## TIME-ORIENTED FEATURES FOR MEDICAL CONSULTATION SYSTEMS

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### ABSTRACT

Medical consultation system is one of the major application of artificial intelligence research, and in this field, it is important to treat time-oriented data. The authors developed a system named MECS-AI (MEDical Consultation System by means of Artificial Intelligence), which is designed as a general purpose tool for constructing systems with capability to treat time-oriented data. The basic idea of this system is to describe the time flow as a chain of discrete events.

As a general purpose tool, the system consists of an inference-engine and a knowledge-base editor, so that consultation systems in any field can be easily defined and tested.

### I INTRODUCTION

Medical consultation system is one of the major applications of artificial intelligence research. Experimental medical consultation systems are now widely constructed such as MYCIN[1] and EXPERT[2].

One of the problems to be solved about medical systems is the management capability for time-oriented data. It is well recognized that the time-oriented data management problem is one of the main characteristics of the medical consultation systems and that it is not an easy problem to solve.

There are several attempt to handle the time-oriented data: Gorry et al.'s Digitalis Therapy Adviser[3] can generate conclusions over time as to the next dose of digitalis. Trigoboff and Kulikowski's IRIS[4] system can attach time specifications to the conclusion. Fagan et al.'s Ventilator Management Program VM[5] can even handle real-time data from the intensive care unit.

In this paper, the authors propose another method to handle the time-oriented data. This method enables the consultation system to give a

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diagnostic Judgement and treatment recommendations according to the treatment and to the patient's status in the past, as well as according to the current patient's status. This time-oriented feature is implemented and tested on revised MECS-AI (MEDical Consultation System by means of Artificial Intelligence), our experimental medical consultation system for cardiovascular diseases [6].

MECS-AI is currently implemented on two different LISP systems. One is INTERLISP, and another is EPICS-LISP.

The whole mechanisms in MECS-AI are packaged so that they will be transferred to the other systems, as a part of general purpose tools for knowledge engineering systems. For this purpose, the authors implemented a knowledge-base editor to define and to modify the knowledge-base.

### II REPRESENTATION OF TIME

The most characteristic feature of MECS-AI is the representation of time. In our approach, the progress of time is represented with a chain of discrete events. Each event corresponds to, in medical context, input data and conclusions given at the time of observation, for example, patient visit etc.

Each event is called as a "time-chunk", and is associated to one Time-ID identifier such as YESTERDAY, FIRST-VISIT etc.

In MECS-AI each datum is thus represented as a five tuple: (Time-ID, Context, Attribute, Value, Certainty-factor). The last four elements are almost the same as those of MYCIN[1].

There is always one time-chunk referred to as "Current-Timechunk". Usually, it corresponds to the newest event.

In the inference process during the consultation, one time-chunk referred to as "Target-Timechunk" will indicate the event for which the inference rules are activated. From this time-chunk, inference rules can utilize past data in order to achieve the further inference.

Time-chunks are generated in the order corresponding to the real time flow. In MECS-AI, the inference process is initially activated for the newest time-chunk. Because the newest time-chunk is referred to as Current-Timechunk, Target-Timechunk is set to Current-Timechunk at the beginning of the inference process. Fig.1 shows the representation scheme of time-oriented data in MECS-AI.

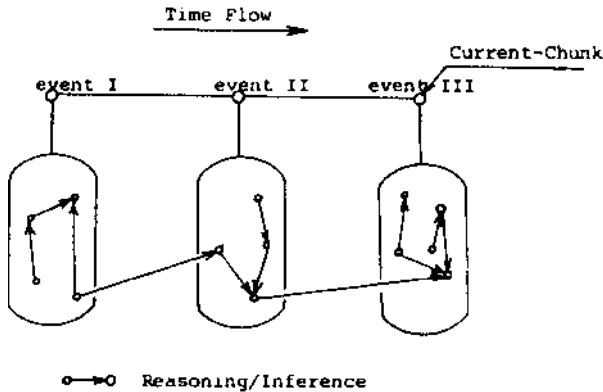


Fig.1 Representation of Time-Oriented Data

In Fig.1, the newest time-chunk is EVENT-III. Therefore, inference rules originally applied for EVENT-III. In MECS-AI, inference rules can access to the data of past time-chunk. Data of EVENT-II or of EVENT-I may be referred to by rules which are applied for EVENT-III. If some data of EVENT-II or of EVENT-I do not have been known when it is referred to, the Target-Timechunk may be shifted temporary to EVENT-II or EVENT-I in order to infer the value first.

### III REPRESENTATION OF RULES

In MECS-AI, rules are denoted in the following BNF syntax:

```

<rule> ::= <premise-part> <conclusion-list>
<premise-part> ::= <premise>
                | <connect-function> <premise-list>
<conclusion-list> ::=
                <conclusion>
                | <conclusion> <conclusion-list>
<connect-function> ::=
                $AND$ | $OR$ | $COUNT$ <count-no>
<premise-list> ::= <premise-part>
                | <premise-part> <premise-list>
<premise> ::= <predicate-1> <context-spec>
                <attribute> <value>
                | <predicate-2> <context-spec>
                <attribute>

```

```

| <predicate-n> <threshold>
  <context-spec> <attribute>
<context-spec> ::= <context> | <context> <keyword>
<predicate-1> ::= $SAME$ | $THOUGHTNOT$ etc.
<predicate-2> ::= $KNOWN$ | $NOTKNOWN$ etc.
<predicate-n> ::= $HIGH$ | $LOW$ etc.
<keyword> ::= PREVIOUS | IN-PAST etc.
<conclusion> ::= <context> <attribute> <value>
                <certainty-factor>

```

The time related information is given by the <keyword> part of the <bontext-spec>. According to this syntax, rules which refer to the past data can be defined. Fig.2 shows an example of a rule which refers to the past data. Using this type of rules, the system is able to modify its conclusion according to the treatment or to the patient's status in the past. It is also possible to adopt "wait-and-see" strategy when diagnostic conclusion is not very clear.

IF.

1. SAND\$
  - 1 (\$SAME\$ DIAGNOSIS FUNCTION EU)
  - 2 (\$SAME\$ (DIAGNOSIS IN-PAST) FUNCTION HYPER)
  - 3 \$OR\$
    1. (\$SAME\$ (TREATMENT PREVIOUS) DRUG 1131)
    2. (\$SAME\$ (TREATMENT PREVIOUS) DRUG MERCAZOL)

THEN.

1. (DIAGNOSIS IDENT WELL-TREATED-BASEDOW 0.7)

Fig.2 an Example of Rules referring past data

It is also noted that each attribute may be defined to have special datatype for its values, in MECS-AI. Datatype "UNIQUE" will be used for attributes which take only one valid value at one-time. Similarly, "MULTIPLE" is used for attributes which may take several values at one-time, and "NUMERICAL" is used for attributes which take numerical values. This kind of datatype definition is quite useful for data access, rule syntax check, and data inquiry processes.

### IV CONTROL STRUCTURES

In MECS-AI, as usual with the general knowledge engineering tools, the knowledge-base is separated from the inference-engine. Our system provides an inference-engine, but does not provide any knowledge-base by itself. Instead, it provides a knowledge-base editor to define and to modify knowledge-bases in any application field.

It is our special feature that the body of knowledge-base itself may be implemented as a

collection of several number of knowledge-units, instead of one single knowledge-unit. Every knowledge-unit has an "apply-condition", and rules in a knowledge-unit are applied only when its apply-condition is satisfied. Fig.3 shows the whole structure of MECS-AI.

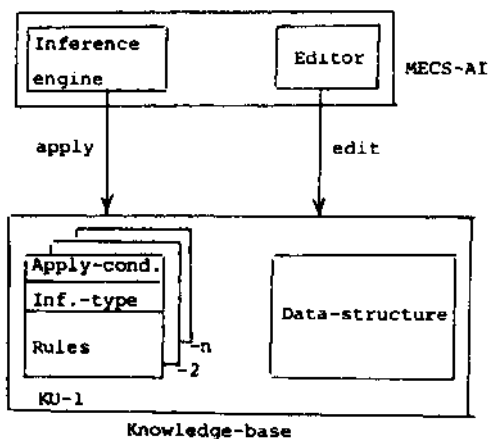


Fig.3 Structure of MECS-AI

The user of MECS-AI can select "inference-type" for each knowledge-unit. When "apply-all" is selected, rules in the knowledge-unit will be applied exorstively, while when a list of "(context at-ribute value)" is selected, rules in the knowledge-unit will be applied according to the backward chaining scheme to find out the (context attribute value) at the time of Target-Timechunk.

Adopting this control structure, rules belong to certain knowledge-unit will never be applied if the apply-condition is not satisfied. And therefor more effective inference process can be realized.

This control structure is effective and adaptive for any inference systems.

#### V CONCLUDING REMARKS AND FUTURE PLANNING

We have descrived our approach to the time-oriented features for the medical consultation systems. We adopted a rather simple but efficient representation and management mechanism through the time-chunk and rule application scheme.

In MECS-AI, our features are cupsuled to be used as a general purpose tool for any knowledge engineering system that needs time-oriented capabilities. A knowledge-base editor is attached to ease the application of MECS-AI to any field. This editor is powerful in the sense that it can define or modify the data-structure, the knowledge-units, and their applicability.

The followings are known through the application of our method to a consultation system for thyroid diseases:

- (1) The system can change the conclusion according to the treatments and patient's status in the past.
- (2) The system can analyze the situation which cannot be handled only through the one-time consultation.
- (3) The system can adopt the powerful strategy such as "wait-and-see".

Application of MECS-AI for other disease categories is now under consideration.

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