UNCERTAINTY TREATMENT IN FUZZY PRODUCTION SYSTEM OF CC_SHELL

Ernest CZOGALA, Wojciech CHOLEWA
Technical University
Gliwice, Poland

Abstract

CC_SHELL is an expert system shell that can handle several kinds of uncertain data and knowledge simultaneously. The processing of such information is based on fuzzy logic, possibility theory, as well as frames for statement representation. The shell is composed of the following main parts

1. Fuzzy Production System (FPS)
2. Frame Interpreter (FI)
3. Tools for programmers

In this paper we shall mainly focus on the uncertainty treatment in the Fuzzy Production System of CC_SHELL.

Keywords: expert system shell, uncertainty, fuzzy set, production rule, frame

1. Introduction

Generally we cannot avoid in expert systems the processing of uncertain knowledge and data. There already exists a number of valuable expert system shells mentioned, for example, in [4,5] which are able to handle the uncertainty of various kinds connected with the processed knowledge.

In this paper we present another implementation of an expert system shell called CC_SHELL which treats some uncertainty kinds simultaneously. CC_SHELL results from two independently designed products, i.e. FMIEXCF [3] and VV_SHELL [2] .

The kinds of uncertainty handled by CC_SHELL can be classified as below:

1. uncertain relationship between rule conditions and conclusions
2. fuzzy conditions within rule conditions
3. vague, or incomplete data
4. unreliable rules and data

Each of the two main parts of CC_SHELL has some interesting features. One of the most important features of the Fuzzy Production System of CC_SHELL is the implementation of Linguistic Approximate Reasoning Inference Engine for Expert Systems (LARIEES) [1] which realizes the generalized modus ponens. It seems to be a considerable advantage of CC_SHELL.

The paper is organized as follows. Section 2 presents the general structure of CC_SHELL. The basic processing methods used in the Fuzzy Production System of CC_SHELL are given in section 3. They also include the main ideas of uncertainty treatment implemented in FPS. Section 4 contains some concluding remarks.

The presented CC_SHELL has many additional capabilities which are not mentioned here for the sake of compactness of this paper. They are described in detail in user's guides and reference manuals [2, 3].

2. General Structure of CC_SHELL

CC_SHELL is a computer implementation of an expert system shell which is composed of the following main parts:

1. Fuzzy Production System (FPS)
2. Frame Interpreter (FI)
3. Tools for programmers

The general block structure of CC_SHELL is shown in Fig. 1.

In the first two parts the respective types of knowledge, i.e. production rules and frames may be applied.

The Fuzzy Production System is such a production system which is able to manipulate heuristic knowledge described by rules and statements. There are many real problems in which a handling of uncertain knowledge and data cannot be avoided while building expert systems. The existence of differing varieties of uncertainty involves the construction of such expert system tools which are capable of handling multiple types of uncertainty at once [4]. The Fuzzy Production System may help to solve such problems, especially when they are described by means of uncertain data and rules. Rule base description language allows to describe various practical problems almost in a natural way.

The Frame Interpreter is a processing unit specially designated for handling different types of statement structures. It can also handle so called approximate statements. The features of the Frame Interpreter and basic elements of LISP-like frame description language have been discussed in a separate paper. Frame description language allows to take into account different kinds of inheritance.

Tasks realized by CC_SHELL can be partitioned between FPS and FI (having access to shared statements) in order to simplify the representation of knowledge, although FPS and FI can call each other.

3. Processing Methods in Fuzzy Production System of CC_SHELL

In order to explain the main ideas of uncertainty treatment in the Fuzzy Production System of CC_SHELL let us assume that the knowledge to be processed consists of rules and data (working memory elements). For the sake of simplicity such knowledge will be written in a general format which is independent of the actual FPS syntax. Inference processes are carried out, taking into account a generalized modus ponens. For an elementary case it can be expressed by means of the following scheme

$$\frac{\begin{array}{l} A \rightarrow C \ , \alpha \\ A' \qquad\quad , \beta' \end{array}}{C' , \gamma'} \qquad (3.1)$$

The conclusion C′can be found by means of the composition operation

$$C' = A' \circ (A \rightarrow C) \qquad (3.2)$$

and for the confidence value of the conclusion we have

$$\gamma' = *_t(\alpha, \beta') \qquad (3.3)$$

Taking into account, e.g. sup-$*_t$ composition, the membership function of the conclusion can be expressed as follows

$$\forall u \in U, \quad C'(u) = \sup_{x \in X} (*_t (A'(x), (A \rightarrow C)(x,u))) \qquad (3.4)$$

where:

A(A′)- means a simple premise (a condition) or a clause(or a statement)

C(C′)- stands for the conclusion

α - represents the uncertainty of the relationship between the rule condition and conclusion, a confidence value cf= α in the value range [0,1]

β' - represents the uncertainty factor of the working memory element (data), a confidence value cf′= β' in the range value [0,1]

γ' - denotes the uncertainty factor resulting from (3.3)

$*_t(*_s)$- stands for the operator of any t-norm (s-norm)

For composite premises within the multidimentional rules the generalized modus ponens can be expressed in the form

$$
\begin{array}{ll}
A_{jn_j} \wedge \ldots \wedge A_{j1} \longrightarrow C_j & , \alpha_j \\
A'_{jn_j} & , \beta'_{jn_j} \\
\vdots & \\
A'_{j1} & , \beta'_{j1} \\
\hline
C'_j & , \gamma'_j
\end{array}
\qquad \text{for } j=1,\ldots,m \qquad (3.5)
$$

where for the conclusion C'_j we have

$$C'_j = A'_{j1} \circ \ldots \circ (A'_{jn_j} \circ (A_{jn_j} \ldots A_{j1} \longrightarrow C_j)) \qquad (3.6)$$

The confidence value of the conclusion C_j can be evaluated from the formula

$$\gamma'_j = *_t(\alpha_j, *_t(\beta'_{j1}, \ldots, \beta'_{jn_j})) \qquad (3.7)$$

however for $C'_1 = \ldots = C'_m = C'$, the actual value of γ'_j should be computed from the formula

$$\gamma'_j = *_s(\gamma'_1, \ldots, \gamma'_m) \qquad (3.8)$$

The membership function of the conclusion in (3.6) has the form

$$\forall u \in \mathbb{U}, \; C'_j(u) = \sup_{x \in \mathbb{X}}(*_t(A'_{j1}(x), \ldots$$

$$\ldots \sup_{z \in \mathbb{Z}}(*_t(A'_{jn_j}(z), (A_{jn_j} \wedge \ldots \wedge A_{j1} \longrightarrow C_j)(x, \ldots, z, u)))\ldots)) \qquad (3.9)$$

The formulas given above form the basis of the so called Linguistic Approximate Reasoning Inference Engine for Expert Systems (LARIEES) described in detail in [1].

Let us point out the most important features of LARIEES. In order to match working memory elements (premises A'_{ji}) and rule conditions (statements A_{ji}), (i.e. matching in which two data items for which no accurate values can be assigned) different measures of equality between them have to be determined.

First, the system calculates the height measure of the intersection, viz.

$$\rho_{ji} = \max_{x \in X} \min (A_{ji}(x), A'_{ji}(x)) \tag{3.10}$$

and

$$\rho_j = \min_i (\rho_{ji}). \tag{3.11}$$

After that, it tries to order all the rules taking into account the inequalities $\rho_j > \rho_{j+1}$. Then, if this is done successfully, the system checks whether $\rho^* = \max_j (\rho_j) \geq \rho_0$ (where ρ_0 is a threshold on ρ).

If $\rho_j = \rho_{j+1}$, the area between the membership functions is calculated

$$\Theta_{ji} = \sum_k \left| A_{ji}(x_k) - A'_{ji}(x_k) \right| \tag{3.12}$$

and

$$\Theta_j = \max_i (\Theta_{ji}). \tag{3.13}$$

Trying to order the rules with respect to the inequalities $\Theta_j < \Theta_{j+1}$ (for $\rho_j = \rho_{j+1}$), the system checks whether $\Theta^* = \min_j (\Theta_j) \geq \Theta_0$ (where Θ_0 is the threshold on Θ).

If $\rho_j = \rho_{j+1}$, $\Theta_j = \Theta_{j+1}$, the confidence value $cf_j = \gamma'_j$ is determined.

Ordering the rules, taking into account the inequalities $cf_j > cf_{j+1}$, the system checks again whether $cf^* = \max_j (cf_j) \geq cf_0$ (where cf_0 is a threshold on cf).

In the case, when $\rho_j = \rho_{j+1}$, $\Theta_j = \Theta_{j+1}$, $cf_j = cf_{j+1}$, the sequence of appearing of the rules in the knowledge base decides about their firing.

Another important feature of LARIEES is the pruning of fuzziness after each stage of approximate reasoning. In chaining (multistage inference) the fuzzy conclusions obtained from approximate reasoning tend to grow faster than those obtained from LARIEES. LARIEES prunes the fuzziness at each stage of reasoning while chaining in order to produce a final fuzzy conclusion with smaller support and kernel (where the membership values of the respective fuzzy set are equal to one).

The application of LARIEES to the control problem has been described in [1].

4. Conclusion

The presented CC_SHELL may be successfully applied for knowledge bases describing various practical problems.

Another useful purpose of this software is the possibility of its expressive demonstration in didactic processes concerning the subject of expert systems.

CC_SHELL makes it also possible to verify in practice the parallel applications of different kinds of uncertainty.

Acknowledgements

Both authors, having been granted with fellowships of the Alexander von Humboldt Foundation, would like to express their gratitude to this Foundation for their continuous support.

References

1. J.J. Buckley, E. Czogala, Linguistic Approximate Reasoning Inference Engine for Expert Systems (LARIEES), Proceedings of the World Congress on Expert Systems, Orlando, Florida Dec. 16-19, 1991

2. W. Cholewa et al: VV_SHELL User's Guide and Reference Manual (in Polish), Report G-547/RMT-4/91, Technical University, Gliwice 1991

3. E. Czogala et al.: Approximate Reasoning in Knowledge-Based Systems (in Polish), Report RRI.14 T/15/52/90, Technical University, Gliwice 1990

4. H. Koyama, T. Miyoshi, S. Fukami, M. Umano, Management of Uncertainty in LIFE FE Shell Fuzzy Production System, Proceedings of the Fourth World Congress IFSA'91, Brussels, Vol. Artificial Intelligence, 121-124

5. T. Miyoshi, H. Koyama, S. Fukami, M. Umano, Fuzzy Frame System in LIFE FE Shell, Proceedings of the Fourth World Congress IFSA'91 Brussels, Vol. Artificial Inteligence, 141-144

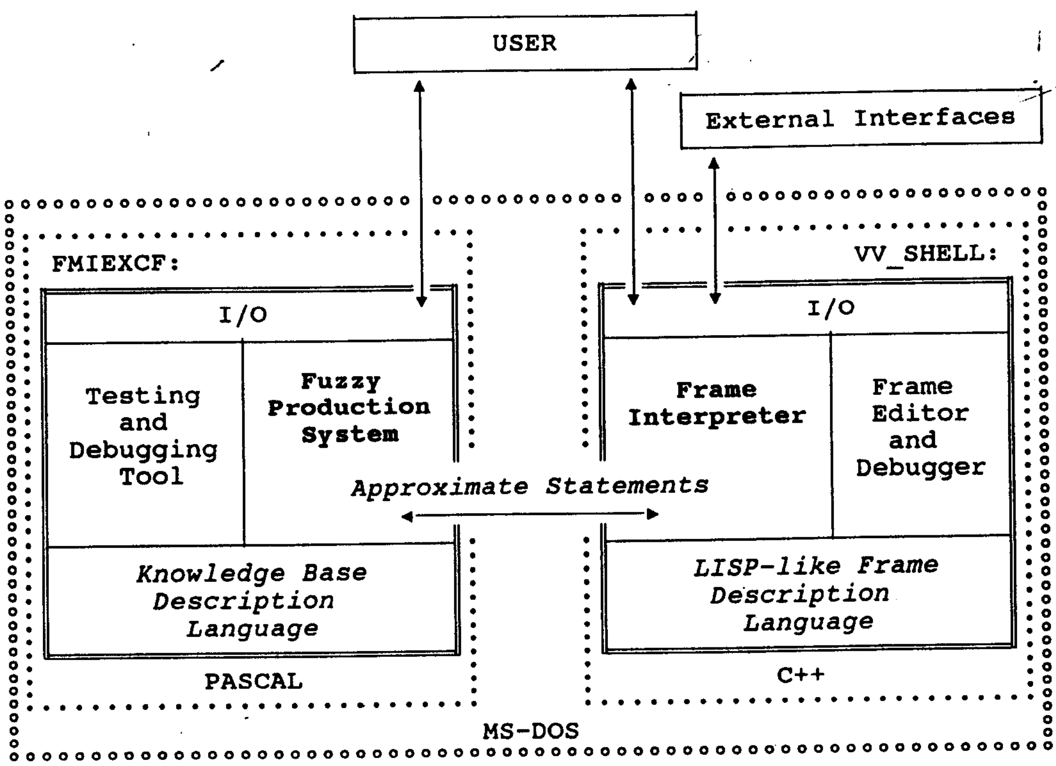

Fig. 1 General block structure of CC_SHELL