Variable Precision Fuzzy Rough Sets Model in the Analysis of Process Data

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Abstract. This paper is concerned with describing and analyzing the control actions which are accomplished by a human operator, who controls a complex dynamic system. The decision model is expressed by means of a decision table with fuzzy attributes. Decision tables are generated by the fuzzification of crisp data, basing on a set of fuzzy linguistic values of the attributes. A T-similarity relation is chosen for comparing the elements of the universe. Fuzzy partitions of the universe with respect to condition and decision attributes are generated. The task of stabilization of the aircraft’s altitude performed by a pilot is considered as an illustrative example. The limit-based and mean-based variable precision fuzzy rough approximations are determined. The measure of $u$-approximation quality is used for evaluating the consistency of the human operator’s decision model, and assessing the importance of particular condition attributes in the control process.

1 Introduction

Uncertainty and vagueness are inherent features of data that are obtained from real processes controlled by an expert. The knowledge acquisition from such a kind of data is an interesting and important task especially in the area of engineering, expert systems and decision support systems.

In contrast to the classical approach of control theory, which treats the human operator as a controller, a new paradigm in form of the fuzzy sets theory was elaborated in the recent decades, which turned out to be suitable for modelling the expert’s controlling behavior. The expert formulates his knowledge of proper control actions in the form of fuzzy decision rules. He defines the input and output variables and the membership functions of the linguistic values which are used in the rules. However, the experts can not always formulate the rule system explicitly. Hence, the decision system of the human operator has to be discovered, basing on the recorded process data. In such a case the rough sets theory can be successfully applied.

The use of the rough sets paradigm for modelling the human operator’s control in industrial processes was initiated by Mróz [12][13][14]. He utilized basically decision tables with crisp attributes. The intervals of the attributes values were coded as integers. Only static or slow processes were taken into account.
Modelling dynamic processes using the crisp rough sets description was investigated in our former work \[8,9\]. It concerned the issue of generating and analyzing decision tables, which represented the control actions of a skilled military pilot, performing various flight tasks on a flight simulator. The obtained information systems were relatively large. The original rough sets approach is very sensitive to small changes in data. It can be especially observed in case of large decision tables. Therefore, we could effectively adopt the variable precision rough sets model (VPRS) introduced by Ziarko \[6,17\].

In this paper we consider some issues connected with application of the variable precision fuzzy rough sets model (VPFRS), proposed in \[10,11\], to modelling the human operator’s decision system. This is a new contribution to our previous work, in which mainly theoretical aspects of the VPFRS model were considered. In particular, we discuss how to construct from process data decision tables with fuzzy attributes, choose an adequate fuzzy similarity relation, and analyze decision tables with the help of the VPFRS model. Additionally, we give a new definition of the upper variable precision fuzzy rough set approximation.

By using fuzzy sets one is able to introduce suitable linguistic values in the decision rules. In consequence, we obtain fuzzy decision tables, which are more adequate for describing the control actions of a human operator, because the human utilizes linguistic terms rather than numbers in his inference. The fuzzy rough sets extension is necessary for analyzing the obtained decision tables with fuzzy attributes. The variable precision fuzzy rough sets model is particularly advantageous in analysis of large fuzzy information systems, which are usually generated in case of dynamic processes.

## 2 Human Operator’s Decision Model

### 2.1 Decision Tables with Fuzzy Attributes

Let us introduce the necessary description needed for construction of fuzzy decision tables. To this end we adopt an extension of Bodjanova’s idea of fuzzy concepts \[1\], which was improved by Fernández Salido and Murakami in \[4\].

We have a finite universe \( U \) with \( N \) elements: \( U = \{x_1, x_2, \ldots, x_N\} \). Each element \( x \) of the universe \( U \) is described with the help of fuzzy attributes, which are divided into a subset of \( n \) condition attributes \( C = \{c_1, c_2, \ldots, c_n\} \), and a subset of \( m \) decision attributes \( D = \{d_1, d_2, \ldots, d_m\} \).

For each fuzzy attribute a set of linguistic values can be given. We denote by \( V_{i1}, V_{i2}, \ldots, V_{in_i} \) the linguistic values of the condition attribute \( c_i \), and by \( W_{j1}, W_{j2}, \ldots, W_{jm_j} \) the linguistic values of the decision attribute \( d_j \), where \( n_i \) and \( m_j \) is the number of the linguistic values of the \( i \)-th condition and the \( j \)-th decision attribute respectively, \( i = 1, 2, \ldots, n \) and \( j = 1, 2, \ldots, m \).

For any element \( x \in U \) its membership degrees in all linguistic values of the condition attribute \( c_i \) (or decision attribute \( d_j \)) have to be determined. It is done during the fuzzification stage, by utilizing the recorded crisp value of a particular attribute of \( x \). When the linguistic values of an attribute have the