Performance Enhancement of the Fuzzy Rule Interpolation Method FRISUV by Rule Weights

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Abstract: Fuzzy rule interpolation based on subsethood values is a low complexity FRI method. In this paper, we present its enhanced version that makes possible the weighting of the individual rules. Thereby FRISUV becomes better tuneable and adaptable.

Keywords: fuzzy rule interpolation, FRISUV, clonal selection

1. Introduction

Fuzzy Rule Interpolation (FRI) methods (e.g. [1][3-11][15]) offer solution for the problem of inference in sparse rule bases. While the traditional compositional reasoning techniques demand a full coverage of the input space by rule antecedents FRI techniques can give an interpretable result even in cases when there are no directly applicable rules. In several cases the practical applicability of the FRI methods depends on the time demand of the inference process and the tuneability of the rule base. This paper offers a solution by introducing a new factor in the algorithm of the Fuzzy Rule Interpolation based on Subsethood Values (FRISUV) [6] method.

The original version of FRISUV similarly the major part of the known FRI methods did not support the weighting of the individual rules. Thus in course of the parameter optimization only the parameters of the fuzzy sets and the ordinal number of the sets included into the consequent part of the rules could be tuned. Although these parameters give enough elasticity for the system in most of the cases, but one gets at the end of the optimization quite often “strange shaped” fuzzy sets or partitions. It means that we lose one of the main advantages of the application of fuzzy logic, namely the self-explaining and humanly interpretable character of the rule base.

In order to solve this problem we enhanced FRISUV by including the weighting of the individual rules in course of the calculation of the conclusion. Thus in several cases the tuning of the rule base can be solved only by optimizing which sets are selected into the consequent part of the individual rules and by modifying the weights associated to the rules. The modification of the position and shape of the sets can remain as a last tuning opportunity.

The rest of this paper is organized as follows. Section 2 presents the enhanced version of FRISUV containing the rule weighting possibility, and the conclusions are drawn in Section 3.

2. Fuzzy Rule Interpolation based on Subsethood Values and Rule Weights

Fuzzy Rule Interpolation based on Subsethood Values and Rule Weights (FRISUVW) has been developed aiming the creation of a fast technique with low computational complexity and applicability in case of all the valid (convex and normal) fuzzy (CNF) sets. The inference's low time demand makes possible the application of the method in real-time or embedded systems as well. FRISUVW extends the concept of fuzzy subsethood values and applies it in conjunction with a relative distance aiming the measurement of the similarity between rule antecedents and observations. Later the conclusion is calculated based on this similarity. The method differs mainly from FRISUV [**Hiba! A hivatkozási forrás nem található.**] in the application of rule weighting.

2.1. Similarity Measurement using Fuzzy Subsethood Values

In order to measure the similarity between the current fuzzy input and the antecedents of the known rules the antecedent parts of the rules as well as the observation can be viewed as *n*-ary fuzzy relations of form

$$\widetilde{R}=\left\{\left(x_1,x_2,\ldots,x_n\right),\mu_{\widetilde{R}}\left(x_1,x_2,\ldots,x_n\right)\middle|\left(x_1,x_2,\ldots,x_n\right)\in X_1\times X_2\times\ldots\times X_n,\mu_{\widetilde{R}}\left(x_1,x_2,\ldots,x_n\right)\in[0,1]\right\}. \tag{1}$$

The similarity between the observation (*n*-ary relation $\widetilde{O}$) and the rule antecedent (*n*-ary relation $\widetilde{R}$) depends on two components, i.e. the shape similarity and the distance between the reference points of the relations.

The shape similarity measure can be based on the fuzzy subsethood value [14], which represents the degree to which a fuzzy set is a subset of another fuzzy set. In the multi-dimensional case it can be expressed as

$$FSV(\widetilde{O},\widetilde{R})=\frac{\sum_{x_1\in X_1}\sum_{x_2\in X_2}\ldots\sum_{x_n\in X_n}\mu_{\widetilde{O}\cap\widetilde{R}}\left(x_1,x_2,\ldots,x_n\right)}{\sum_{x_1\in X_1}\sum_{x_2\in X_2}\ldots\sum_{x_n\in X_n}\mu_{\widetilde{R}}\left(x_1,x_2,\ldots,x_n\right)}, \tag{2}$$

Further on, in order to keep low the computational complexity a simplified version (*SFSV*) is going to be used. SFSV works with the projections of the relations in each dimension

$$SFSV(\widetilde{O},\widetilde{R})=\frac{\sum_{i=1}^{n}FSV\left(P_i\left(\widetilde{O}\right),P_i\left(\widetilde{R}\right)\right)}{n}, \tag{3}$$

where $P_i(.)$ is the projection of the relation to the dimension *i*, i.e. the component fuzzy set of the relation in *i*th dimension. The value of *SFSV* belongs to the unit interval.

The second component of the applied similarity measure is the relative distance between the observation and the rule antecedents.

$$d_{rel}\left(\widetilde{O},\widetilde{R}\right)=\sqrt{\sum_{i=1}^{n}\left(RP_i\left(\widetilde{O}\right),RP_i\left(\widetilde{R}\right)\right)^2}\Big/d_{\max}, \tag{4}$$

where $RP_i(.)$ is the reference point of the relation in the ith dimension, and d_{max} is the distance between the point defined by the lower endpoints of the input ranges and the point defined by the upper endpoints of the input ranges.

The dissimilarity of the relation $\widetilde{O}$ describing the observation to the relation $\widetilde{R}$ describing a rule antecedent will be

$$D\left(\widetilde{O},\widetilde{R}\right)=1-SFSV\left(\widetilde{O},\widetilde{R}\right)\cdot 0.5-\left(1-d_{rel}\left(\widetilde{O},\widetilde{R}\right)\right)\cdot 0.5\cdot \tag{5}$$

2.2. Fuzzy Rule Interpolation based on Subsethood Values and Rule Weights

The key idea of the Fuzzy Rule Interpolation based on Subsethood Values and Rule Weights (FRISUVW) is that one calculates the reference point of the conclusion from the position of the known rules' conclusion sets using the previously defined dissimilarity as well as taking into consideration the weights associated to the individual rules. The functional relationship is an extension of the well-known Shepard crisp interpolation [15]

$$RP\left(B^*\right)=\begin{cases}\dfrac{\sum_{j=1}^{N_R}D\left(\widetilde{O},\widetilde{R}\right)^{-1}\cdot RP\left(B_j\right)\cdot w_j}{\sum_{j=1}^{N_R}D\left(\widetilde{O},\widetilde{R}\right)^{-1}\cdot w_j} & if\ D\left(\widetilde{O},\widetilde{R}\right)>0\\[2ex] RP\left(B_j\right) & otherwise,\end{cases} \tag{6}$$

where B_j is the consequent fuzzy set of the jth rule, and w_j is the weight associated to the jth rule. Having the position of the conclusion determined its shape is simply copied from the characteristic shape type of the consequent partition.

3. Conclusions

The presented fuzzy rule interpolation method ensures low computational complexity and easy implementability. However, there is a constraint in its application. It can be used only in cases when all the existent sets of the consequent partition share the same shape and they differ only in their position. The application of rule weights introduces an extra optimization possibility. This feature makes possible that in some cases a fuzzy system with good performance can be achieved only by changing the sets included into the consequent part of the rules and tuning the values of the rules. Further research will cover application possibilities in fields of autonomous mobile systems [2], different fuzzy controllers [13], decision making systems [12][16], etc.

References

[1] P. Baranyi, L. T. Kóczy, and T. D. Gedeon, "A Generalized Concept for Fuzzy Rule Interpolation," in IEEE Transaction on Fuzzy Systems, ISSN 1063-6706, Vol. 12, No. 6, 2004, pp 820-837.

[2] M. Bošnak, D. Matko and S. Blažič (2012): Quadrocopter control using an on-board video system with off-board processing, Robotics and Autonomous Systems, vol. 60, no. 4, pp. 657-667, Apr. 2012.

[3] B. Bouchon-Meunier, C. Marsala, and M. Rifqi, "Interpolative reasoning based on graduality," in Proceedings of the FUZZ-IEEE'2000, San Antonio, USA, 2000, pp. 483-487.

[4] Z. H. Huang, and Q. Shen, "Fuzzy interpolation with generalized representative values," in Proceedings of the UK Workshop on Computational Intelligence, 2004, pp. 161-171.

[5] Z. C. Johanyák and S. Kovács, "Fuzzy Rule Interpolation by the Least Squares Method," in Proceedings of the 7th International Symposium of Hungarian Researchers on Computational Intelligence (HUCI 2006), Budapest, Hungary, 2006, pp. 495-506.

[6] Z. C. Johanyák: Fuzzy Rule Interpolation based on Subsethood Values, in Proceedings of 2010 IEEE Interenational Conference on Systems Man, and Cybernetics (SMC 2010), 10-13 October 2010, ISBN 978-1-424-6587-3, pp. 2387-2393.

[7] L. T. Kóczy and K. Hirota, "Approximate reasoning by linear rule interpolation and general approximation," in International Journal of Approximative Reasoning, Vol. 9, 1993, pp. 197–225.

[8] L. T. Kóczy, K. Hirota, and T. D. Gedeon, "Fuzzy rule interpolation by the conservation of relative fuzziness," in Journal of Advanced Computational Intelligence, Vol. 4/1, 2000, pp. 95-101.

[9] L. Kovács, "Rule approximation in metric spaces," Proceedings of 8th IEEE International Symposium on Applied Machine Intelligence and Informatics SAMI 2010, Herl'any, Slovakia, pp. 49-52.

[10] S. Kovács, "Extending the Fuzzy Rule Interpolation "FIVE" by Fuzzy Observation," Advances in Soft Computing, Computational Intelligence, Theory and Applications, Bernd Reusch (Ed.), S pringer Germany, 2006, pp. 485-497.

[11] Z. Krizsán, S. Kovács, "Double Fuzzy Dot Extension of the FRIPOC Fuzzy Rule Interpolation Method," 4th IEEE International Symposium on Logistics and Industrial Informatics (LINDI 2012), September 5-7, 2012, pp. 191-196.

[12] T. Portik, L. Pokorádi, "Fuzzy rule based risk assessment with summarized defuzzyfication," in Proceedings of the XIIIth Conference on Mathematics and its Applications, 2013, pp. 277–282.

[13] R.-E. Precup, M. L. Tomescu and S. Preitl (2007): Lorenz system stabilization using fuzzy controllers, International Journal of Computers, Communications & Control, vol. II, no. 3, pp. 279-287, Oct. 2007.

[14] K. A. Rasmani, Q. Shen, "Data-driven fuzzy rule generation and its application for student academic performance evaluation," in Appl. Intell., 25, 2006, pp. 305-319.

[15] D. Shepard, "A two dimensional interpolation function for irregularly spaced data," Proc. Of the 23rd ACM International Conf., 1968, pp. 517–524.

[16] Ján Vaščák, Kaoru Hirota: Integrated Decision-Making System for Robot Soccer (2011), In: Journal of Advanced Computational Intelligence and Intelligent Informatics, Vol. 15, No. 2, pp. 156-163, ISSN 1343-0130.