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A Type-2 Fuzzy Logic for Measurement of Meta-Management Success in Virtual Organisation

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Abstract

In Small and Medium Industries (SMI), in pursuit competitive advantages, one of the collaboration type commonly applied is temporary collaboration. The industries that are involved in a collaboration would arrange a contract so that such industries could work with common objectives. By the support of Information Technology (IT), temporary collaboration mostly was managed virtually and the involved industries form a Virtual Organisation (VO). In VO, the management called as meta-management, which provides a systematic approach to the exploitation of competitive economic advantages for the VO. It consists of basic activities including analysing and tracking requirements, allocating satisfiers to requirements, and adjusting the optimality criteria. In term of management improvement, there is lack mostly on success measurement that actually could be the basis of further improvement. This paper presents the use of Type-2 Fuzzy Logic (T2FL) for measurement of meta-management success. The success is measured based on aspects that have been mentioned above, and a T2FL is proposed to cope with uncertainties in every aspect. A numerical examples was solved to show how the proposed method works.

Keywords : *Type-2 fuzzy logic, meta-management, success measurement, virtual organisation, uncertainty*

1 INTRODUCTION

Competitive market encourages industries to collaborate each other to pursuit competitive advantages. For Small and Medium Industries (SMI), besides collaboration, another important issue is flexibility . When the market demand is keep on changing, hence, one of the effort to be flexible is having temporary collaboration with other industries. The temporary collaboration enables an industry to have chance to collaborates with other companies dynamically. A contract would be arranged among involved industries in a collaboration so that such industries could work with common reference.

In a dynamic collaboration, information and knowledge would flow among involved industries fast. Hence, Information Technology (IT) support plays an important role in the

collaboration. When the involved industries use IT support to manage the collaboration, hence, a Virtual Organisation (VO) would be formed. Management system in a VO is called as meta-management, and, similar with conventional management, meta-management is also need to be analysed for further improvement. The analysis must be started from performance measurement of the meta-management, hence, a system to evaluate success score of the application of meta-management is urgently required.

Analysis about management would involves activity-based measurements. It could not be measured directly using some measurement tools. Hence, experts opinion would plays major role in analysing the data. In uncertainty condition, expert opinions would mix with uncertainty and vagueness. In engineering field, Fuzzy Logic (FL) is one of the established technique that could be used to model uncertainty and vagueness. FL was introduced by Zadeh in 1965 (Zadeh, 1965) and has been successfully applied in so many fields, such as engineering, operational science, management and so on. Parallel with the increase of problem complexity, FL also received positive critics from researchers. The conventional FL, called as Type-1 Fuzzy Logic (T1FL), models the uncertainty and vagueness of the input variables with fuzzy sets. However, the fuzzy sets in T1FL is still fix, there is no interval in the fuzzy curves so that sometime the fuzzy curves do not represent experts opinion. Some researchers proposed T2FL to accomplish T1FL in accommodating uncertainty and vagueness by applying interval fuzzy sets to fuzzify the input variables. This study tries to elaborate the used of T2FL to measure success score of meta-management in a VO.

2 RELATED WORKS

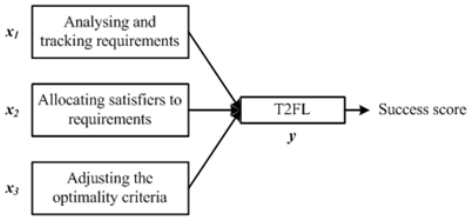

Figure 1: Model for success meta-management measurement

Several studies on VO and meta-management has been conducted by previous researchers. However, in our knowledge, there is still no study about success measurement for the meta-management in VO. In term of management improvement, such measurement could be the basis of evaluation. Following sections discover several previous studies on development of VO and meta-management.

Khalil and Wang (2002) elaborated that Information Technology (IT) plays major roles in VO. In electronic commerce era, virtualisation will make companies to have cross-boundaries organisation, automatic work flow and lower transaction cost and marketing. Such advantages raises the complexity in VO and IT could be one of the tool to manage the complexity. Basic activities of meta-management have also elaborated and the role of IT in supporting them. Such basis activities would be the basis of the inputs to evaluate success of meta-management in this study.

Manring and Moore (2006) investigated a model for managing a virtual inter-organisational learning network for greener production. The dimensions used for green company evaluation are ecological, economic and social and the stakeholders are textile production chain, their local and provincial communities, regulators and policy makers. Such study shows that the proposed model could be used as learning tool for MBA students in learning green company management. Indirectly, such study also shows that success of green company could be achieved from team learning through virtual organisation.

In microscopic level of meta-management, Lin et al. (2010) established a model by drawing from key postulates and findings under coopetition to explain the formation of perceived job effectiveness in team collaboration. The goal is to evaluate perceived job that influenced directly by knowledge sharing, cooperative attitude, and competitive conflict, while knowledge sharing is influenced by cooperative attitude and competitive conflict. Perceived job effectiveness is also influenced indirectly by shared value, perceived trust and perceived benefit via the mediation of cooperative attitude and competitive conflict. The study also elaborates managerial impact from the result.

Management evaluation, usually conducted based on interview and or questionnaires distribution and the result is subject to the respondent's perceptions . Hence, the result could mixed with uncertainty and vagueness. Those factors are very hard to be incorporated in exact analysis method, such as mathematical model or algorithm. One of the formal method that could be used to represent uncertainty and vagueness is Fuzzy Logic (FL). In the Type-1 FL (T1FL), uncertainty and vagueness is represented by a Fuzzy set instead of Crisp value. The Fuzzy set has tolerance to accommodate the uncertainty and vagueness. However, there are several positive critics for T1FL when representing the uncertainty and vagueness. Curve line in T1FL represents single value of membership and it is not deal with uncertainty and vagueness. Hence, T2FL has received major attention from researchers to be used to represent uncertainty and vagueness.

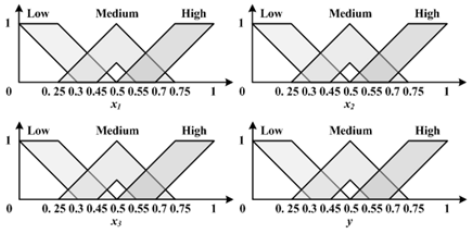

Figure 2: Fuzzy set for every input and output variable

Mendoza et al. (2009) investigated the application of T2FL which combined with modular Artificial Neural Network (ANN) for pattern recognition case, that is face recognition. There are 2 T2FL applied, the first T2FL was used for feature extraction in the training data while the second T2FL was used to predict the relevance of the modular ANN as the recognition module. Such study shows that FLT2 could increase the performance of modular ANN by facilitating the representation of human expert perceptions. Miller and John (2010) investigated the application of T2FL for multi echelons supply chain modelling. The FLT was used to model several parameters in the supply chain such as forecast demand, inventory level, transportation distances, transportation cost, stock out level, stock out cost, carry over and

Table 1: Fuzzy rules

R	Fuzzy rule	R	Fuzzy rule
1	x1: Low AND x2: Low AND x3: Low y: Low	15	x1: Med AND x2: Med AND x3: Hi y: Med
2	x1: Low AND x2: Low AND x3: Med y: Low	16	x1: Med AND x2: Hi AND x3: Low y: Med
3	x1: Low AND x2: Low AND x3: Hi y: Low	17	x1: Med AND x2: Hi AND x3: Med y: Med
4	x1: Low AND x2: Med AND x3: Low y: Low	18	x1: Med AND x2: Hi AND x3: Hi y: Hi
5	x1: Low AND x2: Med AND x3: Med y: Med	19	x1: Hi AND x2: Low AND x3: Low y: Low
6	x1: Low AND x2: Med AND x3: Hi y: Med	20	x1: Hi AND x2: Low AND x3: Med y: Med
7	x1: Low AND x2: Hi AND x3: Low y: Med	21	x1: Hi AND x2: Low AND x3: Hi y: Hi
8	x1: Low AND x2: Hi AND x3: Med y: Med	22	x1: Hi AND x2: Med AND x3: Low y: Med
9	x1: Low AND x2: Hi AND x3: High y: Hi	23	x1: Hi AND x2: Med AND x3: Med y: Med
10	x1: Med AND x2: Low AND x3: Low y: Low	24	x1: Hi AND x2: Med AND x3: Hi y: Med
11	x1: Med AND x2: Low AND x3: Med y: Low	25	x1: Hi AND x2: Hi AND x3: Lo y: Med
12	x1: Med AND x2: Low AND x3: Hi y: Med	26	x1: Hi AND x2: Hi AND x3: Med y: Hi
13	x1: Med AND x2: Med AND x3: Low y: Low	27	x1: Hi AND x2: Hi AND x3: Hi y: Hi
14	x1: Med AND x2: Med AND x3: Med y: Med		

holding cost. For decision variables optimisation, a Genetic Algorithm (GA) has been used. Such study shows that T2FL has better performance in representing uncertainties compared to T1FL.

Fazel Zarandi et al. (2012) applied T2FL for prediction case, that is carbon monoxide concentration forecasting. In such study, footprint of uncertainties of Fuzzy sets are extracted by implementation of an interval type-2 Fuzzy C-Means (FCM) algorithm and based on an upper and lower value for the level of fuzziness m in FCM. The study shows that T2FL has superior performance in comparison with T1FL.

Based on the literatures survey above, it could be understood that T2FL has potentiality to be used for measurement of a meta-management success. The following sections would elaborate in detail the application of T2FL in modelling meta-management success measurement.

3 RESEARCH METHODOLOGY

In order to explain the modelling of meta-management success in a VO, a numerical example is given as in the following section. The diagram of meta-management success measurement is shown in Figure 1.

This study is using Mamdani style FL and the first step is fuzzification, Such step is carried out by providing fuzzy sets for every input and output variable. In order to get uniform scale for every variable, then normalised data is used to develop the fuzzy sets. Figure 2 shows the fuzzy set for every input and output variable. In T2FL, every fuzzy curve has an interval to cope with uncertainty and vagueness. That's why T2FL has superior performance in accommodating uncertainty and vagueness compared to T1FL. The fuzzy rules are shown in Table 1. All of fuzzy sets and rules are defined by expert.

For further analysis, an input vector is required. Let say, an input vector of $\{0.7, 0.75, 0.8\}$ is obtained from questionnaires data processing, then following analysed could be carried out. It is different from T1FL, in T2FL, since there is an interval in every fuzzy curve, when evaluating an input vector using Fuzzy rules, there will be two membership value, called lower $\underline{(f)}$ and upper membership value $\overline{(f)}$. In this study, y (output) is assumed at the middle point of the fuzzy set. For instance, R1, y is low, it means that the lower and upper membership

Table 2: Firing of every fuzzy rule (non-zero result only)

Rule	Firing interval	Consequent
R18	[0, 0.2]	[0.5, 1]
R27	[0, 0.8]	[0.5, 1]

value is find based on y = 0.125. Hence, $\underline{y^1}$= 0.5833 and $\overline{y^1}$ = 1. Membership value for every input value in every fuzzy set is shown as follows while Table 2 shows firing of every fuzzy rule.

$$\left[\mu\underline{x_{11}}(0.7), \mu\overline{x_{11}}(0.7)\right] = [0, 0]$$
$$\left[\mu\underline{x_{12}}(0.7), \mu\overline{x_{12}}(0.7)\right] = [0, 0.2]$$
$$\left[\mu\underline{x_{13}}(0.7), \mu\overline{x_{13}}(0.7)\right] = [0, 0.8]$$
$$\left[\mu\underline{x_{21}}(0.75), \mu\overline{x_{21}}(0.75)\right] = [0, 0]$$
$$\left[\mu\underline{x_{22}}(0.75), \mu\overline{x_{22}}(0.75)\right] = [0, 0]$$
$$\left[\mu\underline{x_{23}}(0.75), \mu\overline{x_{23}}(0.75)\right] = [0.2, 01]$$
$$\left[\mu\underline{x_{31}}(0.8), \mu\overline{x_{31}}(0.8)\right] = [0, 0]$$
$$\left[\mu\underline{x_{32}}(0.8), \mu\overline{x_{32}}(0.8)\right] = [0, 0]$$
$$\left[\mu\underline{x_{33}}(0.8), \mu\overline{x_{33}}(0.8)\right] = [0.4, 1]$$

Since there are still 2 values in firing of every rule, then the next step is defining switching point from upper to lower firing (L) and from lower to upper firing (R). In this study, Karnik-Mendel (KM) algorithm was applied to define the switching points. See Mendel (2001) for detail explanation of KM algorithm. Based on the KM algorithm, it is found that L = R = 18, and following defuzzification could be conducted.

$$y_l = \frac{((0.2x0.5) + (0x0.5))}{0.2 + 0} = 0.5$$

$$y_r = \frac{((0x1) + (0.8x0.1))}{0 + 0.8} = 1$$

$$y = \frac{0.5 + 1}{2} = 0.75$$

Hence, the success score for the investigated meta-management in a VO is 0.75.

4 DISCUSSIONS

In T2FL, the use of interval fuzzy sets makes the T2FL more acceptable by the experts. However, analysis in T2FL will be more complicated compared to T1FL since there will be two membership value for every input variable. Output domain resulted by inference system in T2FL will be an interval. Therefore, a technique to reduce the fuzzy type, which is from type 2 to be type 1, is required. So far, there is no formal method for reducing the fuzzy type, and in this study, KM algorithm is applied for that objective. Based on the numerical

example above, it is proven that the KM algorithm can be considered as one of the method to reduce the fuzzy type.

FL with Mamdani style uses experts opinion for modelling. Output validation will be carried out subjectively by the experts. Scientifically, there is no reference point to verify the result and so far there is no formal method to verify the result. However, result verification could be conducted based on the acceptance of the solution. In the numerical example above, value of every input variable is slightly high, even though the value is not the maximum value. Logically, the success score of the meta-management in the investigated VO must be relatively high as well. The proposed T2FL produces 0.75 as the success score and it is reasonable. Hence, it could be justified fairly that the result is valid.

5 CONCLUSION AND SUGGESTION

Based on the explanation above, it could be concluded that T2FL could be used to model uncertainty and vagueness in measurement of meta-management success in a VO. Interval in the fuzzy set could be used to accommodate the uncertainty and vagueness that is mixed in the input and output variables. The proposed T2FL also able to produce reasonable result.

Suggestions for further study is, it is recommended to hybrid an optimisation algorithm such as Genetic Algorithm (GA) with the T2FL. The hybridisation could be used to optimise parameter value in the fuzzy sets and to optimise the fuzzy rules when the T2FL being used to model supervised system.

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