International Journal of Innovation and Applied Studies
ISSN 2028-9324 Vol. 15 No. 4 May 2016, pp. 737-742
© 2016 Innovative Space of Scientific Research Journals
http://www.ijias.issr-journals.org/

Fuzzy cognitive maps and computing with words for modeling project portfolio risks interdependencies

Miriam Peña Gónzalez[1], Cesar Gabriel Barrionuevo De La Rosa[2], and Francisco José Cedeño Moran[2]

[1]Facultad de Ciencias Matemáticas y Físicas,
Universidad de Guayaquil,
Guayaquil, Guayas, Ecuador

[2]Facultad de Ciencias Administrativas
Universidad de Guayaquil,
Guayaquil, Guayas, Ecuador

ABSTRACT: Project interdependency modeling and analysis have has been ignored in project portfolio management. There are five types of project portfolio interdependencies: benefit, risk, outcome, schedule and resources. In the case of risks interdependencies a positive or negative correlation of risks occurs provoking risk diversification or amplification effects. In this work project portfolio risk interdependencies are modeled using the computing with word (CWW) paradigm. We propose a new method for modeling project portfolio interdependencies, and specially risks interdependencies, using the 2-tuples linguistic model and fuzzy cognitive maps. This proposal has many advantages for dealing with linguistic information making simpler the elicitation of knowledge from experts. Building a 2-tuple fuzzy cognitive map follows an approach more similar to human reasoning and the human decision making process. An illustrative example showed the applicability of the proposal. The paper ends with recommendation of future works that will concentrate on three objectives.

KEYWORDS: fuzzy cognitive maps, computing with words, project portfolio interdependencies, risks interdependencies.

1 INTRODUCTION

A portfolio of project is a group of project that share resources creating relation among them of complementarities, incompatibility or synergy. Interdependency modeling and analysis have commonly been ignored in project portfolio management [1]. In an international survey only 38.6 % of responders understand this element[1]. Cost increasing, the lack of benefits exploitation[2] and the incorrect selection of projects [3] are among the negative consequences.

There are five types of project portfolio interdependencies: benefit, risk, outcome, schedule and resources [4]. In the case of risks interdependencies a positive or negative correlation of risks might happen provoking risk diversification or amplification effects. In this work project portfolio risk interdependencies are modeled using computing with word (CWW).

The development and evolution of individual and collective mental models is important for continuous learning in organizations [5]. Mental models are used in multicriteria decision support, knowledge management [6], learning and assessment of complex systems knowledge among other areas[7].

Cognitive maps as proposed by Axelrod [8], have been used as a visual representation of mental models [9]. Nodes represent concept or variables in a given domain. Arcs indicate positive or negative causal connections among nodes. Cognitive mapping lacks representation of uncertainty in causal relation, an important and usual factor in complex systems modeling [10].

Fuzzy cognitive maps (FCM)[11] extends cognitive maps with fuzzy values in [-1,1] or linguistic values to indicate the strength of causal relations, frequently elicited from experts[12, 13]. Fuzzy logic allows to express the degree of causality between concepts through the use of fuzzy values in the range [-1,1], using linguistic expressions as " strong", "negatively weak" " positively weak", etc. In these cases, linguistic information models in a flexibly way the knowledge and involves processes of computing with words (CWW) (5).

This paper is structured as follows: Section 2 reviews some important concepts about linguistic representation model based in 2-tuples. Section 3 provides a revision about FCM. In Section 4, we present a model for modeling interdependencies in project portfolio risks. Section 5 shows an illustrative example. The paper ends with conclusions and further work recommendations in Section 6.

2 LINGUISTIC REPRESENTATION MODEL BASED IN 2-TUPLES

The linguistic representation model based in 2-tuples defines a set of transformation functions for linguistic 2-tuple in order to carry out the CWW process without loss of information [14]. This model has many advantages for dealing with linguistic information making easier the elicitation of preferences and knowledge from experts [15] .

Definition 1.[16] Being $\beta \in [0, g]$ a value that represents the result of a symbolic operation in the interval of granularity of the linguistic term terms set $S = \{s_0, \dots, s_g\}$. The symbolic translation is a numerical value assessed in [-0.5, 0.5) that supports the difference of information between a counting of information β assessed in the interval of granularity [0,g] of the term set S and the closest value in {0, . . . , g} which indicates the index of the closest linguistic term in S.

The 2-tuple linguistic representation model defines a set of transformation functions between numeric values to facilitate linguistic computational processes.

Definition 2.[16] The 2-tuple that expresses the equivalent information to β is obtained with the function $\Delta: [0, g] \rightarrow S \times [-0.5, 0.5)$ given by.

$$\Delta(\beta) = (s_i, \propto), \text{with} \begin{cases} s_i, i = \text{round}(\beta) \\ \propto = \beta - i, \end{cases} \quad (1)$$

Where round is the usual rounding operation, $s_i$has the closest index label to s_i and $\propto$ is the value of the symbolic translation.

We note that Δ function is bijective [16] and $\Delta^{-1}: [0, g] \rightarrow S \times [-0.5, 0.5)$ is defined by:

$$\Delta^{-1}(s_i, \propto) = i + \propto \quad (2)$$

Then the 2-tuples of S × [− 0.5, 0.5) will be identified with numerical values in the interval [0, g].

3 FUZZY COGNITIVE MAPS

A fuzzy cognitive maps (FCM) [11] are fuzzy graph structures for representing causal knowledge. FCM have been applied to many diverse areas specially decision support and complex systems analysis [17]. Also multiples extensions have been developed such as fuzzy grey cognitive maps [18], interval fuzzy cognitive maps [19], Intuitionistic fuzzy cognitive maps [20] and recently a linguistic 2-tuple fuzzy cognitive maps[21].

The value of a concept is calculated at each simulation step, computing the influence of the interconnected concepts to the specific concept according to the following rule:

$$A_i^{(K+1)} = f\left(A_i^{(K)} + \sum_{j=1, j\neq i}^{n} A_i^{(K)} \cdot W_{ji}\right) \quad (3)$$

Where $A_i^{(K+1)}$ is the state of the node i at the instant K+1 , W_{ji} is the weight of the influence of j node over the i node, and f (x) is the activation function. The calculation halts if an equilibrium state is reached.

A model for decision making based on fuzzy cognitive maps using the paradigm of computing with words in order to provide causal models that are easily understood is proposed in [21]. To this end, the authors propose the use of linguistic representation model based on linguistic 2-tuple. The main advantage of the proposed decision-making based on fuzzy cognitive map model is that allows increasing the interpretability of causal models. The matrix representation of FCM allows to made causal inferences. In 2-tuple fuzzy cognitive maps [22]

4 FRAMEWORK FOR MODELLING PROJECT PORTFOLIO INTERDEPENDENCIES

Our aim is develop framework for modeling project portfolio and its interrelation based CWW and FCM. The model consists of the following phases (graphically, Figure 1):

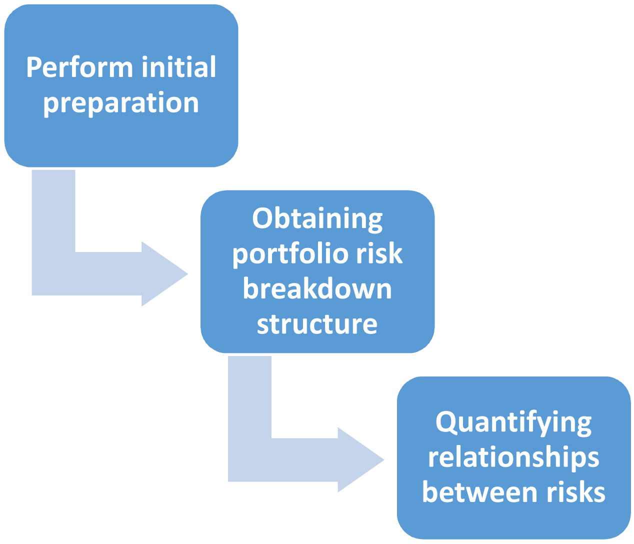

Fig. 1. A Framework project portfolio risk interdependencies

1. Perform initial preparation

First, the information sources to be included in the study are identified. An important parameter to be determined in this step is the "granularity of uncertainty given by the cardinality of the linguistic term set chosen [23], so that a source of information can express more easily the knowledge, it needs to have an appropriate set of linguistic descriptors. In order to facilitate the task, compliance with the following rules is recommended (24):

- The number of terms on the left and right of the middle term should be the same.
- The cardinality of a linguistic terms set should not be too small as to impose a precision restriction to the information that each source of information want to express and it should be large enough as to allow to make discrimination of the valuations by a limited number grades.

2. Obtaining portfolio risks

A portfolio risk breakdown structure with interdependencies is obtained. An example for a risk breakdown structure applicable to IT portfolios with interdependencies is shown in[4]. Each risk will be represented as a node in a FCM.

3. Quantifying relationships between risks

The weight from risk $\mathrm{R_i}$ to risk $\mathrm{R_j}$given is represented my means of the 2-tuple linguistic model as follows:

$$\mathrm{w_{ij}} = (\mathrm{s_u}\,,\alpha)_{ij} \tag{4}$$

In the proposed model, causality type (positive, negative, non-existence) can be identified as follows:

- $\mathrm{W_{ij}} < \mathrm{s_{g/2}}$, which indicates negative causality between nodes $\mathrm{C_i}$ and $\mathrm{C_j}$. The increase (decrease) in the value of $\mathrm{C_i}$ leads to the decrease (increase) in the value of $\mathrm{C_j}$.
- $\mathrm{W_{ij}} > \mathrm{s_{g/2}}$, which indicates positive causality between nodes $\mathrm{C_i}$ and $\mathrm{C_j}$. The increase (decrease) in the value of $\mathrm{C_i}$ leads to the increase (decrease) in the value of $\mathrm{C_j}$.
- $\mathrm{W_{ij}} = \mathrm{s_{g/2}}$, which indicates no relationship between nodes $\mathrm{C_i}$ and $\mathrm{C_j}$.

CASE STUDY

The application of the proposed procedure in a case study is shown, in this case with the participation of an expert. A set of linguistic terms with granularity 9 (Table 1) was defined. Table 1. Linguistic terms associated to causal relationships.

Table 1. Linguistic terms associated to causal relationships

Label	**Description**
S_0	Negatively very strong (NVS)
S_1	Negatively strong (NS)
S_2	Negatively medium (NM)
S_3	Negatively week (NW)
S_4	Zero (Z)
S_5	Positively weak (PW)
S_6	Positively medium (PM)
S_7	Positively strong (PS)
S_8	Positively very strong (PVS)

The five risks $\mathrm{R} = (\mathrm{r}_1, \dots, \mathrm{r}_5)$ identified are shown in Table 2.

Table 2. Portfolio risks

Node	Description
$\mathbf{R_1}$	Project 1 Technical feasibility
$\mathbf{R_2}$	Project 1 Timely completion
$\mathbf{R_3}$	Project 2 Timely completion
$\mathbf{R_4}$	Project 2 Code quality
$\mathbf{R_5}$	Project 3 Timely completion
$\mathbf{R_6}$	Project 3 Cultural acceptance

The expert provides the following linguistic causal relations:

$$W = \begin{matrix} s_4 & s_4 & s_7 & s_4 & s_4 & s_4 \\ s_4 & s_4 & s_5 & s_4 & s_4 & s_4 \\ s_4 & s_4 & s_4 & s_4 & s_4 & s_4 \\ s_4 & s_4 & s_4 & s_4 & s_4 & s_4 \\ s_4 & s_4 & s_5 & s_4 & s_4 & s_4 \\ s_4 & s_4 & s_5 & s_5 & s_4 & s_4 \end{matrix}$$

Once modeled the relationships among concepts from the opinion of the experts, the following FCM is obtained (Figure 2)

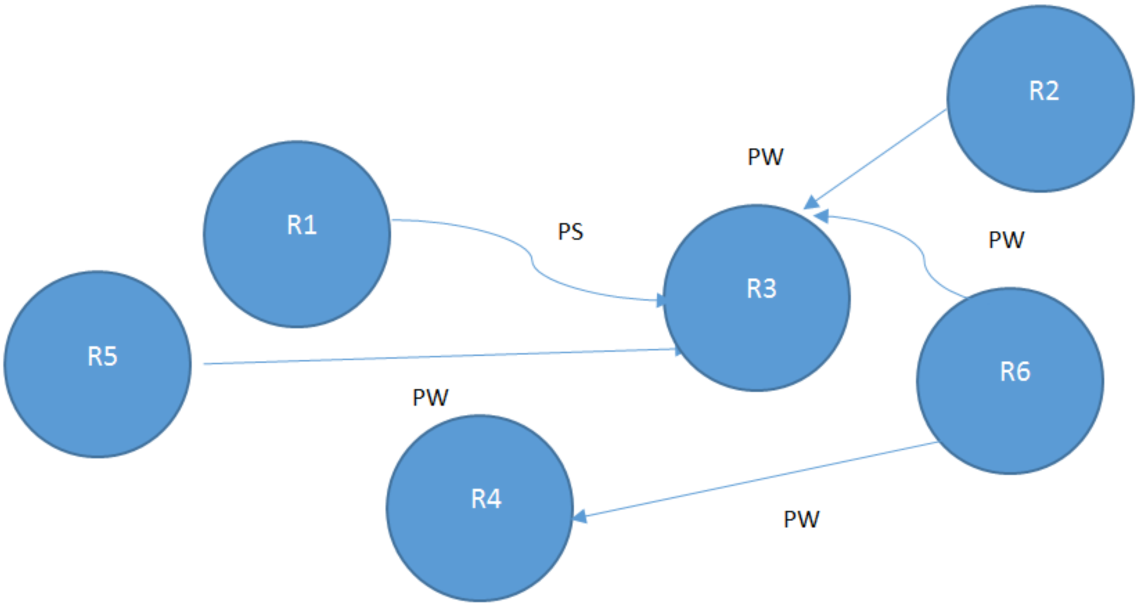

Fig. 2. 2-tuple fuzzy cognitive map with risks interdependencies.

In this example, the technical feasibility of project #1 (technical risk) could severely impact the timely completion of projects #2. Also, if no consistent tooling is used, and the agile development approach (project #3) is not culturally accepted, projects #2 are more likely to experience quality issues and time delay.

5 Conclusion

Interdependency among the many organizational components makes decision difficult. This paper proposes a new framework to model interdependencies in project portfolio. The linguistic 2-tuples representation model is used for representing relation among risks.

Building a 2-tuple fuzzy cognitive map follows an approach more similar to human reasoning and the human decision-making process. An illustrative example showed the applicability of the proposal.

Future research will focus on conducting further real life experiments to test and promote the proposed framework. Further works will concentrate on three objectives: developing a consensus model and developing an expert system based on 2-tuple fuzzy cognitive maps and extending the model to other areas of project portfolio interdependencies modeling. Other areas of future research are the combination with genetic algorithm when the search space is large, and the development of a tool to automate the process.

References

[1] M. Mors, R. Drost, and F. Harmsen, "Project Portfolio Management in Practice," ed: Springer, 2010, pp. 107-126.

[2] I. Sommerville and M. I. A. Galipienso, *Ingeniería del software*: Pearson Educación, 2005.

[3] D. Kundisch and C. Meier, "IT/IS Project Portfolio Selection in the Presence of Project Interactions–Review and Synthesis of the Literature," in *Wirtschaftinformatik Proceedings 2011*, 2011.

[4] M. Arlt, "Advancing the maturity of project portfolio management through methodology and metrics refinements," PHD, RMIT University, 2010.

[5] P. Senge, *La Quinta Disciplina En La Practica/Fifth Discipline In The Practice*: Ediciones Granica SA, 2005.

[6] G. Montibeller and V. Belton, "Causal maps and the evaluation of decision options—a review," *Journal of the Operational Research Society,* vol. 57, pp. 779-791, 2006.

[7] J. Ross, "Assessing Understanding of Complex Causal Networks Using an Interactive Game," Doctor of Philosophy in Information and Computer Science, University of California. Doctor of Philosophy in Information and Computer Science, Irvine, 2013.

[8] R. M. Axelrod, *Structure of decision: The cognitive maps of political elites*: Princeton University Press Princeton, NJ, 1976.

[9] S. P. Borgatti, C. Jones, and M. G. Everett, "Network measures of social capital," *Connections,* vol. 21, pp. 27-36, 1998.

[10] C. Puente Águeda, J. A. Olivas Varela, and A. Sobrino Cerdeiriña, "Estudio de las relaciones causales," *Anales de mecánica y electricidad,,* vol. 87, pp. 54-59, 2010.

[11] B. Kosko, "Fuzzy cognitive maps," *International Journal of Man-Machine Studies,* vol. 24, pp. 65-75, 1986.

[12] E. I. Papageorgiou and J. L. Salmeron., "A Review of Fuzzy Cognitive Maps research during the last decade," *IEEE Transactions on Fuzzy Systems.,* 2012.

[13] C. W. Ping, "A Methodology for Constructing Causal Knowledge Model from Fuzzy Cognitive Map to Bayesian Belief Network," PhD Thesis, Department of Computer Science, Chonnam National University. Doctoral Thesis, 2009.

[14] F. Herrera, S. Alonso, F. Chiclana, and E. Herrera-Viedma, "Computing with words in decision making: foundations, trends and prospects," *Fuzzy Optimization and Decision Making,* vol. 8, pp. 337-364, 2009.

[15] K. Pérez-Teruel, M. Leyva-Vázquez, and M. Espinilla-Estevez, "A linguistic software requirement prioritization model with heterogeneous information.," presented at the 4th International Workshop on Knowledge Discovery, Knowledge Management and Decision Support (EUREKA 2013),, Mazatlán, México, 2013.

[16] F. Herrera and L. Martínez, "A 2-tuple fuzzy linguistic representation model for computing with words," *Fuzzy Systems, IEEE Transactions on,* vol. 8, pp. 746-752, 2000.

[17] M. Y. Leyva Vázquez, K. Y. Pérez Teurel, A. Febles Estrada, and J. Gulín González, "Modelo para el análisis de escenarios basados en mapas cognitivos difusos: estudio de caso en software biomédico," *Ingenieria y Universidad,* vol. 17, pp. 375-390, 2013.

[18] J. L. Salmeron, "Modelling grey uncertainty with Fuzzy Grey Cognitive Maps," *Expert Systems with Applications,* vol. 37, pp. 7581-7588, 2010.

[19] E. Papageorgiou, C. Stylios, and P. Groumpos, "Introducing Interval Analysis in Fuzzy Cognitive Map Framework Advances in Artificial Intelligence." vol. 3955, G. Antoniou, G. Potamias, C. Spyropoulos, and D. Plexousakis, Eds., ed: Springer Berlin / Heidelberg, 2006, pp. 571-575.

[20] D. K. Iakovidis and E. Papageorgiou, "Intuitionistic Fuzzy Cognitive Maps for Medical Decision Making," *Information Technology in Biomedicine, IEEE Transactions on,* vol. 15, pp. 100-107, 2011.

[21] K. Pérez-Teruel, M. Leyva-Vázquez, M. Espinilla, and V. Estrada-Sentí, "Computación con palabras en la toma de decisiones mediante mapas cognitivos difusos," *Revista Cubana de Ciencias Informáticas,* vol. 8, pp. 19-34, 2014.

[22] K. P. Teruel, M. L. Vázquez, and M. E. Estévez, "Computación con palabras en la toma decisiones mediante mapas cognitivos difusos," *2014,* vol. 8, 2014.

[23] M. Espinilla, J. Liu, and L. Martínez, "An extended hierarchical linguistic model for decision making problems," *Computational Intelligence,* vol. 27, pp. 489-512, 2011.