# Fuzzy Cognitive Maps and Weighted Classic Fuzzy Applied on Student Satisfaction Level

Lucas Botoni de Souza
Ruan Victor Pelloso Duarte Barros
Patrick Prieto Soares
DAELE (Electric Department)
UTFPR-CP
Cornélio Procópio, Brazil
lucasbotoni@hotmail.com
ruan_pelloso@yahoo.com.br
p.prietosoares@hotmail.com

Jeferson Gonçalves Ferreira
UTFPR-CP
Cornélio Procópio, Brazil
goncalves_jeferson@outlook.com
Márcio Mendonça
DAELE (Eletric Department)
UTFPR-CP
Cornélio Procópio, Brazil
mendonca@utfpr.edu.br

***Abstract*—This research aims to develop a Fuzzy Cognitive Map (FCM) and Weighted Classic Fuzzy (WCF) for the satisfaction level of students at Federal Technological University of Parana, Campus Cornélio Procópio (UTFPR-CP). The FCM combines aspects of other intelligent techniques. This tool has inference capacity through concepts and causal relations among them (the influence level among the variables of the model). Its development begins with the determination of the possible areas that would affect or fit as indicators for satisfaction level in UTFPR-CP. Through online forms, it was possible to quantify the influence of the following initially detected areas: professor training, structures of laboratories and classrooms, habitation, library and cleaning. In general, educational institutions do not have tools to provide a critical analysis of its quality. This work proposes a tool for improving the institution in a few years. Thus, with the development of the FCM model, it was possible to identify the positive and negative points that affect the satisfaction level in UTFPR-CP. Finally, to validate the results a WCF was used with same structure and heuristic for comparison with FCM.**

***Keywords- Fuzzy Cognitive Maps; Quantitative Analysis; Level of Satisfaction; Operational Research; Weighted Classic Fuzzy.***

## I. INTRODUCTION

In Brazil, educational statistics show that only 9% of young between 18-24 years enrolled in higher education at the beginning of this decade. As motivation of this work, it is observed that in Brazil there is an evaluation policy, SINAES (in Portuguese, Sistema Nacional de Avaliação do Ensino Superior), National System for the Evaluation of Higher Education, which since 2004 allowed the participation of students in the evaluation of their university and graduation courses. It should be emphasized that the increasing number of opportunities itself does not guarantee the permanence of young people in higher education [1]. It is necessary to invest in the conditions that the student enters in the university, trying to understand their needs, difficulties and satisfaction.

Currently, the evaluation of higher education, especially in the engineering area, is an important part of the evaluation of the existing educational system, which plays a key role in strengthening the management of higher education [2]. In that way, one can observe the capacity of evaluation for educational standard. So, the purpose of education is to help students create a modern consciousness to improve the capacity for innovation and criticism by various means, such as university, business and government [3].

It is important to remember that despite the large expansion, many institutional managers do not give importance to students' opinions to identify their level of satisfaction. In the case of public institutions, one has the impression that this aspect does not deserve attention, because it is a service provision. It should also be remembered that public institutions are paid through public resources, which makes it obligatory for the citizen attended by them to be heard and helped in their needs.

Developing and testing methods and techniques that can assess reliability and results of student satisfaction levels is an indispensable task and a powerful tool for academic and financial management. Nevertheless, a statistical analysis cannot be done with the purpose of assessing higher scores of academic productions of researchers. Such data should be part of the management agenda of institutions that should listen to students, teachers and the community.

The preceding paragraphs define the purpose and justification of this work, which is corroborated with the construction of a computational intelligence tool that, based on qualitative information, can quantitatively diagnose and identify critical points. Moreover, Decision Support Systems can provide assistance during the process of decision making. FCMs have been used successfully to develop Decision Support Systems (DSS). The important advantage of FCMs is that they can handle even incomplete or conflicting information. This is essential, where experts should take many factors under consideration before they can reach a decision [4].

Among all computational intelligence techniques, Artificial Neural Networks exceeds by its ability to process

 ISBN: 978-1-61208-555-5 

massive data at the same time [5], or by acquiring knowledge from one or more experts using Fuzzy systems. About the Fuzzy Logic, it can be mentioned its ability to reason based on uncertain data through rules and membership functions [6].

In Fuzzy systems, Fuzzy Cognitive Maps can be highlighted by how it abstracts knowledge, mainly, when structured in graphs [7]. Cognitive maps are the origin of FCM, and they were first proposed by Axelrod [8] to represent words, ideas, tasks or different items connected and radially organized around a central concept. Graphs are diagrams representing connections among concepts from a certain theme. Those elements are intuitively arranged accordingly to its importance in a structured way.

In Franco and Montibeller's work [9], the goal is not to reach a consensus, but that the participants agree about the problem formulation. Throughout this process, the handler has the important duty of supporting the participants on exploring their thoughts on the problem and expressing their perspective.

As mentioned above, in a specific manner, this paper is focused on estimating the satisfaction level of the university student body, and, also on identifying critical points or factors that can be improved in order to achieve better results, in this paper the university [10].

This work is developed as follows: Section 2 discusses the fundamentals of computational intelligence systems and discusses Fuzzy systems applied in correlated areas. Section 3 presents background FCM. In Section 4 is presented and discussed the results. Section 5 concludes, addresses future works and finalize the paper.

## II. Fuzzy System Applicated on Education

Similar works can be found in literature, like the work proposed in [10], which presents a FCM practical use on modelling educational success critical factors for Control Engineering through case study at Istanbul Technical University (ITU). A survey is applied on eight academics and, through the results, eight FCMs are extracted and later aggregated in a resulting FCM. Concepts like academic and personal profile and teacher's excessive work load are used as input concepts, and the output concept is the Control Engineering program success.

One can also cite the work of Gao et al. [2], which uses a Fuzzy Logic method to improve the engineering courses tendencies, having great importance in an engineering professional education evaluation to reach a global dimension.

The work in [11] proposes the Fuzzy Analytical Hierarchy Process (FAHP) to evaluate a case study at Nanyang Institute of Technology, with the objective of offering theoretic and practical orientation for the development of innovative education. In this work, it's proposed an indices' table for the evaluation of teaching quality and innovation, which includes four dimensions: government, society, university and student. In each one of these dimensions are sub-concepts included and specified. For the government dimension: fund entry, management organization, politics and measurements; the university dimension includes: concept and planning, curriculum system, professors staff, cultural environment and base installation; the society dimension consist of: social reputation and environment, company groups; lastly, in the student dimension: research fulfillment and capacity, entrepreneurship and practical activities. The work shown in [12] uses a Fuzzy Neural Network-based model to estimate the contribution of different educational levels of human capital (abilities and expertise). Through Fuzzy Neural Network (FNN) mapping, four contribution levels of education in human capital are estimated in China's three regions, each one with different knowledge areas and technology levels. They are: illiteracy and primary, fundamental, graduation and postgraduate.

The work seen in [13] uses a FNN in students' emotion recognition, and it's applied in smart educational systems that use facial recognition systems for pre-programmed teaching strategy adjustment or adaptation in the proposed intelligent system. The emotion recognition technique uses three characteristics from the students' images: facial area, distance between eyelids, and mouth's corner.

At last, the work in [14] uses a FNN to map human capital levels in the university through two methods. According to the authors, the human capital concept in the university refers to workman knowledge and abilities, which is formed by the educational investment, professional formation, health and migration. More specifically, one can cite the Mendonça and collaborators work [15], which employs a Classic FCM to determinate the student´s satisfaction level in the university.

## III. Fuzzy Cognitive Maps, Background and Development

This section presents a FCM background and development diagnostic using FCM and classic Fuzzy.

### A. FCM Background

Since Kosko's pioneer work [15], which extended Axelrod's cognitive maps [8] for the inclusion of Fuzzy Logic, countless FCM applications are reported in literature in several areas of knowledge. There are applications in artificial life [16]-[17], social systems [18], modelling and decision making in corporate and e-commerce environments [19], image point detection in stereo camera systems [20] and decision making in medical area [21]. The works [22]-[23] apply FCM evolutions in autonomous mobile robotics and process control, respectively Event Driven – Fuzzy Cognitive Maps (ED-FCM) and Dynamic Cognitive Networks (DCN).

In [24] a formal adaptation of the FCM is presented: this new tool is designed as TAFCM (Timed Automata Fuzzy Cognitive Maps). In addition, [17] presents a DFCM (Dynamic Fuzzy Cognitive Maps), an FCM evolution. It is observed that these works also present semantic variations of the original proposal, adapting the FCM structure according to the treated problem.

This work manually develops the FCM, because the desired output is a diagnostic. Thus, causal relations cannot be adjusted by genetic algorithms, for example, because every causal relation has a semantic meaning. The values were defined by checking the student's opinion. In another way, as in robotics and control applications, the FCM controllers must achieve objectives, as in the specific case of valve actuation, used in the Mendonça's and collaborators works [22]-[23]. The cognitive maps technique is widely used in structuring complex problems in groups.

To model the problem and obtain qualitative results, it was decided to use the Classic FCM, which had its structure modeled by concept definitions and causal relations, in order to establish influence between them. Thus, specialists' knowledge was applied in the proposed FCM elaboration, which has as function to evaluate the student satisfaction level of the Cornélio Procópio campus of Federal Technical University of Paraná (UTFPR-CP).

In general, it can be defined that FCM combines Artificial Neural Network (ANN) aspects [5], Fuzzy Logic [6], Semantic Nets [25], among other computational intelligence techniques. In this context, it can be conceptualized that FCM is a knowledge-based causality methodology to model complex-decision systems [15]. A FCM describes an unknown system behavior in concept terms, which represents an entity, state, variable or system characteristic [26]. A Classic FCM example is a graph and a synaptic weights matrix, which can be found in [27].

The FCM concepts can be updated through iteration with the other concepts and their own value. This is given by matrix (3), with the causal relations weights, and is represented by the sum's weight. The concepts values evolve after several iterations, as shown in equation (1), until they stabilize at a fixed point or limit cycle [28].

$$A_i = f(\sum_{\substack{j=1 \\ j \neq i}}^{n} (A_j \times W_{ji}) + A_i^{previous} \quad (1)$$

Since **k** is the iteration counter, **n** is the number of graph nodes, $\mathbf{W_{ij}}$ are the weight of the arc which connects concept $\mathbf{C_j}$ to concept $\mathbf{C_i}$. $\mathbf{A_i^{previous}}$ are the concept value $\mathbf{C_i}$ in the actual iteration (previous), and **f** function (equation 2) is a sigmoid:

$$f(x) = \frac{1}{1 + e^{-\lambda x}} \quad (2)$$

In some cases, the FCM may not stabilize and oscillate, or even show chaotic behavior [27]. Generally, for well-behaved systems, it is observed that after a finite number of iterations, the concepts values reach an equilibrium point or a limit cycle. This can be observed in Fig. 4, in which after 4 iterations the previously modelled concept final values stay fixed. Recently, the FCM convergence is investigated by [38].

### B. *FCM Development*

This paper is models a classic FCM, similar to Kosko's, by identifying the relevant variables of the proposed problem, and the causal relations are obtained through a survey on electric engineering students.

The initial development phase is the identification and construction of the cognitive model using expertise knowledge and the causal relations obtained from student's opinion. Then, the FCM inference equations (2) and (3) are applied. The next phase consists of obtaining the quantitative values of the "satisfaction level of the student body" (main goal of this research), and the values of the other concepts. And finally, validating those results with the opinion of those interviewed. To simplify, all concepts started with score zero, for later evaluation of the FCM inference.

There are many aspects that may have an effect on the satisfaction level. In this paper, eight aspects were chosen and the causal relations among them were defined through a quiz. A sample of students gave a score from zero to ten for each of the concepts connection that could actuate on the satisfaction level of the students of UTFPR-CP (Federal University of Technology – Paraná, Cornélio Procópio Campus), mainly from the electric engineering and control and automation engineering.

Since the 1960s, many researches attempted to identify the students' satisfaction levels. It's important to mention that satisfaction itself is a concept of difficult analysis for being relative to each student perspective. The vast diversity of models, scales and methods to asses this concept proves that complexity. One of the most used methods is the *College Student Satisfaction Questionnaire* [29]. More researches made in Brazil on this topic can be seen in [30] and [31]. Altogether, this paper tries to capture how the students perceive the course and the education conditions propitiated by the institutions, that way being of major interest of manager and teachers.

According to the general statistic theory [32], in the literature an analysis was made with a sample of 30 students, from the data acquired, it was obtained a 90% of reliability and a margin of error of 6.8%, representing a group about 500 students [15]. Considering the Control and Automation Engineering course still has no graduates and have approximately 200 students, this same analysis can be applied, thus, 35 students are used in this research.

The results and structure does not intend to classify nor

 ISBN: 978-1-61208-555-5 

qualify the institution or course. However, because of its exploratory nature, this paper can be used to give a quantitative evaluation of the satisfaction level, work and/or study in the Campus. Another aspect of this approach is identifying possible improvement points on the variables of the cognitive model.

Fig. 3 shows the final model with the structure and its causal relation. It's noteworthy that the model applied is the same classic from [15] and so, does not consider time, in other words, all concepts take place simultaneously. In this context, there are improvements on FCM that deals with this "disadvantage", for example: E-FCM (*Extended*-FCM) on [33], RB-FCM (*Rule Based*-FCM) on [34] and DCN (*Dynamic Cognitive Networks*) on [35]. There is a recent review of the last 10 years about other improvement applications and training of FCMs. The concepts chosen for the FCM model are shown on table I:

TABLE I. FCM CONCEPTS RELATIONS

| | |
|---|---|
| **C1:** | Student Satisfaction Level |
| **C2:** | Professor's Capacitation/Performance |
| **C3:** | Pedagogic Structure - Library |
| **C4:** | Habitation |
| **C5:** | University Restaurant Quality |
| **C6:** | Cleaning - Accessibility |
| **C7:** | Leisure and Sports Activities |

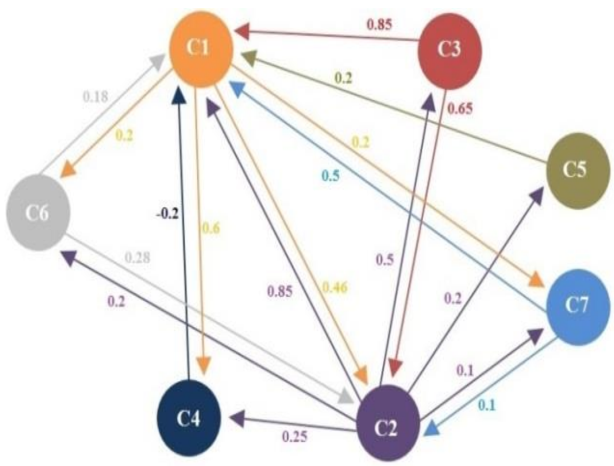


Figure 1. Student satisfaction level FCM

Fig. 1 shows all variable involved on obtaining the satisfaction level of the students. The equation (4) shows the cause and effect relation among the concepts. Thereby, according to the intensity of the causality among the concepts, the final values are changed, especially the C1 – output concept of the satisfaction level.

$$W = \begin{vmatrix} 0 & 0.46 & 0 & 0.6 & 0 & 0.20 & 0.20 \\ 0.85 & 0 & 0.5 & 0.25 & -0.20 & 0.20 & 0.1 \\ 0.85 & 0.65 & 0 & 0 & 0 & 0 & 0 \\ -0.20 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.20 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.18 & 0.28 & 0 & 0 & 0 & 0 & 0 \\ 0.50 & 0.10 & 0 & 0 & 0 & 0 & 0 \end{vmatrix} \quad (4)$$

In order to validate the FCM proposed and establish a possible comparison with the same heuristic, it was opted to use in this research a classic inference system through a Fuzzy system, but it's not in the scope of this paper to demonstrate its development details; more information of can be seen in [36].

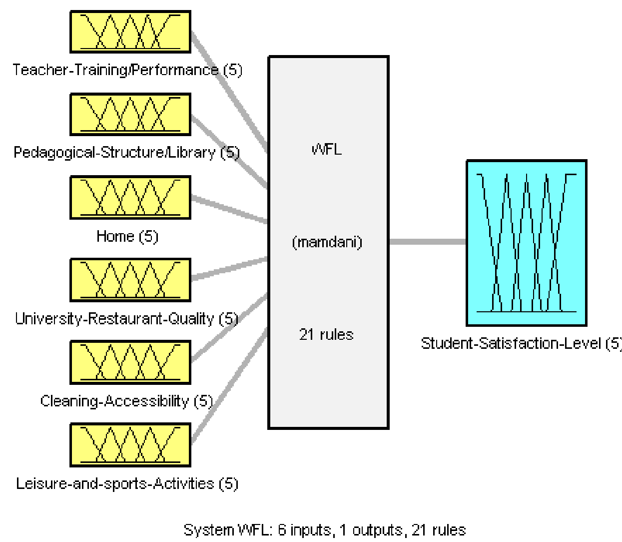


Figure 2. Fuzzy structure

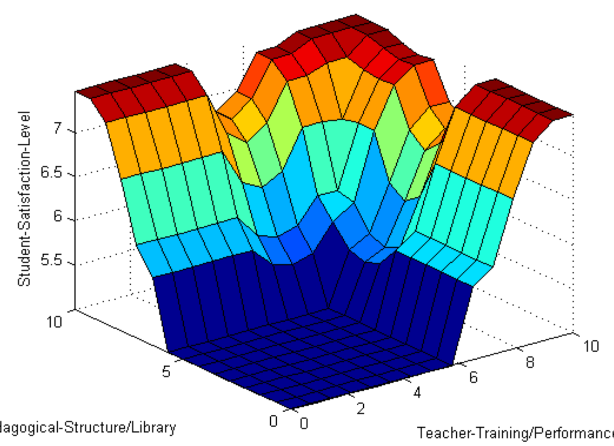


Figure 3. Fuzzy example surface

Fuzzy systems are universal approximators, with applications in many areas, as seen on [6] and [37]. It was opted to use a Weighted Classic Fuzzy with weights given to each rule in order to vary their influence on the Fuzzy inference, and a similar structure of FCM.

The Fuzzy inference method chose was Mandani's with 6 input and 1 output concept. Each variable had 5 membership functions, triangular and trapezoidal ones, and a total of 21 rules were used, for the simplicity of the developed Fuzzy system according to the FCM values. The Fig. 2 shows the structure and figure 3 shows an example of its surface.

## IV. RESULTS AND DISCUSSION

After modeling the concepts, especially the numerical values of the causal relations voted by the students, the model is calculated by equations (3) and (4) and it evolves to the final values, which are the objective of the work. It is observed that the initial values of the concepts were considered zero.

The Fig.4 shows the results and evolution of each of the concepts modeled in a scale from zero to ten, with emphasis on the output concept (level of satisfaction in UTFPR-CP).

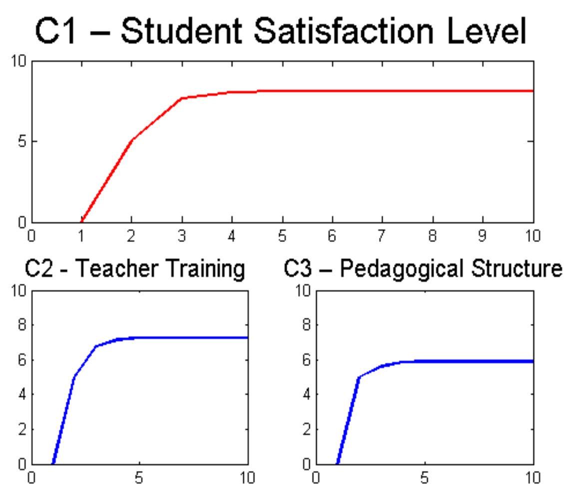


Figure 3. Results by Fuzzy Cognitive Maps

It is observed in this FCM that it stably evolved reaching a critical point (a short variation around the final result). It can also be observed that there were some critical points in the research and construction of the model, such as the parking conditions in places near the University, Quality of the university restaurant in relation to the small physical space for the demand of students causing delays in the classes after lunches and breaks, and others. This is due to its rapid growth in the last ten years and should be reviewed by its managers with government officials for future improvements. However, the final grade of this research was relatively good, close to eight, with possibilities for improvement with treatment of the critical points identified in this research.

Since this work addresses a situation of static or time invariant diagnosis, it does not make sense to present an evolution curve of the fuzzy system, only the output with the inputs based on the values of the weights of the FCM causal relations. Thus, the output of the WCF was approximately 79%. It is emphasized that the classic version of FCM has the drawback of not modeling dynamical systems, because the causal relations are constant [7].

The results are initial, therefore researches that take into account students' perceptions, identifying their satisfaction, are important tools that have the potential to diagnose problems and propose solutions ranging from structural aspects, such as the availability of current titles in the library, to pedagogical aspects. In this context, and according to the obtained results, it can be affirmed that the satisfaction level of UTFPR-CP students had a significant final mark of approval, among the items chosen using FCM and Classic Fuzzy.

## V. CONCLUSION AND FUTURE WORKS

The results obtained from both proposals were similar with approximately 80% of the level of student satisfaction. The result was satisfactory and expected due to the relation with the Brazilian Ministry of Education’s evaluation of UTFPR engineering courses that obtained four stars in a domain of discourse from zero to five. To corroborate the final result found, a sample of 45 students was consulted to assign a final grade to UTFPR and the result found was approximately 8.45 on a scale from zero to ten.

The techniques used the same logic or heuristic in their respective structures, and the objectives were reached by the results obtained from qualitative data of a research done with a sample of the university students. Future works addresses new checking in other UTFPR courses, apply in other universities or institutes. And finally, compare this approach with other intelligent techniques, such as ANFIS.

## REFERENCES

[1] Sistema Nacional de Avaliação da Educação Superior (Sinaes). http://bit.ly/2ml4ILG access date: 10/02/2017
[2] Gao Y., Yang, Jiwei and Liu F. The Research on the Comprehensive Assessment of Higher Engineering Education Based on Fuzzy Comprehensive Evaluation Method, in Future Information Technology and Management Engineering, 2009. FITME '09. Second International Conference on, pp.124-127, 13-14 Dec. 2009.
[3] Pingwen L.Management Analysis & Diagnose”,Fujian: Press of Xiamen University, pp. 310-335, 2004.
[4] E. Bourgani, G. Manis, C. D. Stylios and V. C. Georgopoulos, "Timed-Fuzzy Cognitive Maps: An overview," 2016 IEEE International Conference on Systems, Man, and Cybernetics (SMC), Budapest, 2016, pp. 004483-004488.
[5] Haykin, S. Neural Networks and Learning Machines (3rd Edition), McMaster University, Pearson Prentice Hall, 2008.
[6] Pedrycz, W. and Gomide. F. An Introduction to Fuzzy Sets: Analysis and Design, MIT Press, 1998.
[7] Kosko. B. Fuzzy Cognitive Maps. Int.J. Man-Machine Studies, vol. 24, pp. 65–75, 1986.
[8] Axelrod R., Structure of Decision: The Cognitive Maps of Political, Elites. Princeton, NJ: Princeton Univ. Press, 1976.
[9] Franco, L. A. and Montibeller, G. Facilitated modeling in operational research. European Journal of Operational Research, vol. 205, no. 3, pp. 489-500, 2010.
[10] Yesil, E.; Ozturk, C.; Dodurka, M.F.and Sahin, A., "Control engineering education critical success factors modeling via Fuzzy

Cognitive Maps," in Information Technology Based Higher Education and Training (ITHET), 2013 International Conference on, pp.1-8, 10-12 Oct. 2013

[11] Hezhan, Y. Application of Fuzzy Analytical Hierarchy Process in innovation education quality evaluation of higher education institution, in Information Management, Innovation Management and Industrial Engineering (ICIII), 2012 International Conference on, vol.1, pp.438-441, 20-21 Oct. 2012.

[12] Yu, S. and Zhu, K. Fuzzy Neural Network Applications on Estimating the Contribution of Different Education Levels on Human Capital of China, in Service Systems and Service Management, 2007 International Conference on, pp.1-4, 9-11 June 2007.

[13] Xiang, P. Research on the Emotion Recognition Based on the Fuzzy Neural Network in the Intelligence Education System, in Digital Manufacturing and Automation (ICDMA), 2011 Second International Conference on, pp.1030-1033, 5-7 Aug. 2011

[14] Yu, S. and Zhu, K. Fuzzy Neural Network Applications on Estimating the Contribution of Different Education Levels on Human Capital of China," in Service Systems and Service Management, 2007 International Conference on, pp.1-4, 9-11 June 2007.

[15] Mendonca, M.; Chrun, I. R.; Finocchio, M. A. F. and de Mello, E. E.; "Fuzzy Cognitive Maps Applied to Student Satisfaction Level in an University," in *IEEE Latin America Transactions*, vol. 13, no. 12, pp. 3922-3927, Dec. 2015

[16] Dickerson, J. A. and Kosko, B. Virtual worlds as Fuzzy dynamical systems. In: SHEU, B. (Ed.) Technology for multimedia, New York: IEEE Press, 1996

[17] L. V. Arruda; M. Mendonca; F. Neves-Jr; I. Chrun; E. PAPAGEORGIOU, "Artificial Life Environment Modeled by Dynamic Fuzzy Cognitive Maps," in *IEEE Transactions on Cognitive and Developmental Systems*, vol.PP, no.99, pp.1-

[18] Taber, R. Fuzzy cognitive maps model social systems. AI Expert, v. 9, p. 18-23, 1994.

[19] Lee, K. C. and Lee, S. A cognitive map simulation approach to adjusting the design factors of the electronic commerce web sites. Expert Systems with Applications, v. 24, n. 1, p. 1-11, jan. 2003.

[20] Pajares, G. and De La Cruz, J. M. Fuzzy cognitive maps for stereovision matching Pattern Recognition, vol. 39, no. 11, pp. 2101-2114, Nov. 2006.

[21] Papageorgiou, E.; Stylios, C. and Groumpos, P. Novel for supporting medical decision making of different data types based on Fuzzy Cognitive Map Framework. PROCEEDINGS OF THE 29TH Annual International Conference of the Ieee Embs Cité Internationale, Lyon, France August 23-26, 2007

[22] Mendonça, M.; Arruda, L.; Neves, F. Autonomous navigation system using event driven-fuzzy cognitive maps. Springer Science+Business Media. Outubro, 2011.

[23] Mendonça, M.; Angélico, B. A.; Arruda, L. V. R. and Neves, F. Jr. A Subsumption Architecture to Develop Dynamic Cognitive Network-Based Models with Autonomous Navigation Application. Journal of Control, Automation and Electrical Systems, vol. 1, pp. 3–14, 2013.

[24] Acampora, G.; and Loia, V. On the Temporal Granularity in Fuzzy Cognitive Maps. IEEE Transaction on Fuzzy Systems, vol. 19, no. 6, 2011.

[25] Russell S. J., and Norvig P., Artificial intelligence: a modern approach. Englewood Cliffs: Prentice Hall. 1995.

[26] Kosko, B. Neural networks and Fuzzy systems: a dynamical systems approach to machine intelligence. New York: Prentice Hall, 1992.

[27] Stylios, C. D.; Georgopoulos, V. C. and Groumpos, P. P. The use of Fuzzy cognitive maps in modeling systems. In: 5th IEEE Mediterranean Conference on Control and Systems, Paphos, Cyprus, 21-23 July 1997.

[28] Stylios, C. D. and Groumpos, P. P. The challenge of modeling supervisory systems using fuzzy cognitive maps. Journal of Intelligent Manufacturing, vol. 9, pp. 339-345, 1998.

[29] Betz, E. L.; Menne, J. W.; Starr, A. M. and Klingensmith, J. E. A. Dimensional Analysis of College Student Satisfaction. Measurement and Evaluation in Guidance, vol. 4, no. 2, pp. 99-106, 1971.

[30] Walter, S. A., Tontini, G. and Domingues M. Identificação de Oportunidades de Melhoria em IES Através do Uso Conjunto do Modelo Kano e Matriz de Importância x Desempenho. Available in: https://repositorio.ufsc.br/xmlui/bitstream/handle/123456789/97432/Silvana%20Anita%20Walter.pdf?sequence=3&isAllowed=y access date: 15/02/2017

[31] Schleich, A. L. R., Polydoro, S. A. and Santos, A. A. Scale of satisfaction with academic experience of students of higher education. Avaliação Psicológica, vol. 5, no. 1, pp. 11-20, (2006). Available in: <http://pepsic.bvsalud.org/scielo.php?script=sci_arttext&pid=S1677-04712006000100003&lng=pt&tlng=pt> access date: 23/02/2017

[32] Larsen, Richard J.; Marx, Morris L. Introduction to Mathematical Statistics and Its Applications. 5. ed. Florida: Pearson Higher Ed Usa, 2013. 744 p.

[33] Hagiwara, M. Extended Fuzzy cognitive maps. In: Proceedings of IEEE international conference on fuzzy system, New York, 1992. pp. 795–801.

[34] Carvalho, J. P. and Tomé, J. A. Rule based Fuzzy cognitive maps-qualitative systems dynamics. In: Proceedings 19th international conference of the North America. Fuzzy information fuzzy processing society, pp. 407–411, 2000.

[35] Miao, Y. C.; Miao, Y.; Tao, X.; Shen, Z. and Liu, Z. Transformation of cognitive maps. IEEE Transactions on Fuzzy Systems, vol. 18, no. 1, pp. 114–124, Feb. 2010.

[36] Zadeh, L. Fuzzy Sets - Information and Control, vol. 8, pp 338-353, 1965.

[37] Psssino, M. K.; Yourkovich, S. Fuzzy Control. Menlo Park: Addison-Wesley, 1997.

[38] Nápoles, G.; Papageorgiou, E.; Bello, R. and Vanhoof, K. “On the onvergence of sigmoid fuzzy cognitive maps,” Information Sciences, Elsevier, 2016.

 ISBN: 978-1-61208-555-5 