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Modelling complex systems with distributed agency and fuzzy inference systems. Knowledge-based curricula in higher education

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Abstract

Higher education has become a cornerstone in the arise of knowledge society conceptualization. This concept covers a new type of social configuration that puts knowledge as the main value in human interaction for future social and economic development and also as one of the main actions to improve in order to gain a better quality of life. In this paper we discuss the importance of this structure and its characteristics, then we focus in the need to generate a higher education curriculum that fits this emphasis in social development of a new knowledge-based society. Finally, we use complex systems simulation to analyze six agents including: 1) Students; 2) Teaching - Teachers; 3) Training plan - Teachers; 4) Scientific research, IT development, innovation and professional performance; 5) Management - Managers; and 6) Environment and relevance or External Agents and five variables for this study: 1) Teaching; 2) Extracurricular activities; 3) Research and development; 4) Management; and 5) Educational culture. The final goal is to propose a curriculum that includes a projection to create knowledge-based society from higher education as a main factor to achieve this objective

Keywords: complex systems, higher education, knowledge-based curricula, distributed agency, FIS

1 Introduction

In recent years, computational science has increased the amount of research in complex systems (CS). This scientific points of view try to achieve a correlation between the analysis and application of this computer science approach in conventional and multi factorial research questions. The aim of some techniques, such as fuzzy logic and neural networks points out to understand in a much more quantitative approach some specific social phenomena [1]. A CS is characterized by a highly connected network of entities from which emerges a higher order behavior. Research in the field of CS has become multidisciplinary and has focused on the use of computational modeling and simulation as a methodology for analyzing diverse social phenomena.

2 Knowledge based society as a complex system

Knowledge emerge from information as well as information emerge from data. There is a direct relationship between data, information and knowledge. If the information is transformed into knowledge, then the intervention of a person has occurred [4]. Actions of knowledge generation occur

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in humans [2]. The Information and Communication Technologies (ICT), even though its data processing capacity and information creation, can not create knowledge, this is possible only after the intervention of a human being [3], and it To this we can add the increases it complexity over time [4].

Knowledge societies have existed since man has been organized into groups [5] and have relevance in economic growth and quality of life [7]. Social, economic and cultural developments are now linked to technological progress [8], the presence of these technologies affects how quickly you can develop a society that is based on knowledge [9]. The concept of knowledge society is characterized by three attributes [7]: 1) Creative capacity; 2) Innovative talent; and 3) Ability to determine relevance. These can be generated by an educational system by extending the existing knowledge and innovative talent aimed at satisfying specific needs and developing systems of knowledge in universities[6] [10]. Much of the knowledge available, needs extensive training because it is tacit and can not be easily communicated, even for someone who knows it [7]

Knowledge gets involve in a society and therefore public policy are oriented to fulfilled several requirements defined by the United Nations [11]. Gender equality, democracy, pluralism, indigenous knowledge, freedom of speech and a number of sub-categories in which the knowledge society is divided are the main aspects that define it. The emergence of knowledge is based also in educational schemes that promote the new global reality [12] [1].

3 Complex higher education system. A case study

CS exhibit properties that emerge from the interaction of their parts and which cannot be predicted from the properties of the parts [13]. These systems consist of many diverse and autonomous but interrelated and interdependent components or parts linked through many (dense) interconnections, therefore, they cannot be described by a single rule and their characteristics are not reducible to one level of description. It's necessary to do a depth analysis of its properties and specific characteristics to try to reach an understanding of its behavior [12] [13] [14].

The purpose of modeling an educational program is that through this process the researcher is able to identify the elements that can be improved in order to increase the quality of the results expected of it. In this context, this paper aims to represent the outcome obtained through the analysis of the elements in a research applied in Autonomous University of Baja California in Tijuana Mexico. The agents and variables proposed and involved in this research, have the following agents and variables in this proposed modeling [15] [1] [18] [16] [17] :

Evaluation agents	Variables
Students	Teaching
Teaching [Teachers]	Teaching
Training plan [Teachers]	Teaching. Extracurricular activities
Scientific research, technological development, innovation and professional quality performance [Researchers]	Research and development
Management [Managers]	Management
Environment and relevance [External agents]	Educational culture

Table 1: Agents and variables involved in this research

4 Modelling higher education system with DA and FIS

The methodology of Distributed Agency (DA) represents a general theory of collective behavior and structure formation, which intends to redefine agency and reflect it in multiple layers of information and interaction, as opposed to the traditional approach in which agency is only reflected in individual, atomized and isolated agent [23] [25]. Social simulation aims to cross the gap between the descriptive approach used in the social sciences and the formal approach used in the hard sciences, by moving the focus on the processes/mechanisms/behaviors that build the social reality [19][27]. Following the relationship between agents and variables before and according to theory approach and expert techniques to define variables, this case was divided into the next codes and categories:

Variable	Code	Category
Teaching	DOC-ADCA	Sports, cultural and artistic activities
	DOC-C	Courses
	DOC-ATE	Management of educational technology
	DOC-PEA	Participation in academic events
Research and development	I+D-DI	Research Design
	I+D-EI	Research Execution
	I+D-AR	Resource Management
	I+D-TIC	Information and Communication Technologies
	I+D-IC	Context Interaction
Management	DA-PEE	Educational planning and execution
	DA-SAM	Selection and management of teachers
	DA-AMTE	Acquisition, maintenance and updating of educational technology
	DA-GR	Resource management
Educational Culture	CU-AV	Acquiring securities
	CU-TE	Teamwork
	CU-DOR	Teaching for Results
	CU-L	Leadership
	CU-MGEL	Multiculturalism, gender, ethnicity and language
Extracurricular activities	AE-SA	Student Society
	AE-IF	Tournaments between faculties
	AE-F	Celebrations, parties and fun events
	AE-OV	Travel organization

Table 2: Codes and categories by variable

The findings presented below are the result of qualitative instruments implementation:

Variable \ Agents	Students	Teachers	Researchers	Managers	External Agents
Teaching	DOC-ADCA DOC-C	DOC-C DOC-ATE DOC-PEA	DOC-C DOC-ATE	DOC-ADCA	DOC-ADCA DOC-PEA
Research and development		I+D-TIC I+D-EC	I+D-DI | I+D-EI I+D-AR | I+D-IC I+D-TIC		
Management		DA-GR	DA-GR	DA-PEE DA-SAM DA-AMTE | DA-GR	
Educational Cultures	CU-AV CU-TE CU-DOR|CU-L	CU-AV CD-TE CU-MGEL	CU-AV CU-TE CU-L	CU-AV CU-MGEL	CU-AV
Extracurricular Activities	AE-SA AE-IF AE-F | AE-OV	AE-F AE-OV	AE-F AE-OV	AE-F AE-OV	AE-F

Table 3: Relation between variables and agents

The modeling of a realistic social system cannot be achieved by resorting to only one particular type of architecture or methodology [24]. The methodology of Distributed Agency (DA) represents a potentially ground-breaking applications in engineering and in social sciences areas in which it minimizes the natural distances between physical and sociological systems approaches. In this work we thus lay the foundations for a DA description of socio-educational realities, in a process that weaves different available computational techniques to represent social and individual behavior in a contextualized fashion, accommodating agents with limited rationality and complex interactions [20].

This methodology represents a novel approach to simulation architectures, creating a language that links the social sciences to programmable terminology and that can thus be broadly applied. The DA methodology represents a general theory of collective behavior and structure formation [5], which intends to redefine agency and reflect it in multiple layers of information and interaction, as opposed to traditional approach in which agency is only reflected in individual isolated agents [25] [26].

To build the computational model is necessary to follow the distributed agency methodological steps listed as follows [14]: 1. Determining the levels of agency and their implicit relationships; 2. Data mining 3. Generating a rule-set; 4. Multi-Agent Modelling (Implementation on an agent based

simulation tool); 5. Validating the model; 6. A simulation and optimization experiment; and 7. Analyzing the outputs

Although the methodology covers the life-cycle of a research process, we are describing the data mining and generating rule set steps. We're focused on the neuro-fuzzy approach in order to set up a rule set into agents. An Interval Type-2 Fuzzy Neural Network (IT2FNN) are used for automatically generate rules. The phase of data mining using Interval Type-2 Fuzzy Logic Systems (IT2FLS) [22] becomes complicated, as there are rules to determine which variables to take into account.

Using IT2FNN for automatically generating the necessary rules, this phase of data mining with an IT2FLS [22] becomes complicated, as there are enough rules to determine which variables one should take into account. Using the search method of back propagation and hybrid learning (BP+RLS); being more efficient on other methods such as genetic algorithms, shown in other studies [21] [22]. Since the IT2FNN method seems to produce more accurate models with fewer rules.

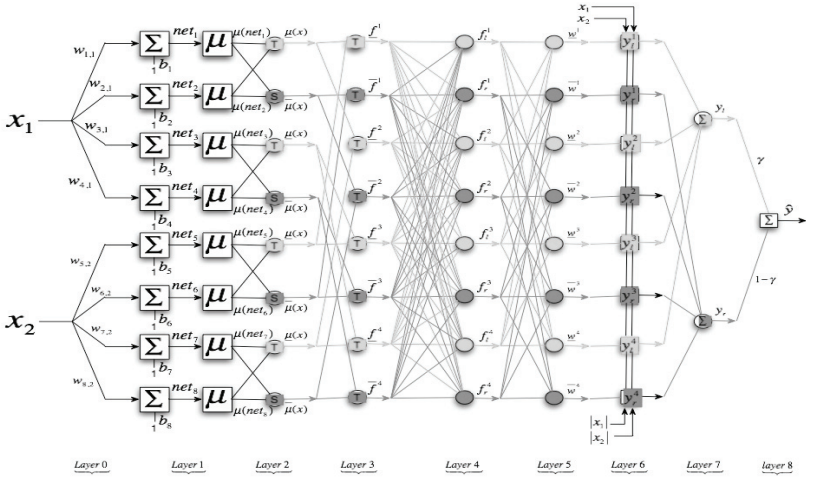

Figure 1: Architecture IT2FNN of Knowledge-base curricula in higher education [22]

This optimization algorithm is widely used and is a numerical method to minimize an objective function in a multidimensional space, and the approximate global optimal solution to a problem with N variables, which minimize the function varies smoothly [21]. Using this grouping algorithm we obtain the rules, the agent receives inputs from its environment and also must choose an action in an autonomous and flexible way to fulfill its function [11] [1] [12].

5 Conclusions

In this paper the agents (students, teachers, researchers, managers and external agents) consider knowledge as the most valuable assets. The study indicates that in order to achieve knowledge society, education evolution must be one of the most important goals in society. Also, the different agents must be able to create a relationship between actions and executioners. Second, the use of computer tools and frameworks tend to facilitate the understanding of this phenomena. Using distributed agency and fuzzy inference systems helps to build scenarios that any social researcher can analyze and use it as a methodological tool that may helps to test their research questions and hypothesis. In order that societies can move toward a true knowledge society, it is necessary also to assess the scientific and technological knowledge, evaluate space and the value of traditional knowledge. In future works it's going to take part the implementation of the model using the data we collect in a simulation software. Also its necessary complete test the FIS developed for this research with new data in its goal of determine how accurate is to increase performance acquisition to develop knowledge-based societies.

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