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MODELING OF THE HUMAN RESOURCES AS DYNAMICAL SYSTEMS

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Rezumat. *Obiectul acestui studiu este modelarea resurselor umane folosind sistemele dinamice. In general, munca in echipa este distribuita intre menrii echipei care au un scop comun. Oricum, interactiunile complexe dintre menbrii echipei pot conduce la indeplinirea sarcinlor cu success sau fara. In mediile stintifice de cercetare, unde echipe international pot lucra impreuna, interactiunea dintre membrii echipei pot defini incheierea cu sucess a proiectului. Oricum, dinamica echipei poate fi una dificila si presupune multe provocari. In acest studiu porpunem un model matematic pentru simularea dinamicii echipei ca ssitem dinamic.*

Abstract. *This research concerns the modelling of human resources as dynamical systems. Generally team work is distributed among the members of the team which have a common goal. However, the complex interactions of the team's members may lead to successful or unsuccessful completion of the tasks. For scientific research, where international teams may work together on common project, the interaction among team members defines the successful completion of the project. However, the team's dynamics is a cumbersome one and poses significant challenges. In this research we propose a computational model which models the team's dynamics as a dynamic systems.*

Keywords: numerical modeling, dynamical systems, team dynamics, human resources

1. Introduction

The group and team interactions have been of interest for many decades [1-3, 5-16]. Some of these studies concerned the conflict between the labor unions and manages within the organization [16]. It was acknowledged that although the work conflict is not explicitly expressed it is always present in any organization or society and has to be avoided at any cost [6, 8]. Usually these

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conflicts are generated by the differences in the goal's perspective of an individual or a group inside the organization. Cultural difference may be the cause of unsuccessful completion of a goal or project [10, 12, and 16]. Personnel of different cultural backgrounds may or may not enhance the productivity of the team. However, it worth to mention that if properly managed these conflicts may have a positive outcome such as high motivation, innovation, positive changes or restructures, of course in the positive direction.

Another important factor in the development and completion of research projects is the structure of the organization [7]. Thus, there are significant difference between the research performed in the corporate and academic environments. In corporations, the research is always aligned with the end product. Therefore, the deadlines for research completion are much stricter than in the academic research setup. For the corporate research there is always a customer and a market that waits for the end product and thus, the research deadlines are more rigid. In the academic research there may or not be an end customer, depending on the type of research, fundamental or applied research. Therefore, the deadlines are somehow more relaxed and thus, less prone to conflicts associated with time contains. It is widely recognized that the communication is a major issue in any collaborative work and a major source of conflict generation. This could be encountered in the same team, organization or country.

It has been recognized that the integration of the millennia work force poses more challenges regarding the team integration [8]. One of the main issues is due to the fact that they come with desire to make a significant change and have a significant impact in the team in very short time. This is a very critical issues, particularly in research projects where the major breakthroughs take time and does not happened instantaneously. As the team members may realize that their input does not materialize in a very short time, they may lose motivation and interest in the research.

There are two main component elements, which ensure a successful team and finalization of a research project, namely the match between the project requirements and team member's individual experience. Usually, R&D teams are formed from members with extensive experience related to the topic of the research project. Another issue is the attraction and retention of the members inside the team. Although attraction into a team may easy, retention is a challenging task for project managers, since members of the team are always seeking career advancement and thus, more attractive research projects of financial incentives are always the trigger. Another parameter that plays a key role in the team dynamics is the size of the team. Larger teams are always more prone to instabilities, generation of conflicts and finally unsuccessful finalization of the research.

2. Background

Generally working teams consists of two or more people. In psychology the interaction, between the individuals, means understanding the individual's mental and behavioral [3]. However, it has been proven that these are not sufficient and therefore, models are need to represent and predict the behavior of individual members of a team. Previous researchers proposed to model the human resources as dynamical systems [8]. However, this is a challenging problem and complex dynamical systems must be employed. Previous studies showed that the teams can modeled using several approaches such as, attractors, perturbation, synchronization and fractals (power-law) [4].

3. Modeling and algorithms

In this research we focus on the modeling of teams as attractors and fractals.
As already mentioned, the members of the team are always on the look for new and better opportunities, challenges or career advancements. The incoming or outgoing personal plays a critical role in the successful completion of a research project. Usually, the in and out flow of human resources generate delays in the execution and finalization of the project.
A predictive method that can estimate the team's dynamics would help to minimize the impact of relocation of human resources. Thus, in the following we propose a mathematical framework for the modeling of human resources as dynamical systems. Since the dynamics of the human resources exhibits a random behavior, we propose and develop a model that is based on the Metropolis–Hastings algorithm. Metropolis–Hastings algorithm is a Markov chain Monte Carlo (MCMC) approach.
The Metropolis–Hastings algorithm generates a collection of states according to a desired distribution $P(x)$. This is accomplished when the Markov process convergences asymptotically to a stationary distribution of $\pi(x)$ such that $\pi(x) = P(x)$. Thus,

$$P(x^{'}|x)P(x) = P(x|x^{'})P(x^{'}) \quad (1)$$

which can be rewritten in the form

$$\frac{P(x^{'}|x)}{P(x|x^{'})}=\frac{P(x^{'})}{P(x)} \tag{2}$$

Defining the conditional probability as $g(x^{'}|x)$ of proposing state $x^{'}$ given x and the acceptance distribution $A(x^{'},x)$ is the probability to accept the proposed state $x^{'}$. The transition probability can be written as the product of them:

$$P(x^{'}|x)=g(x^{'}|x)A(x^{'},x) \tag{3}$$

Similarly, we have

$$\frac{P(x^{'})}{P(x)}\frac{g(x|x^{'})}{g(x^{'}|x)}=\frac{A(x^{'},x)}{A(x,x^{'})} \tag{4}$$

Based on the Metropolis acceptante ratio

$$A(x^{'},x)=\min\{1,\frac{P(x^{'})}{P(x)}\frac{g(x|x^{'})}{g(x^{'}|x)}\} \tag{5}$$

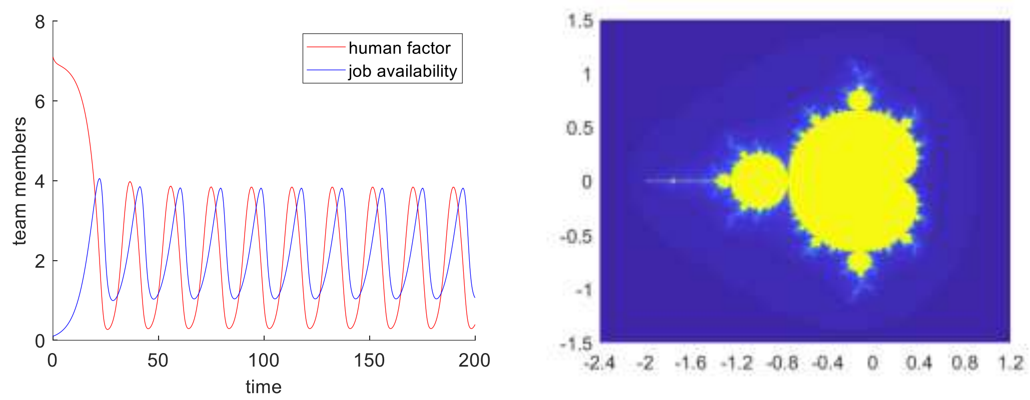
A second approach employed in the current research is the Henon attractor/map which is a discrete-time dynamical system. The motivation for this model stems from the fact that it may predict the chaotic behavior of the individual which may occur due to external perturbations. The Henon system of equation is defined as

$$\begin{cases} x_{n+1}=1-ax_n^2+y_n \\ y_{n+1}=bx_n \end{cases} \tag{6}$$

The Henon map depends on two parameters a and b which for a chaotic map have the values $a=1.4$ and $b=0.3$.

4. Results and discussion

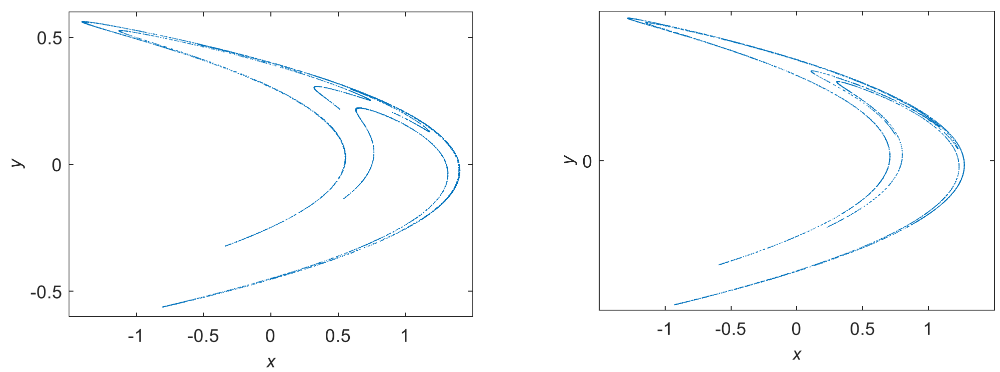
Figure 1 presents the correlation between the human factor and job availability. Thus, the red color data represents the response of human factor to the job availability, while the blue color graph represents the job availability. The model assumes that both the job availability and individual’s attraction to the job availability varies in time. The delay between the individual’ response and job availability is associated with the individual decision’s uncertainty. It is common that human individual exhibit long term memory behavior, and thus, showing similar behaviors in time [5]. This is defined by the psychology of the individual and personality formation. Previous studies pointed out that this kind of behavior can be modeled as fractals. Thus, Figure 1b shows the fractal behavior of an individual. The fractal model is based on the Mandelbrot equations.



a. Attractor model b. Fractal model

Figure 1. Numerical modeling of team as dynamic systems

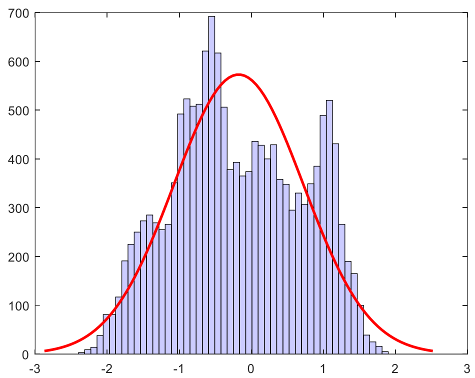
From Figure 1b, it can be seen that the Mandelbrot equations define a pattern of fractals that can associated with the long-term memory of individual. For visualization purposes a limited number of fractal interactions are shown. From the data analysis of Figure 1, a perfect symmetry it observed in the pattern of the fractal.



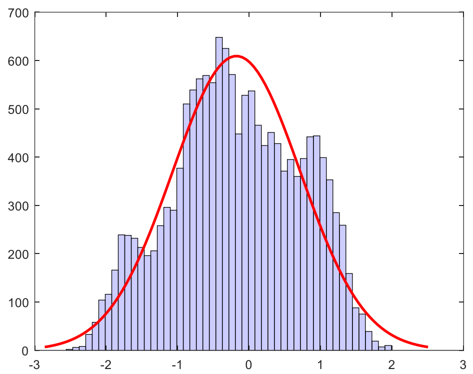
a. a=1.2, b=0.4 b. a=1.3, b=0.2

Figure 2. Henon map

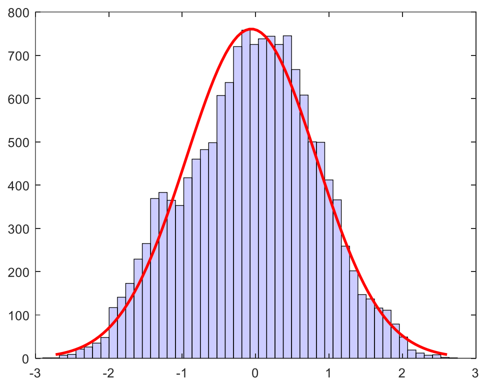
Figure 2 presents the Henon map for the modeling of team dynamics. The main idea of the model is to predict the stable, unstable or chaotic behavior of the team/individual. It is worth mentioning here that for values of $a = 1.4$ and $b = 0.3$, the Henon map exhibits a chaotic behavior. Thus, the values of parameters have to be identified with the stable, unstable or chaotic behavior.



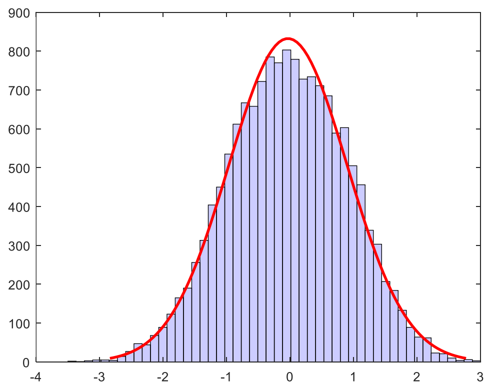
a. iteration - 100 values



b. iteration - 200 values



c. iteration - 300 values



d. iteration - 400 values

Figure 3. Metropolis-Hastings algorithm

Figure 3 presents the numerical results, based on the Metropolis-Hastings algorithm. The analysis of data, shown in Figure3, reveals that the algorithm requires multiple iterations to reach converge. Therefore, the higher the number of interaction the higher the data accuracy and thus, better prediction.

Conclusions

A computational model using the Metropolis–Hastings algorithm is developed for the modeling of dynamical systems. The present studies shows that the model provides accurate prediction of the system dynamics. The Henon attractor model is a promising approach for the numerical modeling of human resources as dynamical systems. The model offer the advantage of modeling highly chaotic systems and this occurs for values of $a = 1.4$ and $b = 0.3$. The Henon model shows that for small values of a and b variables, the system behaves chaotically.

REFERENCES

[1] Abney, D. H., Paxton, A., Dale, R., and Kello, C. T., Complexity matching in dyadic conversation. J. Exp. Psychol. 143, 2304–2315, 2014

[2] Abraham, R., and Shaw, C. D., Dynamics: The Geometry of Behavior, 2nd Edn. Boston, MA: Addison-Wesley, 1992

[3] Bak, P., How Nature Works: The Science of Self-Organized Criticality. New York, NY: Copernicus, 1996

[4] Beran, J., Statistics for Long-Memory Processes, Vol. 61. New York, NY: Chapman & Hall, 1994

[5] Coey, C. A., Washburn, A., Hassebrock, J., and Richardson, M., Complexity matching effects in bimanual and interpersonal syncopated finger tapping. Neurosci. Lett. 616, 204–210, 2016

[6] Cooke, N. J., Gorman, J. C., Myers, C. W., and Duran, J. L. (2013). Interactive team cognition. Cogn. Sci. 37, 255–285, 2013

[7] DeChurch, L. A., and Mesmer-Magnus, J. R., The cognitive underpinnings of effective teamwork: a meta-analysis. J. Appl. Psychol. 95, 32–53, 2010

[8] Fine, J. M., Likens, A. D., Amazeen, E. L., and Amazeen, P. G. Emergent complexity matching in interpersonal coordination: local dynamics and global variability. J. Exp. Psychol. 41, 723–737, 2015

[9] Gorman, J. C., Amazeen, P. G., and Cooke, N. J., Team coordination dynamics. Nonlinear Dynamics Psychol. Life Sci. 14, 265–289, 2010a

[10] Gorman, J. C., Cooke, N. J., Pederson, H. K., Connor, O. O., and DeJoode, J. A., Coordinated awareness of situation by teams (CAST): measuring team situation awareness of a communication glitch. Proc. Hum. Fact. Ergon. Soc. Annu. Meet. 49, 274–277, 2005

[11] Gorman, J. C., and Crites, M. J., Learning to tie well with others: bimanual versus intermanual performance of a highly practiced skill. Ergonomics 58, 680–697, 2015

[12] Marmelat, V., and Deligniéres, D., Strong anticipation: complexity matching in interpersonal coordination. Exp. Brain Res. 222, 137–148, 2012

[13] Newell, K. M., Liu, Y.-T., and Mayer-Kress, G., Time scales in motor learning and development. Psychol. Rev. 108, 57–82, 2001

[14] Schroeder, M., Fractals, Chaos, Power Laws: Minutes from an Infinite Paradise. Mineola, NY: Dover, 2009

[15] Thelen, E., and Smith, L. B., A Dynamic Systems Approach to the Development of Cognition and Action. Cambridge, MA: MIT Press, 1994

[16] Van Orden, G. C., Holden, J. G., and Turvey, M. T., Self-organization of cognitive performance. J. Exp. Psychol. 132, 331–350, 2003