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Toward a new generic behavior model for human centered system simulation

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ABSTRACT

The simulation of Human Centered Systems (HCS) has attracted increasingly attention in recent research. These systems involve individuals playing key roles, such as workers in manufacturing systems, soldiers in military operations, and investors in stock markets. The complexity simulating such systems is due to the need for modeling individual and group behavior and the integration of psychological and socio-technical aspects that can affect individual and HCS global performance. Although several models have been proposed to simulate such systems, most of them suffer from limitations pertaining to the integration of some factors, an inadequacy that will be discussed and elaborated on in this paper. The current study presents a new model for HCS simulation based on recent social and psychological theories. A model implementation example involving the simulation of a manufacturing system, considered as a HCS, is presented.

1. Introduction

During last few decades, the simulation of complex systems has become an interesting and important area of research. Several studies have been performed to develop new simulation platforms that simulate complex systems, such as manufacturing systems [8], military operations [49], astronaut activities [32], and stock markets [11]. The simulation of such complex systems must be able to model the interaction dynamics that hold between the components of the title system and to build models that closely mimic the behavior of this system in the real world.

Human Centered Systems (HCS) are complex systems involving individuals who play key roles, including workers in manufacturing systems, soldiers in military operations, and investors in stock markets. Several of these systems have been modeled and simulated using different approaches and tools, such as cellular automata [53] and cognitive or fuzzy cognitive maps [75]. The challenge in simulating such systems resides in the integration of intricate socio-technical factors, such as motivation [63] and emotions [81]. In fact, the simulation of human behavior has attracted the attention of researches for a long time, and the literature presents several attempts to understand and test the mechanisms of various behavioral factors for incorporation in HCS simulation models [21,66].

Several tentative propositions have been introduced to develop a simulation software that integrate human behavior models and reproduce, as realistically as possible, the human behavior in HCS. One of the major limitations of traditional models, however, is that they often representing behavior using deterministic data. Moreover, those models are centered on few aspects of human behavior, such as emotion, personality, and culture, while ignoring several other equally important individual, social, and psychological aspects. According to Baines [5], individuals in HCS are treated as a pseudo-technolog-

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ical elements and expected to behave in much the same way as an item of equipment. In practice, however, human behavior is more complex, which justifies the error margin between the simulation results and reality.

The present study was undertaken to develop a new behavioral model that aims to overcome the limitations associated with the existing ones. It seeks for a better integration of human behavior in simulation models through the integration of psychological, individual, and social factors. The proposed model can be implemented in a Multi-agent system in which each agent represents a human. This study is a first step toward the development of a new behavior model and, therefore, does not involve a complete empirical validation for the proposed model. Its driving objective is to identify a set of behavioral factors that must be integrated in a model to simulate individual behaviors in HCS.

The remainder of this paper is organized as follows: Section 2 introduces the simulation of human centered systems. It reviews the major attempts made for the simulation of HCS systems and presents the different approaches used to build simulation models. Section 3 presents and discusses some of the so far developed agent based HCS simulation models. Section 4 is devoted to presenting our model. Section 5 reports on a model implementation example wherein a manufacturing system, considered as a HCS, was simulated. It also presents and discusses the simulation results obtained. The final section provides a conclusion and suggestions for future research.

2. Simulation of human-centered systems

The simulation of Human-Centered Systems (HCS) has been one of the main research topics in the domain of artificial intelligence (AI) during the last few decades [45,12]. A human-centered system is a complex system that involves individuals playing key roles, such as workers in manufacturing system, soldiers in military operations [49,59], and investors in stock markets [11]. It also involves actors, organizational structures, rules, procedures, and computerized tools. The simulation of such systems needs the modeling of human behavior and the integration of socio-technical aspects or behavioral factors in the simulation model.

The interest in the simulation of HCS derives from the works of psychologists, sociologists, anthropologists, and economists concerned with the human behavioral patterns and social processes. The simulation of such systems is usually used to determine and evaluate the consistency and relevance of the theories generated in quite independent disciplines [50]. The simulation of human behavior has been an interesting and important area of research and application for a long time [18,66]. Those works have been driven by the interest to understand and test the mechanisms of several sociological and psychological aspects of behavior and to evaluate the impacts of such factors on the global performance of systems. Human behavior is a complex system that has been modeled and simulated by different approaches and tools, including cellular automata [53] and statistical approaches [81]. The table below presents some of the simulation approaches so far used in the literature to model and simulate human-centered systems.

The simulation of HCS can also be considered as a bridge connecting the works of psychologists, sociologists and several other scientists. Some researchers from the military domain [51,49] have, for instance, proposed behavioral models of soldiers that were integrated in a virtual training environment. Other simulation models have also been used in education [58], and also in economy to understand economic growth at a macro-economic level [31].

Some interests for simulating systems and organizations with a social viewpoint are listed below:

- *The implementation, verification, and validation of some social theories.* For example, Sibertin-Blanc et al. [67] attempted to implement a simulation model of Sociology of Organized Action theory in a multi-agent system, whereas Andriamasinoro and Courdier [4] proposed a behavioral dynamic model of agents using the Maslow's hierarchy of needs.
- *The clarification of links that can exist between social phenomena in a social structure.*
- *The analysis of social a process and structure.* As described by Troitzsch [76], a role of social simulation is to inform the analyst's understanding of the structure and processes of the system.
- *The prediction in social organization* where a great number of actors have to accomplish some common tasks. In this case, the simulation has to test new working strategies or methods and predict the system's behavior before their real application.

Several statistical models have been developed to model and analyze social systems [81]. In statistical approaches, HCS are modeled as a set of n entities – called *actors* – and information about binary relation between them. Binary relations are represented by a matrix Y, where Y_{ij} is 1, if actor i is somehow related to j and is 0 otherwise. Nowadays, the well know statistical models are the family of $p*$ models [3], also known as Exponential Random Graphical Models (ERGMs). Snijders et al. [71] maintain that "the strong point of these models is that they can represent structural tendencies, such as transitivity, that define complicated dependence patterns not easily modeled by more basic probability models."

Such approaches, however, model complex systems with static considerations. They do not allow for the formulization of the dynamic and complex behavior of individuals in HCS as well as the interactions between system components. Garbolino et al. [28] emphasize that such approaches do not take feedback effects into account.

The System Dynamics (SD) models has also been used to simulate HCSs and to analyze of the causal relationships between HCS elements [34,21,12]. System dynamics [26] combines the theory, methods, and philosophy needed to analyze the behavior of complex systems in several fields, including environmental change, politics, economic behavior, medicine,