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USING EXPERT SYSTEMS (ES) TO CONTROL UNSTABLE BEHAVIOR OF ORGANIZATIONS: THE DESIGN OF THE CONCEPTUAL ARCHITECTURE AND FUNCTIONALITY OF ES

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ABSTRACT

Disturbances of the dynamic business environment represent a threat to the stability of the organizational behavior. However, principles of cybernetics provide some important insights according to which control systems capable of responding to the changes in the environment could be designed. In this investigation we argue that if the functionality of an Expert System (ES) is based on principles of cybernetics, then such ES and can serve as a mean of controlling the stability of organizational behavior. We outline a possible set of functionalities of cybernetic-based ES, as well as a set of structural components constituting such ES.

Keywords

Complex systems, Organizational behavior, Expert system, Cybernetics

INTRODUCTION

A perspective on organizations as Complex Systems (CS) sensitive to the disturbances of the environment and characterized by periods of unstable behavior is by now well established (see Samoilenko (2008) for detailed overview). Recently, this perspective has also been extended to the context of organizational Information Systems (Samoilenko & Osei-Bryson, 2007; Samoilenko, 2008). But while previous inquiries offered a set of insights and implications regarding the functionality of the control system capable of managing the unstable behavior of organizations (Samoilenko, 2008), the past studies shed no light regarding the possible design of such system. Assuming that the behavior of an organization is controlled by means of an *Expert System* (ES), the results of previous studies provide some valuable guidelines outlining the functionality of ES in this regard. Namely, in order to manage the organizational behavior under the threat of external and internal disturbances, ES must establish communication channels, and then manipulate the flow of information through those channels across the organization (Samoilenko, 2008). However, at this point there are no insights regarding the possible architecture of such system; thus, it is not clear how ES should be designed in order to generate the information required for organizational decision making in the first place.

Consequently, the overall aim of this study is to obtain a set of insights regarding the possible structural design of an IS capable of controlling an organizational behavior, which we define as *a pattern of activities associated with the maintenance of an organizational goal.* In this study we rely on the assumption of relativity of an organizational goal, and focus on organizations that consider the states of their internal and external organizational environment in formulation of their strategies. Especially, we concentrate on the context where the achievement of an organizational goal is dependent on the level of performance of the organization, commonly measured in terms of the levels of the efficiency of utilization of inputs, effectiveness of the production of outputs, and efficiency of conversion of inputs into outputs. Resultantly, we limit the scope of our inquiry to *productivity-driven organizations*. Due to the relativity of the concepts of efficiency and effectiveness of the performance, productivity-driven organizations must take into consideration performance of the competitors. However, the dynamic nature of the business environment will cause the levels of performance of competing organizations to change over time, which will require reassessment of the values of the levels of effectiveness and efficiency of an organization relative to its competitors. There is an apparent link between significant changes in productivity of the competitors of an organization and changes in the business environment; if productivity of the competitors has improved, then a productivity-driven organization must respond with its own improvements in productivity.

Calls for improvements in the levels of effectiveness and efficiency are endemic to productivity-driven organizations. Significant changes in the levels of effectiveness and efficiency often require structural reorganizations (e.g., ERP, BPR, etc.) that bring about the periods of unstable behavior, which, if not managed, escalates and becomes chaotic (Samoilenko, 2008). Granted, some improvements in productivity do not require any structural transformations but simply call for a gradual type of improvements in the level of performance (e.g., TQM, BPI, etc.). However, in the absence of perfect scalability the appropriate course of action leading to improvements will change in time, primarily due to the law of diminishing returns. Resultantly, in a dynamic business environment any static model that used to describe the relationship between inputs and outputs will have a limited life span. In the absence of an adaptive mechanism that allows for discovering the new pathways for improving overall organizational performance, a productivity-driven organization will engage in the process of search and exploration, during which the number of the possible states or behaviors of an organization will proliferate. While periods of search and exploration are common to dynamic CSs, these periods also bring about the danger of a system not converging on the global maximum, and settling, instead, on multiple suboptimal local maxima. This outcome of search and exploration process will result in instability of organizational behavior and overall suboptimal performance of an organization.

Keeping the above mentioned in mind, we suggest that ES can fulfill the role of an adaptive mechanism capable of controlling an organizational behavior. However, in order to do so the design of ES must take into consideration two questions that an organizational control system must be able to answer, namely, relative to what context the performance of an organization is going to be measured?, and, second, what are the determinants of the given level of the relative performance? We express the research goal of this study by asking the following question: *What constitutes robustness of the design of a ES capable of controlling the behavior of an organization?* For the purposes of this investigation we provide the following definitions. First, we define a *robust design* of an ES as *a design allowing for managing of the unstable behavior of an organization*. Second, we define an *unstable behavior* of an organization as *a behavior that is characterized by the perception of the loss of control* (Samoilenko, 2008) *over the process of the maintenance of the organizational goal caused by the precipitous increase in the number of the possible states or behaviors of an organization* (Heylighen &Joslyn, 2001). The *management of a behavior* is defined as *a capability to control the number of the possible states or behaviors of an organization*. A state or a behavior of an organization, in turn, is determined by the set of *constraints*, and constraints serve the purpose of reducing the uncertainty about the system's state or behavior (Heylighen & Joslyn, 2001). We define a constraint as *an attribute or a set of attributes that accurately represent a particular dimension of the business environment in the model that an organization uses in its decision making process*. In line with this definition we propose that an unstable behavior is unconstrained (e.g., the model is inaccurate), whether the stable behavior is constrained (e.g., the model is accurate). We note that a constrained model does not have to be complete. Finally, taking the abovementioned into consideration, we define ES as *a medium that allows an organization to reduce the uncertainty about its state and behavior by means of providing a set of constraints utilized in the decision making process involved in the maintenance of an organizational goal.* Resultantly, one of the functional requirements of ES is associated with the capability of creating the constrained (accurate) model of the business environment that is utilized by an organization.

The modern business environment is dynamic, and the assumption of instability of the internal and external environment is advantageous when designing ES, for such assumption will make its design more robust. The meaning of a dynamic environment from the perspective of ES is easy to decipher, for it implies the absence of a static set of constraints and relationships between constraints that are used in creating models of business environment used in the decision making process. Conversely, an embedded in the design assumption of stability, exemplified by fixed data and process models that describe constraints and the relationships between constraints, will greatly limit the capability of a ES, for any significant disturbance could render a set of constraints and their relationships obsolete and invalidate the embedded models.

However, traditional approaches to IS Development (ISD) are based on functionalism, and due to their reliance on stable models functionalist approaches do not allow for a dynamic discovery of new relevant constraints and disposal of the obsolete ones. Nor functionalist approaches allow for the dynamic adaptation and evolution of their design models. Furthermore, it is commonly accepted that a non-linearity of interaction between the system's components, as well as the presence of emergent properties caused by a non-linearity, are some of the traits that characterize social systems, and it is those traits that are partially responsible for the complexity of an organizational behavior. But the traditional functionalist approaches to ISD employ reductionism to abstract away the complexity of not only the structure and behavior of an organization, but also the complexity of the relationship between an organization and its environment. Consequently, the use of the mainstream and extended functionalist methodologies in designing ES will result in systems that are inadequate for managing the periods of unstable behavior that are endemic to such CSs as organizations. New approaches are needed. We propose that second-order cybernetics, which emphasizes principles of autonomy, adaptation, and self-organization of CSs, could serve as a valuable vantage point from which important insights regarding the design and structure of ES capable of managing behavior of an organization could be obtained. Because the advocated perspective is context-independent, we expect the results of this study to offer equally valuable insights regarding the design of the department-, firm-, industry-, or economy-level control systems.

We present our investigation as follows. Part One outlines the justification for our approach in the current investigation. Part Two offers an overview of the principles of the second-order cybernetics. Part Three translates the principles discussed in Part Two into the set of implications relevant for designing ES. Part Four Part suggests a set of structural components that could be utilized in the construction of the cybernetic-centered ES. Brief conclusion follows.

Part One: Justification of the Approach

We would like to offer a justification for why the principles of cybernetics could serve as a solid foundation of the structural design of ES; we argue that cybernetics can provide a suitable foundation for the following three reasons:

- First, domain of inquiry of cybernetics includes not only artificially engineered systems, but also naturally evolving ones. Organizations exemplify such engineered, yet evolving systems.
- Second, the subject of inquiry of cybernetics is goal-directed systems. Organizations are goal-directed systems, survival of which is dependent on achievement of the organizational goal.
- Third, the focus of cybernetics is on the use of information, models and control actions by goal-directed evolving systems. Organizations are such systems, and organizations actively use information, models and control actions in order to counteract internal and external disturbances that threaten stability of the goal-oriented behavior.

Based on this brief assessment of eligibility, the use of principles of cybernetics for designing control structures of organizations appears reasonable. However, despite fitting well for the purposes of our inquiry, cybernetics is not concerned with a structure of the control system, but rather with its function. For this reason, it cannot directly provide a prescriptive blueprint of what the possible design of a control system might look like. Therefore, we take a three-step indirect approach to outlining the conceptual design of ES. First, in Step 1 we offer an overview of the general principles of cybernetic systems. Second, in Step 2 we outline, based on the identified in the step 1 principles, a set of functionalities that a cybernetic system must possess. Finally, in Step 3 we offer a mapping of the identified in Step 2 functionalities to the design components that could be used in the design of ES.

Part Two: A Brief Overview of Cybernetics

Norbert Wiener was the founder of cybernetics as a field of study of the “control and communication in the animal and the machine” (Wiener, 1948); this came to be known as *first-order cybernetics*. According to first-order cybernetics, a system under study can be represented by its simplified model and perceived to be independent of its observer. Some cyberneticists felt that the emphasis in studying the systems must be placed on autonomy, self-organization, cognition, and the role of the observer in the modeling of a system; later this movement became known as *second-order cybernetics* (Heylighen &Joslyn, 2001). Being a complement, rather the alternative to its predecessor, second-order cybernetics (Von Foerster ,1960; Ashby, 1962) recognizes a system under study as an agent in its own right, actively interacting with the observer. The summary of the state-of-the-art in cybernetics, as well as a brief review of the subject which considers first, second order and a proposition for a third order cybernetics, can be found in Dubois (1995). And while in this paper we are concerned with second-order cybernetics, its principles are by now so firmly embedded in the overall foundation of cybernetics that it is appropriate to discuss this subject by simply referring to it as *cybernetics*, without making a clear-cut differentiation between first- or second-order cybernetics (Heylighen & Joslyn, 2001). Overall, cybernetic systems are characterized by complexity, mutuality, complementarity, evolvability, constructivity, and reflexivity (Joslyn, 1992); these characteristics and their interpretations are summarized below.

Table 1 General Characteristics of the cybernetic systems

Characteristic	Interpretation of the Characteristic
Complexity	Cybernetic systems are complex structures, with many heterogeneous interacting components.
Mutuality	Components of the cybernetic system interact in parallel, cooperatively, and in real time, creating multiple simultaneous interactions among subsystems.
Complementarity	Complementarity, which is brought about by the complexity and mutuality, refers to the irreducibility of the level of analysis to any one dimension.
Evolvability	Cybernetic systems tend to evolve and grow in an opportunistic manner, rather than be designed and planned in an optimal manner
Constructivity	Cybernetic systems tend to evolve and grow in size and complexity, while historically being bound to previous states.

Reflexivity	Cybernetic systems can enter into the feedback of reflexive self-application, which may result in the reflexive phenomena of self-reference, self-modeling, self-production, and self-reproduction.

The fundamental principles of cybernetics are selective retention, autocatalytic growth, asymmetric transitions, blind variation, recursive systems construction, selective variety, requisite knowledge and incomplete knowledge (Heylighen, 1992); these principles and the interpretations of the principles are summarized in Table 2.

Table 2 General principles of the cybernetics

Principle	Interpretation of the Principle
Selective Retention	Stable configurations of the system are retained, while unstable ones are eliminated
Autocatalytic Growth	The stable configurations, which facilitate the appearance of configurations similar to themselves, will become more numerous.
Asymmetric Transitions	A transition from an unstable configuration to a stable one is possible, while the transition from stable to unstable configuration is not.
Blind Variation	The variation processes cannot identify in advance which of the produced variants will turn out be selected.
Selective Variety	The larger the variety of configurations a system undergoes, the larger the probability that at least one of these configurations will be selectively retained.
Recursive Systems Construction	BVSR (blind-variation-and-selective-retention) processes recursively construct stable systems by the recombining the stable building blocks.
Requisite Variety	The larger the variety of actions available to a control system, the larger the variety of perturbations it is able to compensate.
Requisite Knowledge	In order to adequately compensate perturbations, a control system must “know” which action to select from the variety of available actions.
Incomplete Knowledge	The model embodied in a control system is necessarily incomplete.

Part Three: Implications of the General Principles of Cybernetic Systems for Designing ES

Based on general principles of cybernetics and their implications, summarized in Table 2, we can derive the set of implications regarding the required functionality of ES. The set of proposed functionalities provided in Table 3.

Table 3 Implications of general principles of the cybernetics on the functionality of ES

Principle	Implication of the Principle in Regard to the Functionality of ES
Selective Retention	ES must not only be able to contribute to the development of the stable organizational configurations, but also to recognize them as such. For example, a successful product development process or a particularly productive organizational sub-structure must be identified (e.g., by using internal benchmarking?), and then retained within the organization.
Autocatalytic Growth	ES must promote the increase of the stable successful structures within an organization; this could be done through the process of the organizational learning utilizing knowledge-management systems.
Asymmetric Transitions	ES must be able to recognize the inferior solutions in advance, possibly by means of simulation and modeling.
Blind Variation	While ES might not be able to ensure the production of only successful configurations, it must be able to identify the obviously inferior ones. This could be done by means of using what-if analysis and scenario-building.
Selective Variety	ES must allow for a large variety of its own possible configurations; this could mean that ES should be characterized by a large number of independent components.
Recursive Systems Construction	ES must be able to construct stable systems by the recombination of the stable subsystems and elements, which suggests high cohesion and lose coupling of ES components.
Requisite Variety	ES must not be constructed for one specific purpose or with a predefined functionality; instead, it must constantly be in the process of growth and development.
Requisite Knowledge	ES must be able to select from multiple available actions an appropriate response to a particular event. This may mean that ES must have scenario-building capabilities, possibly utilizing modeling and simulations.
Incomplete Knowledge	ES must not function in the closed environment; instead, ES must be able to interact freely with not only the competitive environment of the firm, but with the global environment as well.

Part Four: Identification of the structural components of ES

A set of implications outlined in Table 3 suggests the presence of a concept that is central to a productivity-driven organization, namely, that of the *superior stable configuration*. In line with the principles of cybernetics, stability of the behavior a goal-oriented system is associated with presence of the successful stable configuration of the system. Given the goal of achieving a high level of efficiency of conversion of inputs into outputs, a superior stable configuration in the context of a productivity-driven organization may imply *a model of conversion of inputs into output (input-output model) characterized by a high level of relative efficiency*. Consequently, we put forward the following propositions:

Proposition 1: *Stability of the organizational behavior of a productivity-driven organization is dependent on the presence of the stable input-output model.*

Proposition 2: *Accomplishment of the organizational goal of a productivity-driven organization is dependent on the creation and implementation of a stable input-output model characterized by the high level of relative efficiency.*

Proposition 3: *In order to control the behavior of a productivity-driven organization, ES must be able to create and identify superior stable configurations, represented by the input-output models characterized by the high level of relative efficiency.*

Table 4 Possible interpretation of the functionality of ES in productivity-driven organizations

Functionality of ES	Interpretation
ES must contribute to the development of the stable organizational configurations	Stable configurations allow for the presence of a consistent model depicting the process of conversion of inputs into outputs by an organization, in the form of an input-output model
ES must promote the increase in the stable successful structures within organization	Stable configurations promoted on the basis of the effectiveness and efficiency of conversion of inputs into outputs in such way, that every distinct consistent model is characterized by the distinct level of relative efficiency of conversion of inputs into outputs
ES must be able to recognize the inferior solutions in advance	Inferior solutions represent stable configurations characterized by lower levels of effectiveness and efficiency of conversion of inputs into outputs, while superior solutions represent stable configurations characterized by higher levels of effectiveness and efficiency
ES must allow for a large variety of its own possible configurations	A process of evaluation of the stability and quality of configurations is independent of the structure of input-output model representing a given stable configuration; single ES must be able to evaluate many configurations
ES must be able to construct stable systems by the recombination of the stable subsystems and elements	A process of evaluation of the stability and quality of configurations must rely on information-rich components that could be reused in new processes
ES must be able to select from multiple available actions an appropriate response to a particular event.	A process of evaluation of the stability and quality of configurations must allow for variations in inputs, outputs, as well as the variations in the process of conversion itself; ES must be able to identify not only the superior configurations, but also the factors that impact the quality of configurations
ES must not function in the closed environment	Stable configurations must be regularly assessed and re-assessed relative to the internal and external organizational environment

Keeping the relativity of the concept of efficiency in mind, the functionality of ES can be presented as encompassing two subsets of functionalities: internally-oriented and externally-oriented. Externally oriented functionality of ES is directed towards evaluating external competitive environment of a productivity-driven organization, as well as identifying the differences between the current state of the organization and the states of its competitors. Internally-oriented functionality, on the other hand, is directed towards optimization of the level of productivity of the organization, as well as towards identification of the factors impacting the efficiency of the input-output process. We suggest that outlined above functionality of ES could be implemented by means of using combination of parametric and non-parametric data analytic and data mining techniques, such as Data Envelopment Analysis (DEA), Cluster Analysis (CA), Decision Trees (DT), Neural Networks (NN), and Regression Analysis (RA).Table 5 provides a summary of how the above mentioned components could be utilized to implement the required functionality. In our future investigations we will demonstrate the detailed design of such ES, as well as provide the illustrative example of its functionality in the real-world context.

Table 5 Possible Structural Implementation of the Functionality of Cybernetic-Centered ES

Functionality	System Requirement	Structural Components
Externally-Oriented	Detection of changes in the external competitive environment	Cluster Analysis
	Identification of the possible factors that resulted in changes	Combination of Cluster Analysis and Decision Trees
	Identification of the relative efficiency of the organization relative to its competitors	Data Envelopment Analysis
	Identification of the factors associated with the differences in the relative efficiencies of the competitors	Combination of Data Envelopment Analysis, Cluster Analysis, and Decision Trees
Internally-Oriented	Identification of the factors impacting the current level of the relative efficiency of the input-output process	Regression Analysis
	Identification of the most effective ways of increasing the level of efficiency of the input-output process	Combination of Data Envelopment Analysis and Neural Networks

CONCLUSION

Results of our investigation suggest that a cybernetic-centered ES must be constructed from the collection of platform and implementation-independent components, which are highly cohesive and loosely coupled. Moreover, ES must be scalable, fluid, and be able to reconfigure itself in response to changes in the competitive and global environments. Furthermore, it must have scenario, model building, and simulation capabilities. Cybernetic-centered expert system must have multiple feedback loops and information inputs from the global and competitive environments. While the proposed in this paper complete design of ES capable of managing organizational behavior is still in its conceptual form, the parts of the outlined functionality have been implemented (e.g., Samoilenko &Osei-Bryson, 2007; Samoilenko &Osei-Bryson, 2010).

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