

# MMBSM: A Meta Model for Biological System Modeling

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## Abstract

Increasing the complexity and interactions, network centric organizations would become less effective and it seems that getting pattern of biological system might represent an appropriate approach to this problem. Based on Capra Cognitive Framework, basic parameters in a biological system and the whole role of these parameters will be evaluated and then again according to the mentioned framework, a model of biological-social systems and their effective elements will get analyzed in this paper. Moreover, the relations between existed elements in noticed model will be assessed and their impacts on each other will get presented. The proposed model (MMBSM) will be considered through looking at the functionality of the Immune System and after that, its approach will get evaluated based on existed elements in the Immune System and the way they operate.

**Keywords:** *Agent, Capra Cognitive Framework, Immune System, Modeling.*

## 1. Introduction

Network is a collection of relations [1] and Network Centric Organizations is an organization based on relations and could be introduced as a new approach to the information-based organizations in distributed environments. Managing such organizations needs to overcome the dominant and noticeable dynamic and complexity in these systems. In a network centric organization, sources of the system have been dispensed in the whole set. But despite this source distribution, the system management has been centralized in many cases. Getting inspired by biological- social systems could make an appropriate approach to produce a network centric organization with a higher robustness and effectiveness.

The Immune System (IS) of human body is one of the most complete and effective biological systems and considering its functionality, the way it would react to the diverse diseases, overcome the Pathogenesis and save their structure through consecutive generations [2]. Using cognitive agents, the IS could produce a decentralized system which enjoys the capacity of self-management.

Modeling the IS and taking pattern of that could lead to production of network centric organizations with a high robustness.

In this paper, the related works were considered briefly at first, then the biological systems and their characteristics are going to be assessed and after that, the Capra Cognitive Framework (CCF) will be presented for biological systems and subsequently, regarding to CCF and the IS, the represented model (MMBSM) and its functionality in a network centric organization will be analyzed. Furthermore, the proposed model (MMBSM) would be adapted to the functionality of the IS and also CCF and after all, the results will get represented.

## 2. Related Work

Modeling of system dynamics, function, and structure has been widely studied in software engineering and artificial intelligence fields. Inspirations of the biological system almost represent a new idea in engineering science. Nonetheless, biological system modeling is a challenge in engineering. There are many methods for biological system's modeling. Statecharts is an executable representation formalism of dynamics of reactive systems. They enjoy broadcast communication and work with hierarchal state machines. Statecharts separate the system into structural components and for each of them define and use own Statechart. With this method, they can represent a concurrent behavior [3 and 4].

To provide classification hierarchies of structural and functional biological-role categories, controlled vocabularies that provide a categorization of biological structures, processes, and functions were introduced [5]. This vocabulary uses to classify processes as relationships and sub-processes as part-of relationships. Ontology is a way for Transparent Access to Multiple Biological Information Sources (TAMBIS). In this method, an ontology used for describing data achieved from bioinformatics sources. TAMBIS represents biological

concepts and a semantic network of relationships between concepts. Furthermore, it used logic-based knowledge representation formalism for concepts defining based on their properties [6].

EcoCyc represents a functional model for metabolic reactions using a frame-based formalism. It represents reactions by specifying their reactants and products. Furthermore, it couldn't attempt to represent all types of non-metabolic reactions and high-level processes. Besides, it was a static-structure model and didn't have a dynamic model for parallel processes, process triggering, and temporal constraints [7].

Rzhetsky presented a knowledge model for regulatory networks. Like EcoCyc, this model could be used to specified static-structural and functional aspects of regulatory networks. High-level processes could be categorized into a number of biological processes and could contain one or more actions. Each action was defined as having both a biochemical and logical definition that specify the catalyst, upstream, downstream, and side action-agents. However, there was no underlying dynamic model, and high-level processes simply contain ordered lists of their constituting actions [8].

Peleg et al. combined the best aspects of Workflow/Petri Net and a biological concept model. The Workflow model can represent nesting and ordering of processes, the structural components that participate in the processes, and the roles that they play. The model was tested by representing malaria parasites invading host erythrocytes, and composed queries, in five general classes, to discover relationships among processes and structural components [9]. With joining Statecharts and other models new models such as The Object Modeling Technique (OMT) and the Unified Modeling Language (UML) were presented that could represent system structure and function.

### 3. Main Characteristics of Biological Systems

Assessing the biological systems might be better get started by the smallest element which means a cell. The membrane and cellular metabolism has formed the essential characteristics of life [10]. Every living creature should be able to change through its interactions with the environment to live with the least cost. The metabolism process would be defined as the interaction between the living creature and its environment. This interaction could increase the environmental perception for that creature. Also a living creature's physical dimension would alternate as time goes and through this time it could adapt itself with the environmental conditions. This adaptation is to be transferred to the subsequent generations and also causes evolution. Looking at the amount of the environmental conditions perception in any creature, this could be

observed that creatures adapt themselves with the new situations and this adaptation has always been in order to reach the appropriate conditions [11].

In a living creature, chemical actions and reactions with the environment would lead to the chemical (network) interaction with that environment. So the material (structure) and the chemical network could be mentioned as the vital characteristics of life in living creatures [12]. The communication network in biological-social systems has been one of the most effective factors in convergence within set members and robustness of the whole system. The formation of a common image among the members of a set would be caused by such an interaction system.

There are two forms which members of a biological system might make structural changes. The first kind of structural change could be defined as self-renovation which would lead to the constant changes in every living creature and also keep its organizational structure through this process. The second kind of these structural changes has been generating new communicational structures. A living creature's responses to the environmental changes could be done by means of structural changes and this process would cause the subsequent behavioral changes in that creature. This phenomenon has been called Learning in living systems [11]. Structural changes have been coming from environmental changes, adaptation and learning and also should be mentioned as the basic characteristic of a living creature. In addition, through keeping former structural changes, the living creature imports the new structural changes in its future behaviors [13]. Considering all noticed issues and based on the Santiago Theory of Cognition [14-16], these structural changes could lead to Cognition and the cognition would make the living creature have an appropriate reaction to the actions of its environment. Therefore, this process of life itself should be considered as the cognition process [17].

### 4. Capra cognitive Framework (CCF)

Capra Cognitive Framework (CCF) has been represented to make understanding the biological and cognitive processes easier. The biological and cognitive phenomena have been assessed through four viewpoints of Pattern, Structure, Process, and Semantic, by this framework. The Structure point of view has been focusing on the physical dimension of the living creature, the Pattern would notice about the relations between elements of a living system, the Process have been talking about the context of reasoning method and, the behavior generation would result in merging the two first viewpoints. The Semantic has to be added to the last three points of views to make life generalization possible to the social dominant. This should be also notices that the Semantic has been a context

which would cause the system to become converge and robust. The Semantic as the main parameter in a biological-social system has always been the representative of some contexts according to convergence and robustness in a system. For a single creature, the Semantic would present some basic contexts like survival and reproduction. Here, it can be seen that the Semantic should be mentioned as the basic difference between living systems and machines. The CCF has been shown in figure 1 and further, details of this issue have been presented in [12].

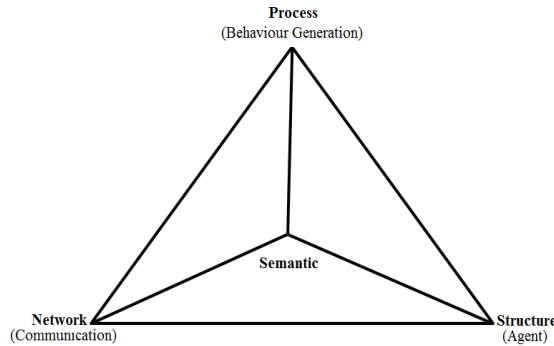


Fig. 1 Capra Cognitive Framework (CCF).

## 5. The Proposed Model (MMBSM)

Creatures would react to the actions of their environment by means of structural changes. These changes could cause some actions in the environment which the creature has done before using determined actuators or they could happen as some changes in the living creature's structure. Changes within the elements of a biological system would be generated through the two forms of self-renovation and structural changes. In the first kind, the organizational structure of the living creature has been kept steady in a way which this phenomenon can be assumed as Adaptation. But new communicational structures have been generated in the second kind which could cause further changes in creature's behavior and this process has to be called Learning. Learning could lead the living creature to evolution through the time. In another word, evolution would be defined as the Structural changes in a wide period of time which even could be transferred from a generation to the other ones. Evolution as the context of learning integral in a wider time period could make the behavioral pattern get form and this behavioral pattern could lead to the generation of culture in the more advanced social dominants such as human societies and organizations.

To apply the adaptation, every biological system has been always in need of Awareness about the environment and

without such environmental perception; the biological system would not be able to make an appropriate adaptation in order to the Semantic. In addition to making an appropriate adaption, the Semantic also could cause goal-oriented learning and evolution to come out. One of the other major parameters in the evolution of a social system is the Shared Awareness among system's members which causes robustness of the system to increase and also make in the process of forming the organizational and system's convergence accelerate. The Shared Awareness has been generated from sharing the Awareness of an organization or a system's elements. In basic social-systems like ant colony and the IS, this phenomenon has to be done by means of chemical interactions such as pheromone and enzymes. But in more advanced social-systems like mammals societies, it happens through conversation and information transmission. Regarding to the mentioned issues and using the CCF, a cognitive model in three tiers could be proposed for an agent in the social dominant as what has been illustrated in figure 2.

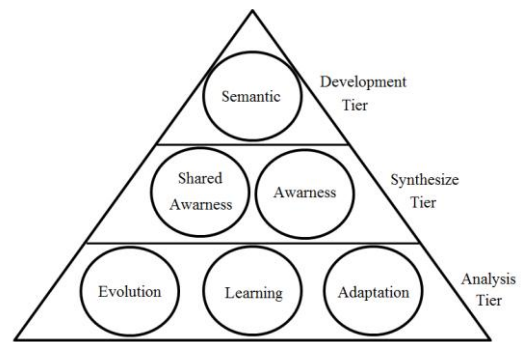


Fig. 2 The Approach of MMBSM.

Structure has been the only physical dimension in CCF which could be considered equivalent to the Awareness, adaptation and learning in the MMBSM. Also Shared Awareness has been the consequence of the existence of pattern and communicational network, which could result in Sense Making and generation of a common sense inside a system. The outcome of sense making beneath the members of a set would lead to Planning. The Semantic dimension in the MMBSM has been equivalent with this dimension in the CCF. The Semantic dimension also includes the existing contexts in a system like trust and commitment which would result in cooperation. Moreover, this dimension could determine the amount of threshold for all contexts. This amount could be changed for any of mentioned contexts regarding to the environmental conditions. Although the Process has been considered as an independent dimension in the CCF, yet in the MMBSM of figure 2 it has not been introduced as an independent dimension and this is because considering that the Process

is the consequent of the Structure and the Pattern, life process has not been able to get formed without the existence of the Structure and Awareness. Behavior generation has been the result of the Process and its physical outcome leads to the final Action. The instance of this outcome can be observed as an environmental action and reaction or the action of adaptation in the Structure. Due to mentioned issues, the decision-making and operation of a cognitive agent in the MMBSM using presented contexts in figure 2 have been shown in figure 3.

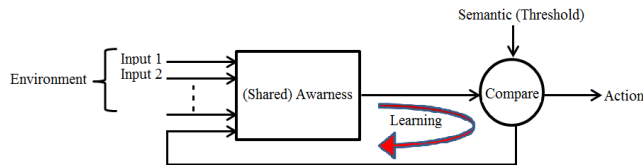


Fig. 3 Decision Making of a Cognitive Agent in MMBSM.

In the cognitive systems with centralized management such as an organization, existing contexts in Semantic dimension and also its threshold amount has been determined by the central element. In this manner, central element would enjoy the ability of increasing and decreasing the amount of threshold regarding to the conditions. This procedure should be mentioned to be effective on having a faster convergence or reaching robustness and in such situation; the collective awareness would arise inside the central element. According to figure 4, the parameters of analysis level could be changed considering the organizational pattern in an organization or a society.

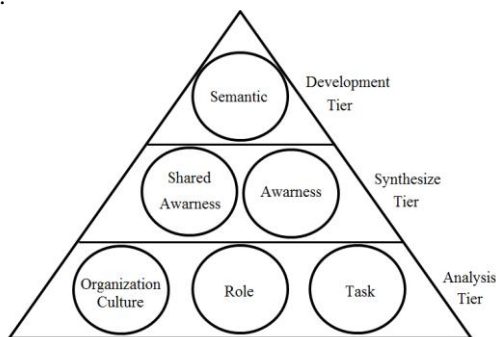


Fig. 4 MMBSM for an Organization.

Modeling of analysis level in figure 4, has been represented in figure 5. The task layer implies the determined tasks for an agent and changes in this layer has been applied as little changes in the environment and so the essence of this behavior has to be reactionary. The role of every agent has been determined in the second layer based on the tasks between all agents. This layer would enjoy learning and memory, the essence of it should be

active. In the other word, this layer could be mentioned as the integral of the task layer. The layer of culture has recognizes existing patterns in the organization and even it would have the power of the patterns prediction. This layer also is the determiner of basic circumstances and therefore has to be proactive. So this can be said that the integral layer is to be the role layer.

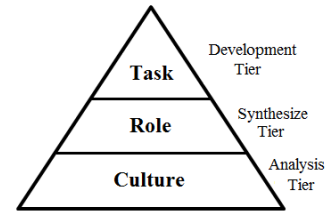


Fig. 5 Modeling the Analysis layer of an Organization.

Determining most processes before generating an organization, might lead to overcome the complexity and decreasing the convergence time between members of the organization, but could make the members' creation and autonomy decrease. The Semantic based systems are not to determine the processes subsequently, so they need more time for convergence at the beginning, but through the time their robustness will be increased and they will enjoy the possibility of new innovations and also need less control to keep set robust. The relations between process, task, learning and evolution have been illustrated in figure 6.

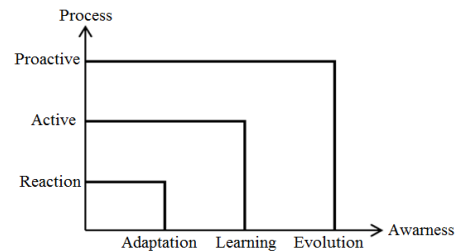


Fig. 6 Relation between the Process and Analysis Tier.

#### 4. Adapting MMBSM with the IS

Living systems such as the IS includes complex elements with complex interactions. Based on the CCF, evolution and life of living systems have been along the process of cognition. Therefore, all the activities of a living creature could be reckoned as cognitive activities [11]. Regarding to the way the IS operates, this could be observed that antibodies would adapt themselves with the environment and also to the functionality of invader cells. They also could enjoy having memory [18-19]. Space divisions in two classes of self and non-self, learning, and the existence

of memory, have constituted main characteristics of the IS. This system should be able to learn the functionality of non-self cells and also the existing information in every cell of the IS could be transferred to the next generation cells of that system. So moreover the ability of learning could be found in every single cell, like a social network the whole system would enjoy learning too and also evolve through the time [2].

Assessing the functionality of antibodies as some evolved elements of the IS, this could be seen that each antibody has kept the information of certain antigens in its memory and has been just able to encounter antigens which had been known before by it. Facing the antigen, the antibody would send a copy of antigen's protein chain to the other antibodies. This process has been done through blood or lymph. Additional details about antibodies' functionality have been presented in [20 and 21].

All antibodies has have cellular metabolism, its structure would change through interactions with its environment and also evolve as time goes. Also these changes could result in keeping former structure and alternation in subsequent behavior of the system. Each antibody could be assumed as a structure which operates autonomously and participate in interactions with other ones through metabolism and information transmission. Also their metabolism and the interactions between them could be mentioned as the communication network among them. From the viewpoint of process, antibody has to be defined as a cognitive system with abilities such as adaptation, learning and evolution. Also contexts like survival, trust to the self element, and commitment to encounter the non-selves could be considered in the dimension of semantic.

Moving and facing antigens, or getting the enzymes from blood or lymph, the antibody gets aware of the existence of antigens inside the body. Enzymes generation by different antibodies would result in information transmission beneath them and all lead to the emergence of shared awareness.

By means of immune cells' interplays with each other, the immune memory could be saved and restored even in the absence of external antigens. These interplays would have been implied as stimulation. The stimulated antibodies also stimulate other ones and this is to be possible through the communications which antibodies have made using Epitope with the antigens, and by means of Idiotope with each other. Therefore, shared awareness has been coming out of the linkage of Idiotoxes within antibodies. The difference between antigen's Epitope with the antibody's Paratope would mean that the recognition of antigen has been done and also that antibody has not been able to overcome that antigen. So if the difference was less than a determined amount, the antibody might be able to adjust its

Paratope with the antigen's epitope through adaptation which would happen in the physical dimension and result in some little changes in the Structure of the antibody. This Structural change has been saved in the antibody and would be observable in the next generations. In another word, this Structural change could lead to the emergence of learning in the antibody.

Now this should be noticed that the IS would be able to show an appropriate reaction to the different antigens by the emergence. As time goes, this procedure could lead to the evolution of the IS and the existence of evolution in the IS could imply that some kind of organizational culture has been forming which would get more evolved through the time. This kind of organization culture has been the consequence of different learning so that all antibodies have been following that.

The functionality of the IS could be presented based on figure 2. In this case, every antibody's physical dimension has been considered as structure or agent. The existing knowledge in any antibody's memory and its awareness about existing elements in its vicinity should be mentioned as the antibody's awareness. Moreover, antibodies have been able to communicate with each other by means of linking network of Idiotoxes and this procedure would result in emergence of shared awareness in antibodies. If possible, each antibody could change its Paratope while encountering unknown antigens in a way which it would be able to adjust with the antigen's Epitope. This procedure signifies the existence of adaptation in the antibody.

Registration of an antigen's structure in the antibody's memory would mean that antibody enjoys the ability of learning. As time goes, this ability could result in increasing the antibodies efficiency and show the emergence of evolution in the IS. Also existence of contexts such as survival, reproduction, trust on other antibodies, and commitment to defend self elements, would be all considered as the semantic dimension. Regarding matters above, this could be observed that the antibody's behavior is just like to the MMBSM of figure 2. Also the existing antibodies' organization in the IS could be noticed as a cognitive organization due to figure 5. In addition, the organizational culture could be defined as the different antibodies' functionality and the way they would encounter the antigens within the IS.

## 5. Conclusions

Assessing biological systems, their main parameters have been introduced based on the CCF. Also using the existing contexts in biological- social systems and the CCF, a cognitive model including three analysis, synthesize and development tiers, has been proposed for the body IS.

Then by means of the proposed model (MMBSM) in figure 2, network centric organizations can be designed based on the structure of the IS. In order such an objective for every single system, semantic should be defined as a nature which is the main reason of convergence among system's elements. Every element's awareness of environment, conditions and also communications between the elements could cause the emergence of shared awareness in the organization and this awareness results in the goal-oriented behavior of the system's elements. Furthermore, parameters like task, learning and evolution have been effective on the robustness of the system and they all could cause the improvement of system's functionality through the time.

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