Knowledge Needs of Self-Organized Systems

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Abstract

Self-organized systems are capable of changing their own structure in order to adapt themselves to significant changes in their environment. They are at the top of a hierarchy of systems that arranges systems according to the degree of control they have upon their own actions. Self-directed systems, self-regulated systems and uncontrolled systems are the reminder levels of that hierarchy.

The framework developed in this paper identifies the necessary components at each level of control. These components include operators, coordinators, regulators, directors, organizers and informers. The framework can be described as a model of the general architecture of self-organized systems. It is used to identify and characterize the knowledge needs of self-organized systems by examining the functionality, characteristics and knowledge needs of each of those components.

Keywords: systems, self-organized systems, knowledge
INTRODUCTION

The use of the term knowledge in contexts related with organizations is becoming increasingly common. Organizational learning and innovation (i.e., organizational innovation capability) are metaphors intimately related with knowledge that are used to study and intervene in organizations. Perspectives on organizations based on such metaphors (e.g., (Argyris, 1993), (Argyris, 1994), (Senge, 1992), (Senge, Kleiner, Roberts, Ross, & Smith, 1994), (Nemeth, 1997)), led to knowledge to be considered as a corporate resource that, like other organizational resources, has to be managed (Davenport & Prusak, 1998), (Stewart, 1997), (Myers, 1996), (O'Leary, 1998). As a consequence, knowledge management has been emerging as a new professional activity.

This paper proposes a framework that describes the use of different types of knowledge in organizations. The framework is mainly composed by a hierarchy of systems that classifies systems according to the degree of control they have upon their own actions. The hierarchy starts with uncontrolled systems and ends with self-organized systems which are described as systems that are capable of defining (or changing) their own structure. The different levels of self-control are explained through the existence of components (sub-systems) whose functionality and knowledge needs are presented and discussed. The framework can be described as a model of the general architecture of a self-organized system.

ASSUMPTIONS ABOUT KNOWLEDGE

Organizations are the context where work is carried out. By work it is meant purposeful action, i.e., activities executed with the intention of contributing to some purpose or to achieve some goal. Purposeful action is performed by someone, or something, that will be called an agent.

It will be assumed that, in order to be able of acting, agents need knowledge. The definition of knowledge underlying this position will be broad. Knowledge includes whatever an agent
knows that enables her/him/it to carry out the activities she/he/it is supposed to perform. It can be related to knowing how to do something, knowing facts or events, past or future, or knowledge resulting from thinking, e.g., ideas, models, judgments.

The identification and explanation of the knowledge needs of active things - agents - will be done using the concept of system and other concepts developed by authors that propose systemic approaches to study the "world".

While talking about the knowledge needs of agents, it might be inferred that the term agent is standing for human agent. That isn't necessarily true, as it is recognized that there are agents capable of automatically performing operations upon knowledge representations. However, the ambiguity is intentional, as it allows eluding the discussion whether knowledge exists only in the human mind or it can also exist in non-human entities. Such discussion is considered to be out of the scope of this paper.

**SYSTEMS**

System is a concept that is useful to study active things, especially when they are complex. A system is the result of viewing the active world from a certain point of view. Any thing (and specially an active thing) can be viewed as being a system. A system (in general or in abstract) can be defined as an active, stable and evolutionary thing or object that operates in an environment with some purpose (Le Moigne, 1977).

<table>
<thead>
<tr>
<th>changed objects</th>
<th>form</th>
<th>space</th>
<th>time</th>
</tr>
</thead>
<tbody>
<tr>
<td>passive things</td>
<td>matter</td>
<td>transformation</td>
<td>transportation</td>
</tr>
<tr>
<td>energy</td>
<td>conversion</td>
<td>transportation</td>
<td>accumulation</td>
</tr>
<tr>
<td>information</td>
<td>processing</td>
<td>transmission</td>
<td>storage, memory</td>
</tr>
<tr>
<td>active things</td>
<td>systems</td>
<td>the alteration of a system addresses its structure</td>
<td></td>
</tr>
</tbody>
</table>

Table 1 - Conversions that a system can produce and the types of objects that can be altered; the table shows some words normally used to refer to some of the alterations

A system converts some input into an output. What is converted can be either a passive thing (material, energy or information) or an active thing, in which case what is being converted can also be considered as a system (cf. table 1).
In the first case (passive things), the conversion can change the thing in its form, in space or in time. In the second case, the alteration modifies the structure of the thing.

System is the nuclear concept of systems theory that can be viewed as a meta science as it can be applied in almost all the scientific areas. It should be noted that the adoption of a definition of system less strict than the definition provided above is frequent. To some authors, (e.g., (Ackoff, 1971), (Laszlo, 1983), (Boulding, 1985), (van Gigch, 1991), (Bunge, 1979), (von Bertalanffy, 1975), (Jordan, 1968)) a system is just something whose components are inter-related. The adoption of Le Moigne’s definition in this work is justified by the richness it brings to the systemic study of an object.

Simpler systems are mere active objects with no cognitive capacities. More complex systems are able of learning and making decisions and they can reach a high level of autonomy, i.e., they have independent existence, they are capable of governing themselves and surviving in a changing (and sometimes hostile) environment. Several authors recognize that systems can be more or less elaborate, and propose classifications of systems according to the level of complexity and characteristics they possess (e.g., (Boulding, 1956), (Boulding, 1985), (Ackoff, 1971), (von Bertalanffy, 1975), (Jordan, 1968), (Checkland, 1981), (Bunge, 1979), (Le Moigne, 1978), (van Gigch, 1974), (Laszlo, 1983), (Skyttner, 1996)).

Systems that are autonomous and viable are particularly interesting. Such systems are capable of existing with a high degree of independence from other systems and they are capable of surviving to hostile changes in their environment by adapting their behavior. Some of these are even capable of trying to improve their performance by changing their own structure (or organization) - the self-organized systems. A structure change may be achieved by means, such as: altering the communication patterns among the existing sub-systems; substituting some of their sub-systems by others capable of performing more effectively or more efficiently; adding or removing sub-systems.
SELF-ORGANIZED SYSTEMS

Self-organized systems are at the top of a hierarchy of systems whose classification criteria is related to the degree of control the system has upon its own actions. In this hierarchy, each level encompasses all the levels below it (see Figure 1).

Figure 1 - Hierarchy of systems according to the level of self-control; each system of a higher degree of control encompasses the system of lower degree of self-control (recursively)

The classification proposed in this work is inspired in a classification suggested by Le Moigne (Le Moigne, 1978) and it includes the following levels:

**Uncontrolled Active System**

An uncontrolled active system executes some processing, i.e., it converts the input into the output without any kind of control upon what is being done. This type of system will be called an *operator*.

**Self-Regulated System**

A self-regulated system is an active system that shows some regularity in its output in spite of the changes in its environment that affect its inputs. The system can be viewed as pursuing some objective.

To be capable of doing this, the system needs to have regulating mechanisms. Two components (sub-systems) can then be considered in the system: the operator and the *regulator*. The operator assures the conversion of inputs into outputs, as described in the
previous section (uncontrolled active systems). The regulator performs three functions: (i) measures the output produced by the operator; (ii) compares the value of the output with some reference value (the desired output, the objective); and (iii) acts upon the operator so the operator changes the way it acts in order to achieve the objective. The regulator has some decision capabilities as it is able of “deciding” what command to issue to the operator.

**Self-Directed System**

While a self-regulated system pursues some objective imposed by an external entity, a self-directed system has the capability of defining its own objective. This is achieved through the action of another sub-system – the director – that interacts with the operator and the regulator. The director pays attention to what is happening in the system's environment, what is happening within the system itself, and sets the system's objectives in such a way that its purpose is best accomplished.

**Self-Organized System**

The self-organized system has the capability of changing its internal structure in order to improve its efficacy and/or efficiency.

Besides the sub-systems that incorporate a self-directed system, the self-organized system includes another sub-system - the organizer. The organizer introduces changes in the system's structure that aim at the improvement of the system's performance.

Self-control of a system is related to its capability to adapt to changes in its environment. Self-regulated systems have only one adaptation mechanism: changing their behavior so their output remains as constant as possible (through the action of the regulator). Self-directed systems have a second adaptation mechanism: changing their objectives (through the action of the director). Self-organized systems have yet another adaptation mechanism: changing their structure (through the action of the organizer).
Looking inside a self-organized system it's possible to identify the other systems with lower control capabilities and all the sub-systems (components) referred to above. Figure 2 attempts to illustrate how these systems (and the different sub-systems that compose them) interrelate to each other.

![Diagram](image)

**Figure 2 - Major relationships between self-organized, self-directed and self-regulated systems:**
a self-organized system includes a self-directed system, which, in turn, includes a self-regulated system

**Self-Coordinated System**

Sometimes, the accomplishment of the conversions implied by a purpose demands the collaborative action of several operators, either because different skills are necessary or because there are available more than one operator with the same skills. The coordination demanded by such situation might be achieved through the action of another sub-system - the *coordinator*. The coordinator receives work requests from the system clients, plans the work sequence and distributes the available resources among the operators in such a way that the consumption of resources is minimized and the system performance is maximized. A system with the capability of coordinating the action of several operators will be called a self-
coordinated system. A self-coordinated system might be considered to exist within self-regulated systems and, therefore, also within self-directed or self-organized systems.

Components of Self-Organized Systems

The explanation of the behavior of the systems at the different control levels has been done using five components or sub-system types: operator, coordinator, regulator, director and organizer. These different sub-systems communicate to each other. However, most of the times, the communication among them is asynchronous, i.e., the emission and the reception of a message are not done at the same time. Moreover, a message is often directed to several receivers. These two characteristics of the communication among components lead to the emergence of another sub-system type - the informer. Informers perform operations such as: collect messages sent by the emitters (it is useful to consider that informers are also capable of collecting information from direct "observation"); store them in some orderly way (so they can be more easily retrieved when the receivers need them); transmit them to wherever they are required; make them accessible to the receivers; process the content and the format of the messages, so they can better fit the receivers needs, or they can be more easily understood by them.

It is interesting to note that regulators, coordinators, directors and informers are components that deal only with information (cf. table 1). Operators deal with any kind of object and organizers deal with active objects (which can be viewed as systems).

Table 2 summarizes the role played by each of the six components that have been identified indicating as well the objects they deal with.
Figure 3 attempts to illustrate the relationships among the different components (or subsystems types) identified above. The figure depicts a self-organized system $S$ which converts some input received from its suppliers into some output that is valuable to its clients. This work is carried out by the operators. Three operators are depicted in the figure - $O_1$, $O_2$ and $O_3$. The operators are coordinated by the coordinator $C$. The coordinator receives work/service requests from the clients through informer $I_1$. Based on the state of the operators - information obtained through the informer $I_2$ ($I_2$ also mediates the communication among operators) - the coordinator allocates workloads and resources to the operators. The results of the decisions made by the coordinator are communicated to the operators through informer $I_8$. The regulator $R$ monitors what is being done by operators (through informers $I_3$ and $I_2$) and sends its commands both to the coordinator and to the operators (through informers $I_7$ and $I_8$, respectively). The director $D$ pays attention to what is happening inside the system (through informers $I_4$, $I_3$ and $I_2$) and in the system's environment (through informer $I_5$) and sends its decisions to the regulator (through informer $I_6$). The organizer $ORG$ intervenes in $S'$ (a sub-
system of S) in order to change its structure so it can better respond to changes in its environment. Informer I9 mediates informal communication among any sub-systems (an example of such an informer is an e-mail service).

Figure 3 - Relationships among the different components
KNOWLEDGE NEEDS OF SELF-ORGANIZED SYSTEMS

The knowledge needs of a self-organized system comprise the knowledge needs of its components. Each of the six components identified in the previous section has its own kind of knowledge needs, depending on its functionality. The identification of their knowledge needs is based on trying to answer the question of what does each component need to know in order to be able of doing what it does?

Three types of knowledge will be considered: behavioral knowledge, factual knowledge and conceptual knowledge (this classification of knowledge is based on a classification of cognition proposed by Bunge (Bunge, 1979)):

i) **Behavioral knowledge** is knowledge about how to do something (know how), the knowledge that enables an agent to perform the conversion (i.e., producing the output) it is supposed to (what to do, what actions to undertake). This type of knowledge is therefore necessary to all the sub-systems types, although sometimes it is not easy to formalize and communicate. Behavioral knowledge can be presented as ranging from two extreme situations:

Explicitly embedded - the behavioral knowledge is embedded in a system's parts and their inter-action; it is not possible to change it without re-assembling the system, i.e., changing its parts or the way they inter-relate (an example of such situation is a mechanical device).

Tacit - It is not possible to articulate the behavioral knowledge; the agent is capable of acting although it is not capable of describing how she/he does it.

As an intermediate situation, behavioral knowledge can be articulated as a sequence of actions that the agent should carry out systematically and/or a set of rules that the agent should comply to.
ii) **Factual knowledge** is knowledge about facts (events or states), past or future\(^3\). The values of well established performance measures, are also considered to be factual knowledge.

iii) **Conceptual knowledge** is knowledge that result from thinking (e.g., ideas, models, judgments). It can correspond to classifications, subsumptions or theories that are developed by applying inference mechanisms to factual knowledge.

The knowledge needs of each component are discussed in the following sub-sections, based on the functionality they provide.

**Operator**

Operators carry out the conversions that make sense according to the system's purpose. Therefore, all of their characteristics are specific to a particular system and it is not possible to make any kind of generalization (table 3).

<table>
<thead>
<tr>
<th>Operator</th>
<th>Functionality</th>
<th>Objects dealt with</th>
<th>Inputs</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functionality</td>
<td>Executes the conversion that gives sense to the system's purpose</td>
<td>Material, energy and/or information or systems; depend on the system's purpose</td>
<td>Depend on the conversion performed by the operator</td>
<td>Depend on the conversion performed by the operator</td>
</tr>
<tr>
<td>Objects dealt with</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inputs</td>
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<td></td>
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</tr>
<tr>
<td>Outputs</td>
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<tr>
<td>Behavioral knowledge</td>
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<tr>
<td>Factual knowledge</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conceptual knowledge</td>
<td></td>
<td></td>
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</tbody>
</table>

Table 3 - It is not possible to generalize the knowledge needs of operators as they depend on the conversion it performs

**Regulator**

Regulators attempt to maintain some regularity in the result produced by operators. Regulators implement the action of a basic control loop: they "measure" the operators' performance and compare the obtained measure with some reference value; whenever the
operators' performance is different from a reference value, the regulator issues a command to the operators so they change their behavior in order to bring their performance closer to the reference value. Table 4 summarizes characteristics and knowledge needs of regulators.

<table>
<thead>
<tr>
<th>Regulator</th>
<th>Controls the action of operators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objects dealt with</td>
<td>Information</td>
</tr>
<tr>
<td>Inputs</td>
<td>Measure of operators' performance</td>
</tr>
<tr>
<td>Outputs</td>
<td>Commands to the operators</td>
</tr>
<tr>
<td>Behavioral knowledge</td>
<td>How to compare the &quot;measure of operators' performance&quot; with the &quot;performance reference value&quot; and what rules to follow after that</td>
</tr>
<tr>
<td>Factual knowledge</td>
<td>Performance reference value (objective)</td>
</tr>
<tr>
<td>Conceptual knowledge</td>
<td>No conceptual knowledge is considered to be needed</td>
</tr>
</tbody>
</table>

Table 4 - Knowledge needs of regulators

**Coordinator**

Coordinators receive work requests from the system clients, plan the work sequence and distribute the available resources among the operators in such a way that the consumption of resources is minimized and the system performance is maximized. The coordinators' outputs are commands to the operators. The commands issued by coordinators are different from those issued by regulators. They often have the form of work plans (e.g., operations schedules), budgets or any other way of representing resource allocations.

To make their job, coordinators must combine factual knowledge about the work situation (available resources, work being carried out, work models) with conceptual knowledge that addresses the way work can be optimized. Optimization models such as those developed in areas related to scientific management (e.g., operations research, optimization) are examples of these models.

The behavioral knowledge needed by coordinators corresponds to how to combine factual knowledge with the optimization models in order to make the decisions that will lead to the
work plans and resource allocation plans. Table 5 summarizes characteristics and knowledge needs of coordinators.

| Coordinator       | Functionality                                                                 | Objects dealt with                  | Inputs                                           | Outputs                                                                                       | Behavioral knowledge                                                                                   | Factual knowledge                                                                                     | Conceptual knowledge                                                                                     |
|-------------------|-------------------------------------------------------------------------------|-------------------------------------|-------------------------------------------------|---------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|
|                   | Coordinates the action of several operators that have to cooperate in order to | Information                         | Requests from the system's clients               | Commands to the operators; these commands are often represented as plans, budgets and other way of representing resource allocation to operators | How to combine factual knowledge with the optimization models in order to make the decisions that will lead to the work plans and resource allocation plans | Existing operators, their competencies, states, and average performance | Decision models (optimization models)                                                                   |
|                   | fulfill the system's purpose and to achieve the system's objectives           |                                     |                                                 |                                                                                             |                                                                                                       | Available resources (other than the operators)                                                          |                                                                                                       |
|                   |                                                                                |                                     |                                                 |                                                                                             |                                                                                                       | Process models (models of the operations necessary to produce the system's output)                     |                                                                                                       |
|                   |                                                                                |                                     |                                                 |                                                                                             |                                                                                                       | Current jobs under operation and their state                                                             |                                                                                                       |

Table 5 - Knowledge needs of coordinators

**Director**

Directors define the objectives to be sought by the system in such a way that the system's purpose is pursued. The objectives are sent to the regulators that will then use them as their reference value. The inputs of a director (cf. table 6) can be viewed as information about the outside (system's environment) and the inside (the system). This information is not restricted to recent events and current states because the director also needs to be aware of any kind of change patterns and evolution trends. This implies that the director is capable of remembering past events (both internal and external), and subsuming these events and their occurring sequence to identify change patterns and evolution trends.
To make decisions, directors use conceptual knowledge that corresponds to cause-effect relationships that involve factors both internal and external to the system - decision models. Directors might obtain this knowledge by different ways. They can get it from outside the system, either by hiring people that know it or by acquiring research results. They can also develop this knowledge internally, by engaging in any kind of research activity (e.g., marketing research) or by induction, from the system's past experience. To be able of inducing this knowledge directors must have advanced reasoning capabilities. They should be capable of remembering past events and states, and the results of decisions made in the past, and also capable of inferring causal relationships based on those facts. Decision models help directors to foresee the likely outcome of their actions, i.e., the decisions they might make.

Decisions are made aiming to contribute to the accomplishment of the system's purpose. So, directors must know the purpose of the systems they direct. The system's purpose is classified as factual knowledge\(^4\).
In what regards behavioral knowledge, the knowledge needs of directors correspond to how to carry out the cognitive operations related to how to subsume information about the system and its environment in order to identify change patterns and evolution trends and how to use decision models in order to foresee the actions that best contribute to the accomplishment of the system's purpose. Table 6 summarizes characteristics and knowledge needs of directors.

**Organizer**

There is a major difference between organizers and directors, coordinators and regulators. While the latter deal with passive objects, the former deals with active objects. The job of organizers is to change an active object in order to improve its performance. Therefore, the input of the organizer is the active object to be changed and its output is the changed active object.

As an active object can be viewed as a system, most of the times, the organizer creates models (systemic models) of the object it has to change and works upon these models. Initial models
correspond to the object "as it is" while later models correspond to the object "as it is sought to be". At some point in time during the change process, there is some work that attempts to make the object being changed to become as described in the "as it is sought to be" models. These models correspond to what has been thought as the most adequate way of organizing the object in order to improve its performance or to solve the problems that led to the organization action. So, during its action, the organizer creates knowledge about the active object being dealt with. Most of this knowledge can be classified as factual (resulting from perceptive activities carried out upon the object, such as models of its structure or its processes) although some conceptual knowledge might also be created. Besides the knowledge created during the change process, organizers also need the following knowledge:

  Factual knowledge - what is the system's purpose; system's performance; major problems within the system;

  Behavioral knowledge - knowledge corresponding to the change methods the organizer uses to carry out its job; it includes aspects such as how to carry out the change or how to model the object being changed;

  Conceptual knowledge - theories about organization and about change processes; this knowledge helps the organizer to foresee the likely outcome of the change decisions it might make.

Table 7 summarizes characteristics and knowledge needs of organizers.
**Organizer**

<table>
<thead>
<tr>
<th>Functionality</th>
<th>Introduces changes in the structure of an active object in order to improve its performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objects dealt with</td>
<td>Active objects</td>
</tr>
<tr>
<td>Inputs</td>
<td>The active object to be changed</td>
</tr>
<tr>
<td>Outputs</td>
<td>The changed active object</td>
</tr>
<tr>
<td>Behavioral knowledge</td>
<td>Change method</td>
</tr>
<tr>
<td>Factual knowledge</td>
<td>The system's purpose, performance and major problems</td>
</tr>
<tr>
<td></td>
<td>Other factual knowledge created during the change process: models of the system's structure and processes</td>
</tr>
<tr>
<td>Conceptual knowledge</td>
<td>Theories about organization and change processes</td>
</tr>
</tbody>
</table>

Table 7 - Knowledge needs of organizers

**Informer**

Informers mediate communication among the other sub-systems types and they can also perform perceiving activities, i.e., they carry out operations of information collection through the use of some type of sensor. To carry out those activities they collect, store, retrieve, transmit and deliver information. So, the inputs of an informer are messages or perceptions and their outputs can also be described as messages.

It is reasonable to consider that informers need to know the structure of the information they deal with. Such knowledge can be classified as conceptual knowledge as it results from some kind of reasoning about the structure of the information it deals with. Moreover, informers also need behavioral knowledge corresponding to how to perform the collection, storage, retrieval, transmission and delivery actions. Factual knowledge might be necessary for security reasons. Examples of such knowledge include the emitters from whom the informer should accept messages or the receivers to whom the informer is allowed to send messages. Table 8 summarizes characteristics and knowledge needs of informers.
<table>
<thead>
<tr>
<th>Informer</th>
<th>Mediate communication among the other sub-systems types and collect information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objects dealt with</td>
<td>Information</td>
</tr>
<tr>
<td>Inputs</td>
<td>Message or perception</td>
</tr>
<tr>
<td>Outputs</td>
<td>Message</td>
</tr>
<tr>
<td>Behavioral knowledge</td>
<td>How to perform the collection, storage, retrieval, transmission and delivery actions</td>
</tr>
<tr>
<td>Factual knowledge</td>
<td>For security reasons: emitters from whom the informer should accept messages or the receivers to whom the informer is allowed to send messages</td>
</tr>
<tr>
<td>Conceptual knowledge</td>
<td>Models of messages’ structure</td>
</tr>
</tbody>
</table>

Table 8 - Knowledge needs of informers

**Learning Activities within a Self-Organized System**

None of the actions performed by any of the components described in the preceding sections addresses the issue of knowledge acquisition or development. However, it is logical to admit that operators, coordinators, regulators, directors, organizers and informers are able of improving the way they act by developing the knowledge they use to act, i.e., by learning. So, it is reasonable to consider that, within any of those system components, there are learning activities that are carried out simultaneously with the activities directly related to the role they play. These learning activities can address any of the knowledge types considered: behavioral, factual and conceptual.

Developing behavioral knowledge is often a matter of perfecting the way of doing something resulting from doing it repeatedly. It can also be attained through the adoption of new and better ways of accomplishing one same task (this strategy demands attention to how the task is being performed in other systems and also to technological innovation).

The development of factual knowledge is related with the capacity of remembering a larger amount of facts. This can be succeeded by paying attention to more facts (i.e., by improving perception mechanisms) or by improving the increasing the capability of remembering (i.e., by improving the memorization mechanisms).
Developing conceptual knowledge is perhaps the most interesting situation. It involves the application of inference mechanisms to empirical data in order to improve the existing classifications, subsumptions or theories. The data necessary to perform these reasoning operations is made available by the informers, whose role is to systematically collect and store them.

**CONCLUSIONS**

The knowledge needs of self-organized systems have been presented as the combination of the knowledge needs of several components whose combined action confer the system with the capability of adapting to external changes, not only by changing its behavior or its objectives but also by changing its own structure.

The presentation suggests that the six sub-systems types and their knowledge needs are *necessary* and *sufficient* to endow a system with self-organizing capabilities.

It should be noted that the self-organized systems model presented in this work, results from a conceptualization based on a combination of systems theories. Its aim is to provide a framework for understanding complex systems. However, this framework demands experimental validation. Two approaches are being considered to carry out such validation: field studies and simulation using a computational environment based on intelligent agents.

The former involves the study of organizations in order to identify the sub-systems and their interrelations and to compare them with the model described in this work. However, difficulties in such task can be anticipated, namely the complexity arising from the existence of interactions and behavior that result from work dimensions other that those directly related with a pure rational view of work (Santos & Carvalho, 1998). So, the second validation approach turns out to be more promising. Although constituting an artificial setting, it enables the execution of laboratory experiments that are immune to influences from non-controllable factors related to human-behavior.
Other possible research paths address aspects related to extensions and comparisons of the proposed model. The existence of knowledge manipulation activities imply the existence of cognitive capabilities. The identification of the necessary and sufficient cognitive capabilities for each component is a side aspect of the model that can be further explored. On the other hand, it would be interesting to compare the model with other models that also propose architectures for complex systems. Among such models it is worth to refer to Stafford Beer's viable system model (VSM) (Beer, 1984), (Espejo & Harnden, 1989).

REFERENCES


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1 This perspective on *self-organized systems* results from trying to explain some pattern of behavior of a system by examining its interior and looking for the components that confer the system the ability to behave the way it does. The concept of *self-organizing systems* is normally used to refer to some pattern of behavior exhibited by a society of similar systems that results from their spontaneous interaction and not from the action of control mechanisms that compel the system to seek some goal.

2 In Le Moigne's classification, the top level of the hierarchy is filled by systems that are able of defining their own purpose. It can be considered that such systems pursue *immortality* as they admit to change radically (their purpose) in order to maintain their existence. However, this poses some problems as the change of purpose of a system is perhaps best described as the disappearance of a system and the rise of a new one. As this question is considered out of the scope of this work, such systems won't be considered.

3 Future events or states, either sought or foreseen.

4 Directors must also know facts about the system and its environment. However, such knowledge is described as constituting the input of a director and not as factual knowledge she/he/it must know beforehand.