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A SYSTEM THEORETICAL APPROACH TO SITUATION AWARENESS AND ITS APPLICATION– A HOLISTIC VIEW OF PURPOSEFUL ELEMENTS

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ABSTRACT: This paper executes a comparison of the theories by Ackoff and Bedny & Meister for situation awareness (SA). The comparison gives a conceptual design for the common part of SA. An example of an architecture that uses the concepts is presented. The conceptual design involves concepts like conscious and unconscious processes, gnostic activity, active and passive memory and dynamic processes. The design captures the ideas presented by Ackoff for adoption and learning, and is intended to work with social systems as described by Ackoff. The aim of the paper is to fill the hole of conceptual general designs for SA systems.

This paper presents a conceptual definition of SA and the comparison result between the two theories. The conceptual design is then used in the development of an Agent Architecture for Multi-Hypothesis Intention Simulation. Suggested future research is presented.

1. Introduction

"The change of change" as Ackoff [1] puts it, is implicating that change is in a constant change. The change is making it harder to make decisions, because the decision-maker does not know what to look for. What was relevant for a decision a time ago have no guarantee to be relevant for decision-making now. In the quest of making as good decisions as possible, decision makers often are presented with all known information. Even if the information is not of any known use for the decision, it is presented to the decision maker, in the misbelieve that the more information the decision maker has, the better decision is made[1]. As a result of the massive information set, the decision maker has to make filtering of what information might be of importance according to decision to make. Because of the limited time, this work is often delegated to other people of the organization. Computers can be used to help with the filtration. The field of data mining and data warehousing is example of computerized information gathering from cooperative and domain data, to make better information for the decision making. This process involves concepts like categorization, grouping, aggregation, summarization, etc. When computers are used as a tool in the filtration process, someone has to tell the computer what to look for. The computers often use pattern matching in the filtration process, matching is done against some known pattern to find similar patterns in the data store. In the filtration process the computer has no understanding for the situation of the data or the situation of the decision-making. The filtration process is just searching for patterns in the data store or environment to find the data of interest [2].

When the whole process of decision-making is to be automated it is the computers that will be in the position of deciding what to look for. This demands that the computer has an understanding of the nature of the decision and what will effect the decision. It is no longer sufficient to match patterns; the computer must be able to reason about the situation. It is a difference between pattern matching and reasoning systems [3]. When pattern matching is used there is often no understanding about the function of the properties and how they affect each other. The properties are just monitored to match a certain pattern. In reasoning systems the elements are understood as goal seeking systems. The properties of the elements are monitored and are used to understand the goal of the element. The understanding about how the different properties of the environment and other elements in the system affect the goal of the element is the main concern[1].
According to Ackoff [1] humans have to be seen as systems with own goals (because of the feature of choice and purposeful systems) not as deterministic machines. This puts a little twist to the understanding of system where humans are involved. A system that at a first glace seems to be totally mechanical and deterministic often involves humans as decision makers, for a part of the system or for the whole system. So to understand the system the goal of the human has to be determined and evaluated in the process.

Systems that have humans (purposeful system) as parts are what Ackoff name social system. Ackoff [1] further claims that the result often is incorrect when a system is described with models intended to describe other types of system. In other words a social system should be described as a social system with models indented for this description.

This paper assumes the theories and thoughts of Ackoff [1] for system theory and Situation Awareness (SA). SA is the process to be aware of the current situation.

In this paper two system theoretical approaches to SA, orientational activity [4] and adaptive-learning management system [1] are compared. Orientational activity is one of three dominant theories in the field of human cognition for SA [5], and adaptive-learning management system is the design by Ackoff [1] for a management system.

2. Background

In this section adaptive-learning management system [1]and orientational activity [4] are presented.

2.1 Adaptive-Learning Management System

The three functions presented by Ackoff [1] of the management of an organization ((1) identification of actual and potential problems, (2) decision-making and maintenance and (3) improvement of performance under changing and unchanging conditions) are implemented in the adaptive-learning management system as subsystems, each responsible for a function. Ackoff [1] has identified that there is a requirement of continuous supply of information for these function, so a forth sub-system is also presented, the management information subsystem. The design of the adaptive-learning management system is presented in Figure 2.1.

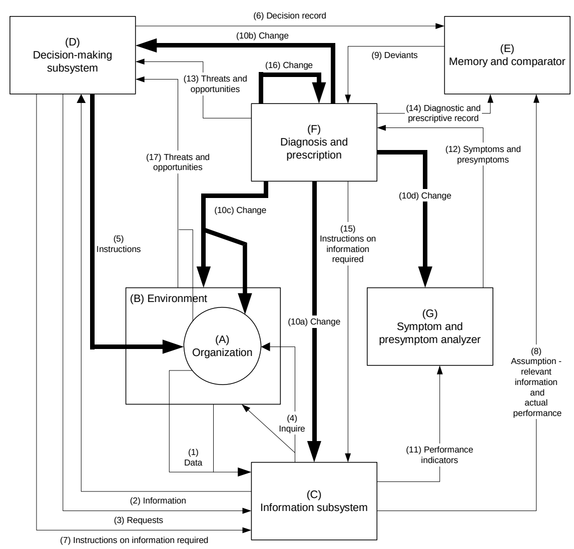

Figure 2.1 Adaptive-learning management system, after Ackoff [1].

The numbers and letters used in Figure 2.1 are the same as in Ackoff [1] the numbers are kept to help to clarify the flow of data/information. The numbers and letters are used in the text to reference to the different associations and elements of the system.
To generate data the management has to observe the organization and its environment. In this design this is handled by the information subsystem (C). For the data (1) to be useful for the organization it has to be processed, the processed data Ackoff calls information (2). Data is signs and symbols representing features of elements and events, information is also signs and

symbols, but of higher importance for the decision-making. The process of making information from data can be done by filtration, aggregation, summarization, etc. The information is then sent from the information subsystem (C) to the decision-maker (D), which makes a valuation of the information (2). The information can be accepted, or needs to be complemented, so the management asks for more information from the information subsystem. The decision-maker may find it hard to understand the information even if it is correct. This can lead to a request (3) for more or new information (revision of information) from the information subsystem. This request of information from the decision-maker to information subsystem makes two requirements on the information subsystem. First it need to be able to examine the organization and its environment, and second it need to be able to reuse the data and information generated earlier. In other word a data store is required. The information subsystem delivers the new requested information (2) to the decision-maker, who again makes a judgment. This can result in a new request (3) of information. The delivery of information and the request for new, results in an information-request cycle. This will finally stop, either because the decision-maker is satisfied or because there are no time left. After the stop of the cycle a decision is made by the decision-maker that results in an instruction (5), which is intended to change the behavior of the organization or parts of it.

2.1.1 Decision-making

A decision is made to make something occur that should not else occur or to make something not to occur that should else occur. In both cases there is an expected result in a time interval. To be able to monitor the decision it is important that the expected result and the time-interval are accounted for. These are saved in the decision-protocol (6) together with assumptions, information, and the process used to make the decision. The protocol is saved in the inactive memory (E).
To be able to make the evaluation, instructions (7) are sent to the information subsystem to deliver the needed information to the memory (E). Information about the state of the organization and the outcome of the decision (8), according to performance and assumptions, is sent to the memory (E). In the memory the information from the information subsystem about the decision is compared against the decision-protocol (6). If there is no difference noting is done, but if there are, this is reported and noted (9). To clarify the difference and why this is, a diagnostic (F) is needed. The diagnostic is to propose corrective and explorative actions for the system.

2.1.2 Threats and opportunities

Threats and opportunities can be reported to the decision maker from external or internal sources (17), but they can also be detected by the management information system (13). First the symptoms have to be identified, and then they are synthesized and diagnosed. Symptoms seldom occur under “normal” states, they often occur when something is wrong or exceptionally right. Symptoms are often associated with something bad, but can as well be something good. To determine what is normal statistical methods are used, the state of the system can then be compared with the normal state to detect the abnormal. Variables for behavior and performance often are used to determine the symptoms. These variables are also used to determine pre-symptoms or omens. With pre-symptoms Ackoff [1] mean something non-random normal behavior, which is something that follows a pattern, a trend or a cycle etc. These are easily identified with statistic testing. It is the responsibility of the information subsystem to obtain and provide the symptoms and pre-symptoms (11), what Ackoff [1] referees to as performance indicators. The performance indicators are then sent to the symptom and pre symptom analyzer (G) for further analysis. The performance indicator should be obtained regularly. As a result of the analysis by the symptom and pre-symptom analyzer (G) symptoms and pre-symptoms (12) are found. These are sent to the diagnostic function (F) to obtain threats and opportunities (13). When symptoms are obtained by the diagnostic these should be reported to the decision making subsystem (D), in the same manner as with the decision record a diagnostic and prescriptive record (14) should be sent to the memory (E) for comparative actions against the information sent by the information subsystem (15). If derivation are identified these should be sent to the diagnostic and prescriptive subsystem, deviants (9). The diagnostic and prescriptive subsystem (F) is then responsible for making changes to the subsystems (10a-10d) and to the diagnostic and prescriptive subsystem (16). According to Ackoff [1] it is from the change of the subsystems and the diagnosis process that the system learns how to learn and adapt.

In the design discussed above Ackoff [1] identifies three levels of control; (1) the system as a whole controls the organization of which it is a part, (2) the diagnostic and prescriptive subsystem controls the management system, (3) the management system controls itself. Next the orientational activity is presented.

2.2 Orientational Activity

Bedny & Meister [4] presents interactive sub-systems as a system theoretical description of SA; it is based on the Russian theory of Activity, known to the western world first in the 90's. To help to understand the interactive sub-system approach some basic concepts of the Activity Theory (AT) are presented. AT try's to explain the human psychological-process in a system theoretical way. According to Bedny & Meister [4] the activity can be psychological, internal, or it can be practical, external. An activity is directed to achieve a particular goal. The method to reach the goal can be changed during the activity because of the increasing knowledge about the situation and its features. The participator can change his behavior in the activity to achieve an accepted goal. This view of self-regulation is not a homeostatic self-regulation, but a goal driven self-regulation process. Within the situation the participators can develop their own goals [4]. Bedny & Meister [4] claims that an objectively given goal is interpreted in a subjective way. Where the past experience of the person and the significance of the goal for the person are affecting the interpretation of the given goal. The given goal and the percept goal are not always synchronized.

Bedny & Meister [4] presents three levels of activity in AT; orientational, executive and evaluative. In the orientational component the person develops a subjective model of the reality, from which different conclusions is drawn. As a result a dynamic image of reality is developed which results in a meaningful and coherent images of reality and expected future situations. This component includes explorative elements that can be internal (mental) or external (practical), and according to Bedny & Meister [4] it includes what Endsley [6] defines as SA (as a part of the function block subjectively relevant tasks condition). The orientational component of activity includes both conscious and unconscious elements and mechanisms that enable the individual to extract both stable and dynamic elements from the situation [4]. The future state of the situation is not only dependent on the current state of the situation, but also on the goal and significance of the situation for the individual, and how the elements of the situation are manipulated. If there is a disturbance in this level it affects the two other levels [4].

According to Bedny & Meister [4] the executive level brings change to the situation in direction to the desired goal. The executive level includes decision-making and performance of action. The evaluative level brings an evaluation of the action through a feedback-loop. The result is then used in decision making for correlation of action, and can affect both the orientational and executive levels.

2.2.1 Reflective-orientation

In this paper the focus is on the orientational component of AT which has various mechanisms that provides not only conscious but also unconscious reflections of elements of the situation [4]. To further examine the orientational component the philosophically important principle of AT, the psychic process of the reflective-orientational component of activity is presented. To describe reflection Bedny & Meister [4] present the following schema:

Reflected object → Reflected system → Reflected representation

The mental representation of reality, reflection, depends not only on the reflected object but also on the features of the situation. It involves concept like goal, significance, motives, mental and behavior actions, that is the concepts that are of great importance in AT. Bedny & Meister [4] claims that it is therefore not possible to solely explain the situation from the position of the traditional information processing theory. From the position of AT the individual makes a sequence of explorative action in an attempt to understand the features of the situation. These actions are called gnostic activity according to Bedny & Meister [4]. In the gnostic activity the individual develops task-problems that aim to get a deeper understanding of the situation. These activities can have separate goals, motives and mental and physical actions. Gnostic activities can be trigged automatically for example in an emergency situation, even when the purpose of the activity is positive, the result may not be. It may result in lower reliability of the performance [4].

According to Bedny & Meister [4] the reflection of the situation in AT is provided not only by memory and attention but also by operative thinking. The individual has a constantly changing internal reflection of the same external situation. This process of continual change of the external situation in the mind (internal process) of the individual is according to Bedny & Meister [4] the gnostic dynamic. The gnostic dynamic is an important element of the self-regulation process [4].

2.2.2 Information processing

SA is one of the important elements of reflective-orientation activity; the other is cognitive analysis [4], which requires a description of the AT definition of information processing.

This process is divided into three levels, sensory-perceptual, imaginative, and verbal-logical. At the sensory-perceptual level the data from the sense organs are influencing the imaging process. This results in a sensory-perceptual image during perception. At the imaginative level images are developed from imagery memory. The process provides derivates from old images as result of a compare. The comparison process is not directly influenced by the sense organs. The images at this level are less precise but they have some advantages. During perception common features of a group of different objects in the same category can be identified. As a result incorrect features are filtered out and the more important features are saved in memory. The feature of the perception process to work with images contributes to execute activities on images. The verbal-logical thinking level contributes with the knowledge that is learned from the work with symbols and signs to solve problems [4].

Bedny & Meister [4] claims that the three levels of reflection are closely bound and are constantly evolving into each other. All these three levels of reflection involve both conscious and unconscious processes [4]. The images has an important part in the goal anticipation because of their ability to express not just what is presented to the sense organs at the moment, but also what happened in the past and what can be expected by the future. This in turn is an important part of the decision maker’s function.

The internal process is performed highly with images, the task requirement is often presented in the form of images, and as discussed earlier the manipulation with the situation is preformed mainly with images. The goal is formed in image-goal; future results are represented in the form of images, with less emphasis on the verbal-logical first presented by [7] and referred in Bedny & Meister [4]. The activities performed by individuals are a mix of logical and image components, where the image-component is that of higher importance. All tasks include both condition and requirement; these are often presented as images [4]. According to Bedny & Meister [4] there is a difference between objectively given goals and subjectively given and developed goals. The past experience of the individual is effecting the interpretation of the objectively given goals. The acceptance of the goals by the individual, are of great importance in the process of self-regulation. The goal is not just dependent on the objectively given task requirements, but also on the significance of the goal to the individual. The notion of the mental model as presented by [8] according to Bedny & Meister [4] is another widely used notion in AT, it is learned as an internal component of activity. In the mental model the individuals “internal world” is presented, and is separated from the informational model, the objectively presented information. The conceptual model is not dependent of a specific task and can therefore be presented in advance of activity [4]. The individual may at every moment make conscious what is relevant for the task. To present what is relevant for the moment the operative image is presented, reflecting only the relevant elements of the situation for the individual (for more information about operative images see [9]. This can involve task and situation images. With the task image, regulative functions are preformed and with the situation image, orientational functions are preformed [4]. The individual is just capable to make a small part of the images conscious. It is the attention that makes what is potentially conscious, to be conscious [4].

2.2.3 Functional model of orientational activity

The model developed by Bedny & Meister [4] is presented in Figure 2.2. Only the activities that precede the execution of action are discussed, to keep the focus on the SA aspects of AT. The functional model is based on the functional analysis, which builds models of goal self-regulation that can be seen as dynamic organizations. The psychological concepts such as memory, thinking, etc. are not discussed because these are to be involved in different ways in the function blocks and are not of interest in this stage of analysis.

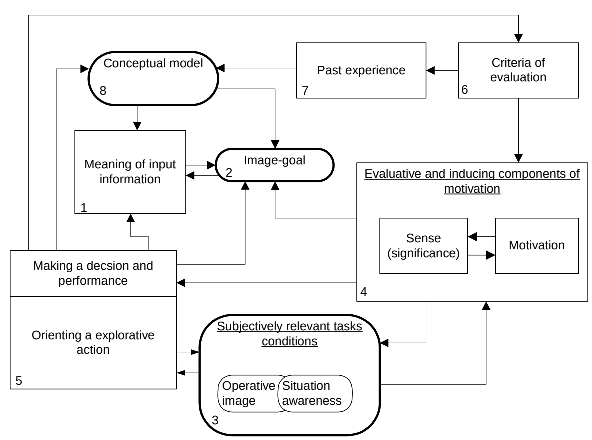

Figure 2.2 the functional model of orientational activity, after Bedny & Meister [4].

All the function blocks in the diagram are connected either through feed-forward or feedback loops. In the first block the information received by the individual is preceded. According to Bedny & Meister [4] interpretation of the information is highly dependent on the past experience (block 7) and the conceptual model (block 8). The individual learns to work with symbols and signs, and to do responding activities to these. According to Bedny & Meister [4] the individual need to have professional experience and knowledge to ensure the proper interpretation of the information. Bedny & Meister [4] further claims the interpretation also is dependent on the image-goal, the goal (block 2) of activity and the motivation (block 4) connected with it. During the interpretation of the information in block 1, the meaning represents reality in consciousness. Both in cognitive psychology and in AT the objective meaning (logical meaning) are distinguished from the meaning of the individuals experience (psychological meaning[10]]) [4]. The meaningful interpretation done in block 1 is reflected in the formation of the goal (block 2). Function block 2, image-goal, is an informational block of activity containing the accepted goal (in the form of images) by the individual. The goal is described as the expected future result of activity. The interrelation between block 2 and 4 (motivation and energy component of activity) is described by Bedny & Meister [4] as a vector that gives the self-regulation a goal-directed feature. The higher the motivation, the more mental and physical effort the individual uses to direct toward the achievement of the goal. Function block 4, the motivation of activity, is divided in two sub-blocks, sense and motivation. Sense is the cognitive-emotional component of evaluation and is linked with the subjective significance of the goal. According to Bedny & Meister [4] motivation determines the directedness and energy for the activity to achieving a specific goal. The two sub-blocks are closely interconnected. The factor of significance is influencing the method of interpreting the information; this is represented in the diagram in the interconnection between block 4 and block 1 through block 5.

Block 3, subjectively relevant task conditions, is another component that according to Bedny & Meister [4] is important in the function of dynamic reflections of the situation. The block includes both conceptual (SA) and image (operative images) components of activity that overlap and together provides a more dynamic reflection of reality. The SA component of block 3 includes a logical and conceptual subsystem of dynamic reflection; in these subsystems the individual is very conscious of information processing. Bedny & Meister (1999) claims that this is also true for the information processing in the overlapping part of the sub-blocks of block 3. The functions of the SA sub-block are preformed by switching from one feature of the object to another. The result is then compared with the goal of the individual, and if required, it can change the activity. Block 3 has the ability to affect the goal (block 2), through block 5 and 4, and if necessary correct it. Block 3 does not just bring orientation in the situation at any time but also brings the ability to make reflections about future states of the situation.

This reflection is done internally, to a large extent unconscious and trough the manipulation of internal images. This process can be enriched with additional data from internal and external sources [4]. According to Bedny & Meister [4] this manipulation is easily forgotten because of the difficulty of verbalization. The part of the imaginative reflection that does not overlap with the SA reflection can be considered preconscious reflection. These reflections can become conscious through a change in the situation, a shift in attention or an increase in will. According to Bedny & Meister [4] this may be reflected in the individual by “vague feelings”, these should also be able to affect conscious components. Bedny & Meister [4] are referring to research preformed by [11] and [12] about solving problems. In the result of this research certain dynamic elements of the situation were discovered, “nonverbalized meaning of the situation” or “situation concept”. According to Bedny & Meister [4] these can be of greater importance than the verbalized components. The individual can from the same situation extract verbalized and non-verbalized meanings in the process of solving a problem. This is most apparent in virtual tasks. Bedny & Meister [4] claim that it because of this block 3 is involved in the dynamic reflection of the situation and the constant transformation of the information on conscious and unconscious levels according to the goal. The aspects subjectively significant to the individual, and represented in the dynamic reflection of the situation, are not always objectively important. According to Bedny & Meister [4] the dynamic reflection of the situation can lead to disturbance of the internal model.

The dynamic reflections of the task can also affect the subjective evaluation of the significance of the situation. The mental model of reality is influenced by the conceptual model (block 8), image-goal (block 2) and subjectively relevant tasks condition (block 3). This defines the mental model from an activity point of view as a complicated three-component structure.

Bedny & Meister [4] claims that in simple situations the unconscious functions can bring a dynamic recognition of the situation. In more complicated situations the direct understanding of the situation may be impossible. The gnostic activity performs explorative functions of the situation to increase the understanding of the situation. The gnostic activity includes mental transformation, decision-making and so forth.

According to Bedny & Meister [4] SA in AT is seen as a goal driven self-regulation process preformed by internal logical and imaginative processes. These processes can be both conscious and unconscious.

3. Problem specification

Even though both of the theories for SA ([1], [4]) are based on system theory, they are intended for different fields. Orientational activity is intended for describing the internal process that a person is presuming to reach SA, and adaptive-learning management system is intended for the management of an organization to do the same. Both of the theories have parts that cannot be found in the other theory. This is because the theories are to describe SA in different fields. Even though the difference in fields there are common aspect according to SA that can be compared. The comparison is focusing on these parts that are common for both of the theories (the intersection of the theories).

In this paper the focus is on the process to achieve SA. The differences between orientational activity [4] (as the most accepted system theoretical theory to describe the process of SA in the cognitive field) and adaptive-learning management system [1] (as assumed theory) are studied. The differences are analyzed and understood. With contribution from both of the theories, a conceptual design for a SA component is designed and discussed. The resulting design is a general SA system. The system is not intended for any specific field. The system that is observed is assumed to be a social system. The process of understanding the situation, the SA of the system, is considered in separation from the decision making process.

The design presented is filling the need of a general design of a SA system. The key concepts of the design are presented, and some are highlighted for further research. The problem results in two objectives presented next.

3.1 Objectives

The problem specification is resulting in two objectives:

- Discuses a conceptual model that is influenced of orientational activity and adaptive-learning management system.

- Identify future research areas.

4. Conceptual system for Situation Awareness

In this chapter the result of the first objective is presented. From the comparison performed in [13]some key functions have been identified. As a summary of the comparison of the two theories, adaptive-learning management system and orientational activity, the result of the discussion is put together to form a system of function blocks. The function of the blocks could be found in both of the theories. In Table 4.1 it is shown how the functions of the two theories are divided in the conceptual design.

Table 4.1 Result of comparison of adaptive-learning management system and orientation activity from [13].

Orientational activity	Management information system	Conceptual system
Meaning of input information	Information subsystem	Data gateway
Evaluative and inducing components of motivation	Memory and comparator	Evaluative system
Conceptual model, past experience	Memory and comparator	Memory
Image-goal	(Decision-making subsystem)	Goal
Making a decision and performance	Decision-making subsystem	Perform
Subjectively relevant tasks conditions	Symptom and pre-symptom analyzer, Diagnosis and prescription	Diagnostic

In the next coming subsections a discussion to clarify the function and connections of the function blocks in the conceptual design is executed. The subsections are divided by function block. Last in the section the conceptual design is presented in a diagram (Figure 4.1) to clarify the relations between the different function blocks of the SA system.

4.1 Data gateway

From the comparison made in [13] the function of the data gateway is identified. The data gateway gives the system a central information system that from past experience makes a translation of the symbols present in the system and its environment to information. The main function of the data gateway is to observe and inquire data from the environment and the system. This data is then processed in the influence of the past experience of the memory block and the goal block. The influence by the goal gives the goal driven interpretation of data.

The perform block may require new data, as the data available is not understood or is not sufficient. The request made by the perform block should result in an information loop, inquiring of data, transforming data to information and finally deliver the new information to the perform block. The required data store to keep track of the earlier processed data of the data gateway is kept in the memory block. The data store is needed by the data gateway to keep track of earlier made processes to process new data. When a decision is made the data gateway should send the required data for the monitoring of the decision to the memory block.
The inquiring of data should be directed by the attention (at least for the conscious process) that is part of the diagnostic function block. The shared attention puts a demand of synchronization and communication between the data gateway block and the diagnostic block.

4.2 Evaluative system

The evaluative block gives the system the regulative behavior. The decision records should be constantly analyzed by the evaluative system to determine eventual deviants between the assumed result and the actual result. If deviants are found, these should be passed to the diagnostic block for further analyze. The evaluative system should also bring the motivation and sense, discussed in Bedny & Meister [4], to the system. In the interaction with the goal a vector is formed that brings goal driven self-regulation behavior to the system. The evaluative block should have two subsystems, motivation and sense; these should have the same function as in OA, to bring regulation of the energy to achieve the goal.

4.3 Memory

The system should have a shared memory. The memory should have its own function block to clarify the importance of the memory in the system. The memory has both an active part and a passive part. The active part is under constant evaluation by the explorative processes of the diagnostic function block (the memory of subjectively relevant tasks conditions of orientational activity). The passive memory is the passive parts (conceptual model) of what Bedny & Meister [4] names the mental model that among other things keep the schemas and scripts. Separated from the mental model the informational model exists representing the objectively given information. The information stored in memory should in a high degree be stored in form of images [4]. The memory also stores the past experience of the data gateway block and the assumptions made at decision-making, the decision record produced by the data gateway. The decision record should be constantly analyzed by the evaluative system to determine eventual deviants in assumption against result. If deviants are found, these should be pasted to the diagnostic block for further analyze.

4.4 Goal

Both Ackoff [1] and Bendy & Meister [4] conclude that the goal of the system is variable over time. The goal affects the whole system, and is affected by the motivation of the evaluative system and by the input to goal from the perform block. The goal function block gives the system a goal driven self-regulation behavior. The goal is stored in a form of an image.

4.5 Perform

From the comparison made in [13], four products of the perform block were identified:

- Instruction of change.
- Affecting of goal.
- Request of information.
- Criteria of evaluation.

The decision made by the perform block results in an instruction to the system to change and a criteria of evaluation (decision record) in the same manner as in the design presented by Ackoff [1]. The criteria of evaluation are used by the evaluative system to control if the instruction gives the expected result. The criteria of evaluation should contain the process by which the instruction where decided, the assumptions made during the process, the information used in the process and the expected result. Even though it is agreed that SA and decision-making should be separated, it is obvious that there should be a close relationship. The decision-making is in control of the SA system in two ways, (1) the information for making a decision is presented by the SA system and (2) the process of the decision-making is guided by change requests of the SA system. The decision will also affect the goal of the system. The affect of the decision may be a change of goal as the decision may result in new rules for the situation. The decision may also give a direction to the goal of which aspects of the situation that is of interest, what to be expected of the future. The request of information may have two reasons (1) the perform block needs more or new information for decision making or (2) to generate the necessary information needed in the criteria of evaluation.

The comparison in [13] also identified three products to be received by the perform block:

- Threats and opportunities.
- Change.
- Information.

The information delivered from the memory is the result of the request of information sent earlier to the data gateway, or the threats and opportunities that were first identified in the data gateway, and then were passed via the memory to the perform block. The memory and data gateway works in close collaboration to generate the requested information. The data gateway is responsible for the inquiring of missing data and the memory is responsible for handling past information and making evaluation of the inquired data.

The change gives the decision making its dynamic process; the process of how decisions are made may change. The product of threats and opportunities that should be handled by the perform block come from the diagnostic block.

4.6 Diagnostic

The operative image of OA, with its gnostic activities is a part of the diagnostic function block together with the conscious and unconscious processes. The deviants identified by the evaluative system should direct the explorative processes. The result of the explorative process should result in three things:

- Update of the situation understanding.
- Present threats and opportunities for the perform block.
- Influence on the goal.

The first function is mainly concerned with updating of the conceptual model and curious exploration of elements of the situation. As new knowledge is learned the goal of the system may be influenced. The new knowledge may also affect the processes of all of the function blocks of the system. The direction of change should be conducted in the same manner as presented by Ackoff [1]. The threats and opportunities presented for the perform block should be investigated (information request cycle) and may result in a decision. As a result of the decision the decision record is stored in the memory and is monitored by the evaluative system.

The decision record should affect the direction of attention of the conscious process. The dynamic and adaptive functions of the system are performed by the change directed from the diagnostic block. This gives the system the ability to adapt & learn [1]. The change of the diagnostic process makes the system to change its diagnostic process (double loop learning). The process starting with the preparation of the decision record and terminated by the direction of change is according Ackoff [1] what gives the system the ability to adapt and learn.

4.7 Conceptual design

From the discussion of subsection 4.1 to 4.6 requirements on the conceptual design have been presented. In Figure 4.1 the function blocks presented in Table 3.1 are shown. The association between the function blocks is identified in the discussions of section 4.

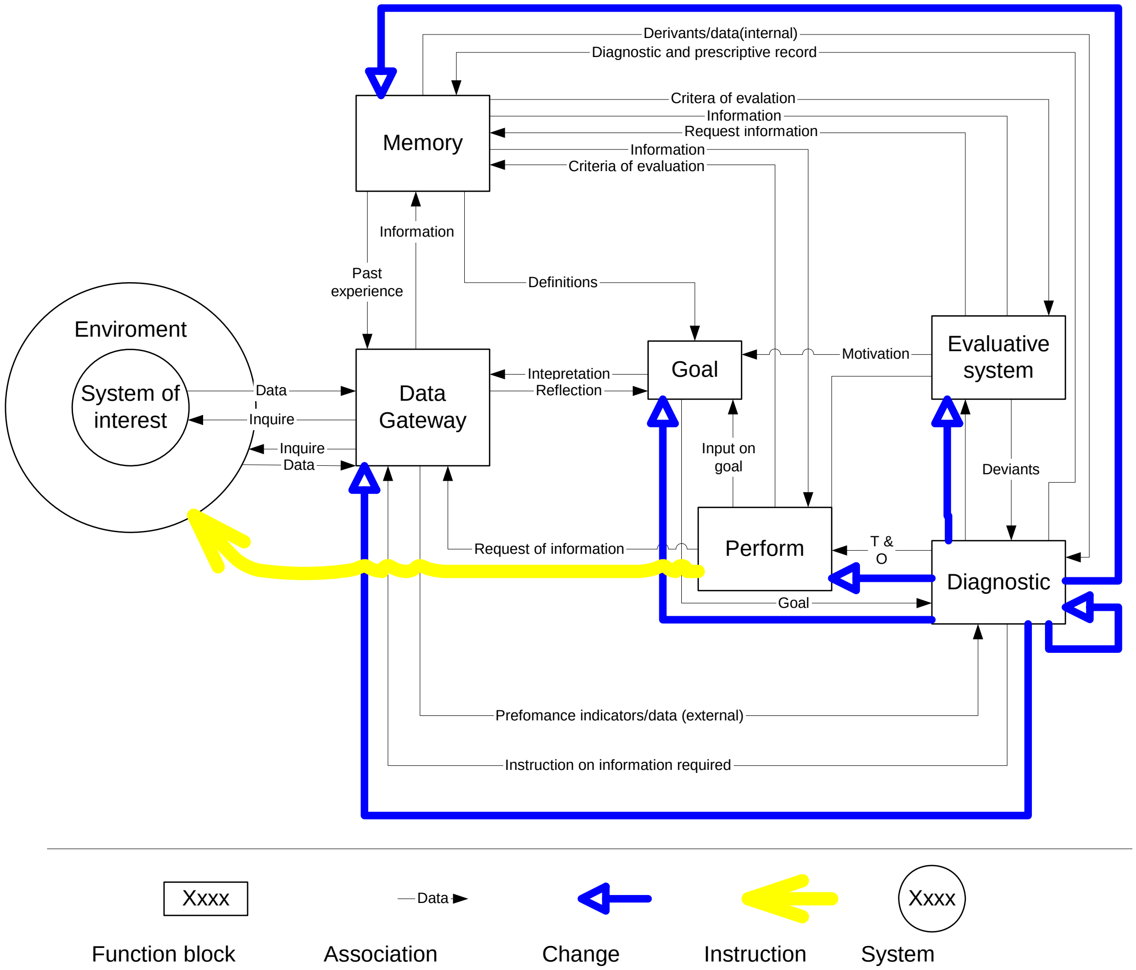

Figure 4.1 Conceptual design of a situation awareness system after [13].

The system of interest is representing the system that is controlled by the SA system. The SA system should also be seen as a part of the system of interest as it is affected by and affects this system. The data gateway is the interface between the SA system and the rest of the system. The data gathered by the data gateway is interpreted with the help of the past experience stored in the memory. The memory block has a central function of the design and has several subparts (active memory, passive memory, decision records, past experience, conceptual model, etc) used by many of the function blocks of the design. The goal gives the system a goal driven self-regulation behavior through the affecting of all the function blocks. The perform block, which is not a part of the SA system, instructs the system how to change to best achieve the goal. The SA system can instruct the perform block through changing of the decision process and through the information given as foundation for decision-making.

The evaluative system has the function to identify differences between the expected and result, and present these for the diagnostic block for further analyzes. The evaluative system also is responsible for determining the significance (sense) of the goal and how much energy the system is using to reach the goal (motivation). The diagnostic block involves the attention of the system and the conscious and unconscious processes. The unconscious processes are performing undirected explorative actions to find new knowledge. The conscious process is performing attention directed exploration. The direction is the attention of the system.

The diagram is to show how the result of the work could be used in an information system of the future. The diagram should be analyzes deeper to increase its performance. Analyzes is out of the scope of this work.

5. Applying the Conceptual design

The commander with the most efficient OODA-loop[14, 15] will gain Information Superiority (IS) and Full Spectrum Dominance (FSD), as described in Joint vision 2020 [16]. The operations planned for are neither pure military nor pure civilian, but are a mixture of both. In the European headline goals 2010 [17] it is addressed that military and civilian organizations and agencies within Europe need to interoperate in operations other than war (OOTW). The proposed approach is to go Net-centric which furthermost address the networks made by the personnel but also requires technical infrastructures such as the Global Information Grid (GIG). The change to a Net-centric paradigm also affects organization and the methods used. The information that flows in the GIG can then be seen by everyone who has been approved access to it. This means that a decision maker can acquire more information. This, in turn, may lead to both information overload and information overflow. The need for increased human and technical support in filtering and assessing the information is therefore vital.

In providing a suitable architecture the authors apply the concept design from above together with Fractal Information Fusion OODA as introduced in [18, 19]. In short the FIF-model combines the JDL-Model [20], OODA-loop [14], data-wisdom model[19] and the concept of time in the system in fusing previous, present and predicted. The decision process is not a single process but involves several levels since the system in focus is also a part of a whole system, see Figure 5.1. The numbers corresponds to the levels in the JDL-model.

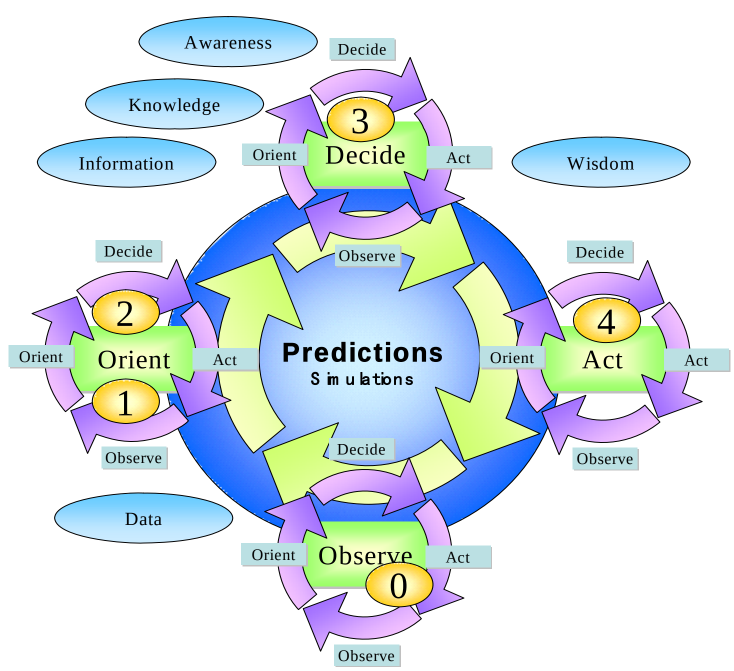

Figure 5.1: Fractal Information Fusion Model

The Conceptual SA design and the FIF put requirements on the system architecture to be able of being self-aware. Self-aware in the sense that it needs to know the other system to a level that enables the best usage of that system. LCIM describes a spectrum of interoperability from technical interoperability to conceptual interoperability. The LCIM has seven layers in the model: No, Technical, Syntactic, Semantic, Dynamic, Pragmatic and Conceptual. To the left in 5.2 only five levels is showed since the Technical interoperability is handled by OpenSIS and SOSC.

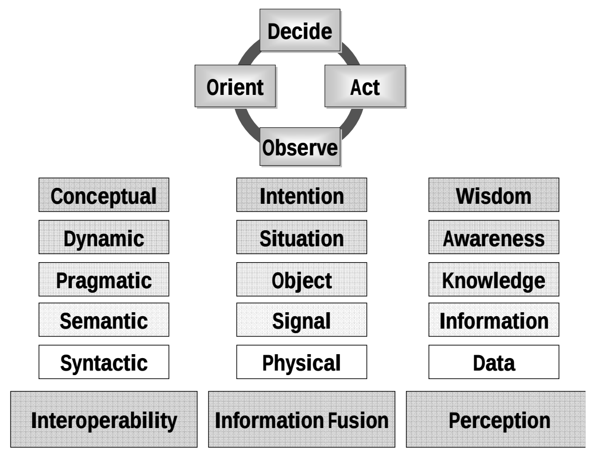

Figure 5.2 : The Core Concepts in MuHISA

Syntactic Interoperability introduces a common structure to exchange information; Semantic Interoperability imply that a common information exchange reference model is used; Pragmatic Interoperability is reached when the interoperating systems are aware of the methods and procedures that each other are employing; Dynamic Interoperability imply that systems are able to comprehend with the state changes that over time occurs within the systems; Conceptual Interoperability means that systems understands the underlying conceptual models of the other systems. In the suggested architecture there is a need for a representation of the interoperability issues from the conceptual model view, i.e. what is the conceptual model of the system, from the connection view, i.e. how should the connections be established and fro the information view, i.e. how the information should be represented. For all three it is important that the representation, i.e., formalism, is unambiguous. The current solution is to use the ontological framework OLW-S [21]. "*OWL-S supplies Web service providers with a core set of markup language constructs for describing the properties and capabilities of their Web services in unambiguous, computer-intepretable form.*"[21]

An agent can then be seen as one Conceptual SA (Figure 4.1) where each agent need to have all the parts describe in section 4. An agent is then within a larger system that also needs to have the parts as in section 4. With a ontology driven interoperability approach combining the recursive agent based idea with existing services forms the MuHISA architecture in Figure 5.3. The intention is to use C-BML (Coalition Battle Management Language) to express the knowledge, i.e. information view, which flows in the system. With a simple mapping between Figure 4.1 and Figure 5.3 and the underlying implications gives: System of interest maps to Sensor, Memory to Database, Goals, Diagnostic, Performance, maps to the Agents. Each agent is then built with the same internal structure.

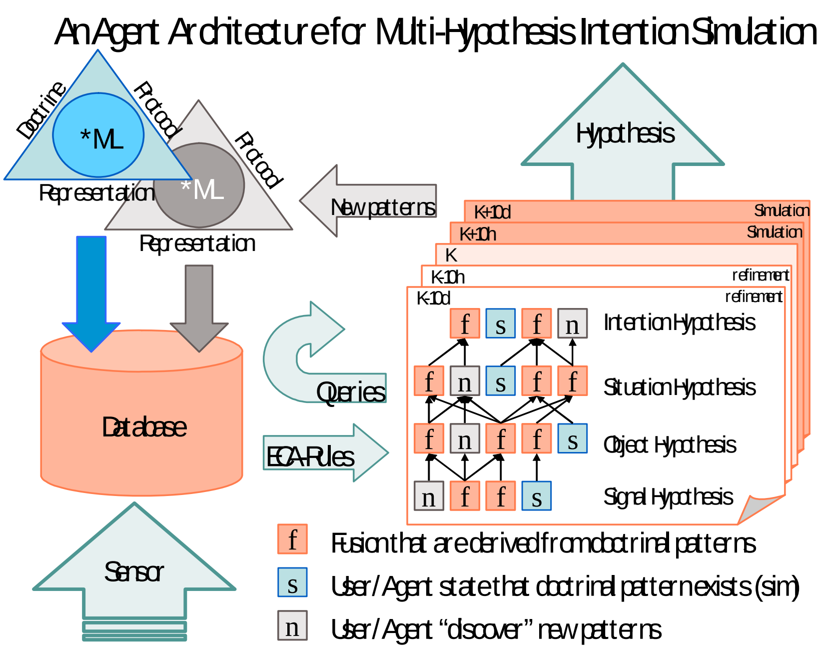

Figure 5.3: MuHISA Architecture [18,19]

5.1 Implementation

A practical implantation of the MuHISA is a costal surveillance application where a Anomaly Detector is a centerfold. The current AD implementation consists of three agents Command, Information and Compiler agent. The agents are not implemented as proactive agents, so the Command agent is the one that keeps telling the other what (and when) to do, e.g.: Commanding the Information agents conduct analyzing of the target picture; For the compiler agent to compile the result from the analyzers and report any deviations to the Tracking Manager (TKM) and to update to the database with the target picture.

The Command agent was needed to schedule the computations in the other agents and packages. The Information agents are the one that performs the actual analyzing and fusion of the data, and the current design enables that new Information agents easily can be added and old can be removed, without changing anything else. The compiler agent is not refining the results from the Information agents further; the results are simply reported to the TKM.

As an example of the currently implemented Information agents the split and join scenario and the pursue scenario is described. The rule-based split and join analyzer, of F type (Figure 5.3), is searching for deviations where the unknown boats suddenly appear or disappear next to another boat. In the case of a new boat appearing there might be a case of a smuggling scenario, where a smaller boat is heading for the shore with some for smuggling lucrative goods. In the case of a boat disappearing next to another boat there might be an ongoing raid where one boat ends up in the "radar shadow" or there might be the case of a picked up smaller smuggler boat.

The pursue analyzer is looking for boats that are tailing or hanging around boats with attractive cargo. It first picks out boats that are within the determined area from the boat with the attractive cargo, and then checks if boats have the same heading and speed for a certain amount of time. These pursuers are tagged as suspicious with a pursue activity. This is a first step and there is more to be researched and investigated of the concept, architecture and from the implementation.

6. Conclusion

This paper shows that there is a essential need for a general SA system. Such a design is presented in Figure 4.1 and is a visualization of the concepts. In section 5 the MuHISA (An Agent Architecture for Multi-Hypothesis Intention Simulation) is presented that uses the concepts in section 4. Further work that needs to be addressed is presented in section 6.3.

6.1 Definition of Situation Awareness (SA)

From the argumentation of [13] the following definition of SA emerged:

The conscious and unconscious dynamic processes to achieve a reflection of the systems purpose and form, function, system state and future system states.

This definition of SA is influenced by the orientational activity presented by Bedny & Meister (1999) and the adaptive-learning management system presented by Ackoff (1999).

6.2 Conceptual design of a situation awareness system

As a result of the comparison of [13] some key concepts and strong contributions were identified. These are put together in a conceptual design of a SA component (presented in Figure 4.1). The figure is discussed in section 4 and the function of each function block is presented. With the presented design in Figure 4.1 and the discussion of section 4, the first objective, discussion about a conceptual model for a SA component of a system, is considered fulfilled.

6.3 Future research

In this section the result of objective two, future research that have been identified, is presented. Some of these may already have been examined earlier, and a solution for the problem may exist. It is out of the scope of this paper to make an inventory of these topics, they are presented to clarify that these are interesting further work. The future research topics are presented without a specific order.

6.3.1 Realization

A deeper analyze of the MuHISA and Costal system in the perspective of the concerns below.

- Memory. It should be analyzed how a shared memory could be used for a decision-making system. The memory should be the same for the SA component and the decision-maker. This could be a problem if the decision-maker is not a part of the computerized system, for example a human being. The separated memory could result in a mismatch between the information given by the SA component to the decision maker, and the memory of the decision-maker. This mismatch could have unfortunate effects, for the decision-making and the use of the system.
  It should also be analyzed how the memory could have both active properties (dynamic) and stable properties (static), and still be able to make comparison between the types. The use of images as a storing type should also be examined. There are, according to Bedny & Meister [4], some benefits with using images. How images could be used in a SA system should be analyzed (storage, indexing, searching, updating, etc.). It should also be examined how to handle common distribution issues like synchronization, replication and conflict handling.

- Unconscious process. The use of unconscious processes is one of the contributions of orientational activity. The explorative action preformed by the unconscious process is a simulation of possible futures, testing how things are working, finding new dependencies, identifying goals of elements, etc. The work of the unconscious process is performed by simulations and testing of hypotheses. It should be analyzed how this type of process could be realized in a computerized system.

- Requiring data. One of the drawbacks of a computerized system is, according to Ackoff [1], that a computer cannot request information not presented in the model describing the problem. The human being can request data not present in the current model of the problem, to find new features of the problem. It should be analyzed how a computer could request data not presented in the model of the problem.

- Curiosity. A human that do not have a problem is not becoming apathetic. The person is curios and makes explorations of the environment to learn more about its features. The computer should not stop to execute just because there are no instructions to execute. There should be a curiosity to learn more about the situation. It should be analyzed how this behavior could be realized in a computerized system.

- Motivation and sense. Motivation and sense as presented by Bedny & Meister [4] together with the image-goal gives the system it regulative features. Motivation is regulating the energy of achieving the goal, and sense is responsible for determine the priority (significance) of the goal for the system. This evaluation of the goal is bringing a function of choice to the system. How the concept of motivation and sense could be computerized should be analyzed.

6.3.2 Human aspects

As the system is taking over functions preformed by humans, questions will rise about how and if computers can imitate and fill the space of humans. Below some of the identified questions are presented.

- Authority of decision. When a computer will give orders to humans, the authority of the decision will be questioned. This will be a problem for the organization to solve. How the authority of automated decision can be keep at a high level should be analyzed.

- Moral. If an automated decision will result in damage to individuals or organization, who will be responsible for the result? Is it more accepted if a human makes incorrect decision than if they were made by a computer? These moral aspects of using automated systems in decision-making should be analyzed.

- Keeping the semantics. Where the SA system is to present a representation of the situation for the decision maker, there will be a problem of keeping the semantic of the information given. Even though the operator of the system is trying to make an objective interpretation of the information given it is hard. The operator is influence by earlier experiences and is making the interpretation of the information in a subjective way. It should be analyzed how information given by computerized systems can be delivered in an objective way to the operator.

6.3.3 Loops and feedback

In the designs of the different theories, loops of regulation and feedback exist. The result and contribution given by these should be analyzed further, it should also be analyzed how and if it would be possible to realized the loops in an automated system. Some of the loops are of special importance and are presented next.

- Goal-driven. The loop of goal-driven regulation is complicated. The goal is constantly evaluated and changing. This change of goal also gives the effect that the process of the different functions of the system is changing. It should be analyzed how a computerized system should be design to supports changing processes that change to best reaches a changing goal.

- Sensor feedback. The data gathering of the system should get a feedback of the importance and how the data is used. From this information the sensors should be able to change their behavior to better match the requirements of the system. It should be analyzed how this information could be given to the sensors and how the sensors should be design to support the given feedback of the gathered data.

6.3.4 Activity theory

Activity theory should bee analyzed closer to identify several interesting areas of application such as decision-making, evaluation of decisions, situation understanding. The ideas of gnostic activity and gnostic dynamic should be closer examined.

6.3.5 Simulation

The design presented in this paper is highly dependent on simulations to build the domain knowledge. As systems are getting more complex and getting higher level of self-learning, the demand for adequate simulations rises. It should be analyzed how simulation should be preformed to learn automated systems.

7. References

[1] R. L. Ackoff: **Ackoff's Best - His Classic Writings on Management**, ISBN 0-471-31634-2: John Wiley & Sons, 1999.

[2] J. Cantwell, J. Schubert, and P. Svensson: "Informationsfusion – Förslag till “strategisk forskningskärna" år 2001-2005", **Försvarets forskningsanstalt, Avdelningen för Ledningssystemteknik. Linköping** 2000.

[3] T. Denoeux and L. M. Zouhal: "Handling possibilistic labels in pattern classification using evidential reasoning", in **Fuzzy Sets and Systems**, vol. 122, 2001, pp. 47-62.

[4] G. Bedney and D. Meister: "Theory of Acivity and Situation Awareness", **Int. J. Cognitive Ergonomics**, vol. 3, pp. 63-72, 1999.

[5] N. Stanton, P. Chambers, and P. J.: "Situational awareness and safety", in **Safety Sci**, vol. 39, 2001, pp. 189-204.

[6] M. R. Endsley: " Design and evaluation for situational awareness enhancement", presented at **Human Factors Society 32nd Annual Meeting**, Santa Monica1988.

[7] B. F. Lomov: " Philosohical and theoretical problems of psychology", presented at **Science Publisher**, Moscow1984.

[8] A. T. Welford: "On the human demands of automation: Mental work conceptual models, satisfaction and training", I. a. b. psychology, Ed., 1962, pp. 182-184.

[9] V. A. Oshanin and "Concept of operative image in engineering and general psychology", in **Engineering psychology.**, B. F. Lomov, V. F. Rubakhin, and V. F. Venda, Eds. Moskow: Science Publisher, 1977.

[10] D. P. Ausubel: **Educational psychology: A cognitive view**. New York Rinehart & Winston, 1968.

[11] V. V. Pushkin: "Formation of situational concepts in structure of activity", in **Problem of general and educational psychology,**, A. A. Simirov, Ed. Moskow: Pedegogy, 1978, pp. 106-120.

[12] O. K. Tikhomirov: **Psychology of thinking**. Moscow: Moscow University Publisher, 1984.

[13] C. Lagervik: "A System Theoretical Approach to Situation Awareness
", in *School of Humanities and Informatics*. Skövde: University of Skövde, 2005.

[14] J. Boyd: "A Discourse on Winning and Losing", **Maxwell Air Force Base, AL**, Air University Library Document No. M-U 43947 (Briefing slides) 1987.

[15] J. Boyd: "The Essence of Winning and Losing ", January 1996.

[16] United States. Joint Chiefs of Staff.: "*Joint Vision 2020*", Washington, D.C., 2000.

[17] **European Council, General Affairs and External Relations Council**: "Headline Goal 2010", 17 May 2004.

[18] P. M. Gustavsson and T. Planstedt: "Multi-Hypothesis Intention Simulation Agents Architecture - Fractal Information Fusion Modeling ", presented at **Winter Simulation Conference**, Orlando, Florida, U.S.A, 4-7 December 2005.

[19] P. M. Gustavsson and C. Brax: "An Agent Architecture for Multi-Hypothesis Intention Simulation: An Ontology Driven Interoperabilty Architecture", presented at **The 10th World Multi-Conference on Systemics, Cybernetics and Informatics: WMSCI** Orlando, FL, U.S.A, July 16-19, 2006 – 2006.

[20] J. Llinas, C. Bowman, G. Rogova, A. Steinberg, E. Waltz, and F. White: "*Revisiting the JDL Data Fusion Model II*", in proc. **The 7th International Conference on Information Fusion**, Stockholm, Sweden, 2004.

[21] "DAML-S / OWL-S", http://www.daml.org/services/owl-s/, 16 April 2006.

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