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Situational Awareness Formation For Large Network-Systems

Viacheslav Abrosimov[1*]

[1)] *Smart Solutions, Samara, Russia*

E-mail: avk787@ yandex.ru

Abstract: An approach to situational awareness formation as a necessary condition for the operation of large network-centric systems is considered. The basis is information acquisition from all system elements according to the "initial data-parameter-event-situation-solution" scheme. The situational awareness model is constructed as a neural network with an ensemble organization and associative-projective structure. The model is learned using precedent examples.

Keywords: network, situation, awareness, neuron, network, ensemble

1. INTRODUCTION

Large systems include a large number of elements and have a complex hierarchical structure and, therefore, a complex character of connections. It is necessary to take into account the existence of random factors from the environment and also the elements of the system itself. The characteristic feature of modern large systems is network centricity, which consists in the network nature of systems and use of various information for decision making. Situational awareness is a necessary condition for the operation of large network-centric systems. Large systems differ from complex systems, as the operator in the control loop is included in system.

The situational awareness systems are actively developed for ensuring the efficiency and safety of large systems in manned aircraft, transport and other fields (e.g., see [1, 2]). The basis of such systems is the high operational efficiency of information interaction. In defence applications, situational awareness models are developed as organizational models for knowledge management on the battlefield and also for the accumulation of incoming information about the current situation in special-purpose databases. These data come to situational awareness system from intelligence agents, advanced units and from higher-level governmental structures including a combat command control information network. Managing the processes of data collection allows to perform a single visualization of the combat space, depending on the level of management and the access rights of government officials [3].

2. SITUATIONAL AWARENESS PROBLEMS FOR LARGE SYSTEMS

According to the Endsley model [4], the situational awareness concept distinguishes between three basic elements: a) information about the spatial and temporal environment of the situation b) situation analysis and prediction in terms of scenarios and c) the actions of other participants. Obviously, to ensure a high degree of situational awareness, all elements of a large system should be considered as information providers. Analysis shows that the main problem of modern large-scale economic systems is the lack of properly organized information and communication network between the elements of the system that implements the principles of situational awareness, i.e., a common information environment and its continuous

[*] Corresponding author: avk787@ yandex.ru

updating using the largest possible information sources (large system inputs). But the major unresolved problems in the situational awareness fields is decision uncertainty caused by the abundance of redundant information.

Events and situations objectively occur in large systems. An event in a large system is understood as the realization of a random process associated with predicted or previously neglected factor demonstration. It is clear that events in large systems are not independent. Moreover, in large systems, the emergence of an event from outside (the influence of the external environment) and the event generated by the system are both observed. Often the source of an event remains undetermined, and its impact on large system functioning is critical. A situation in a large system is understood as a group of events that lead to the result of system functioning and requires decision making. A precedent in a large system is understood as a situation that arose as a result of the onset of an events aggregate caused by external factors or as a result of setting the aggregate parameters of a large system, according to which a) appropriate decisions were made and b) the consequences of such decisions are known.

Consider an example. In the large economic and ecological system "A forest production and extraction" described by various parameters (total area, volume of felling, percentage of deadwood, etc.), the event of abandoned fire occurs, leading to the situation of fire and causing a precedent (annual fires on the territory of the Russian Federation).

It is impossible to study the influence of all factors determining events and situations in large systems. In this case, it is necessary to apply analytical methods allowing, on the one hand, to carry out estimation with maximum complete consideration of all features/

Each element of a large system determines and accumulates information, assesses the situation in accordance with its limited capabilities, thereby being able to act only in its narrow area of responsibility. But in a properly constructed large network-centric system, there is the gradual accumulation of experience and knowledge. All system elements participate in this process with the course of time. However, such phenomena as "the of situational awareness impulse " may arise. This reflects the fact that previously missing information is suddenly detected by observing any of system elements. Such impulses are associated with events occurring in large organizational and technical systems.

In practice, also there may be a “gap in situational awareness”. It occurs as a result of limited or even lost communication and, accordingly, interaction between the elements of the system. With a high degree of situational awareness, the elements of the system may function as autonomous ones. However, in future system life, the accumulated underdevelopment can lead to dangerous errors.

The elements of the system must know, predict and respond to potentially possible situations related to the performance of their own functions. They should also know the strategies of the other elements that are a part of the larger system to coordinate their actions. This means that some information resources should be constantly filled by current information: initial data, events and situations that arise during large system functioning.

Large system situational awareness formation is the process of collective accumulation of information that describes the events and situations generated by the environment and system initial conditions, which is carried out in parallel with system functioning and implemented by all large system elements.

Based on the mathematical model of neural networks, this paper suggests a methodological approach for investigating the problems of situational awareness formation.

3. BASIC PRINCIPLES

Let us formulate some basic principles.

The principle of recurrence. It means that situations that occur during large system functioning in general way are repetitive, similar. However, situations could never be the same. But, according to our approach, a difference comes from a number of inessential background details that do not affect the situation, while the situation's similarity appears due to the coincidence of a few main features. The application of methods based on the principle of analogies for the study of events and situations is exposed to certain criticism in scientific papers. However, this principle is widely and successfully used by many researchers.

The principle of hierarchy. The situational awareness formation can be conditionally described as a certain hierarchical structure that allows to design situational awareness components interacting with each other. The feasibility of such formalizations is obvious. The problem consists not so much in decomposition, but in the representation of constituent elements, the definition of appropriate interconnections between different-level elements of the hierarchy and also in the completeness of these connections and the degree of their mutual influence.

The principle of comparability. The situational awareness entities can be compared using various criteria. In practice, such a comparison is made frequently and, depending on criteria, has either the character of compared integrated numbers or fuzzy statements.

The principle of importance. The situational awareness information can be described by a limited set of most important parameters, events and situations. Other parameters can be considered as a certain background.

4. APPROACH TO SITUATIONAL AWARENESS FORMALIZATION

Among the rich variety of possible mathematical approaches to the formalization of situational awareness, we suggest to use neural networks. Application of neural networks for solving different problems was mentioned in literature. Artificial neural networks are currently actively used in forecasting, pattern recognition, and control.

First of all, the architecture of neural networks is very easy to redesign; this is extremely convenient for adding elements for structure when new influencing factors appear. Secondly, the idea of future events and situations is always objectively incomplete and fuzzy. An advantage of neural networks is that they have ability to restore information from its separate parts. Thirdly, neural networks have learning ability, which allows to make decisions by analogy in case of situations' similarity. Fourthly, neural networks enable to consider complex situations formed under the influence of factors of various nature and dimension. They can use heterogeneous information that is also essential for analysis models. With such networks, statistical data and expert estimations can be used together and the information of various probability can be processed.

A neural representation is based on the concept of a neuron and neural ensemble [6]. As usually a neuron is a formal element whose output activity ranges from 0 to 1 and is determined by the level of input excitation. The excitement level is determined by the sum of input excitations transmitted from other similar neurons taking into account the appropriate weight functions between the neurons. A neural ensemble is a set of neurons united by mutual exciting connections so that the whole ensemble becomes excited if a given number of neurons in it are excited. Neural ensembles have unique properties, which allow working with them as with a single unit and when necessary to split them up on small parts and to create new compound structures. The ensembles are intended for the formalization of neural image concepts with various degree of complexity.

Our model is based on the hypothesis about the separation of a neural network into individual hierarchical levels. At every hierarchical level, neurons are connected to each other and create neural ensembles. There are special operations over ensembles, which allow to add, subtract, create, and destroy ensembles, as well as to establish (destroy) connections between them, and so on.

The ensembles can be united into groups (fields). The opportunity to obtain various fields of ensembles is provided, such as: associative (for creation of ensembles), buffer (for storage of ensembles) and difference (for comparison of ensembles among themselves). Ensembles and ensemble groups are linked to each other by the so-called “connections” transferring the excitation image from one level of hierarchy to another. Through such “connections,” the excitement of ensembles, e.g., at a lower level of hierarchy causes the adjustable excitation of the higher-level ensembles.

High reliability is an important feature of neural models. Practical experiments have shown that the failure of 10% and even more elements of a neural network does not lead to significantly different results. It happens because each element in neural networks with the ensemble structure is responsible for many functions, not only for one. The failure of such an element deteriorates some functions, but owing to the presence of many elements and their interrelations this deterioration is so small that it becomes insignificant for the whole network.

In conventional approaches, the factor of uncertain input information (which can be incomplete, fuzzy, doubtful etc.) may cause errors in decision making, as the elimination of initial uncertainty in prediction models can appear impossible in principle. In neural models, an image can be created using partially uncertain information. This image does not completely fit the reality but nevertheless is very "close" to it. By defining an excitement edge, the most significant factors can be studied. In other words, the influence of uncertain (and very often doubtful) input factors on the result can be reduced.

5. HIERARCHICAL NEURAL NETWORK FOR DESCRIBING LARGE SYSTEM SITUATIONAL AWARENESS

The basic idea of using neural networks to describe the situational awareness formation processes is to employ an excited ensemble as a semantic image of a parameter, characteristic, object, factor, event, situation, precedent, solution and other concepts of large systems operation [7]. From the author’s point of view, the idea to use a neural network for describing situational awareness has certain novelty.

Let us construct a multilayer hierarchical neural network and ensembles exciting by such neurons. The first level will be composed of neurons and ensembles of “input parameters,” corresponding to the initial data on various factors of the large system and its elements environment. The second level consists of neurons and ensembles of “events” that will semantically describe the events of the influencing environment or the facts occurring in the course of large system functioning. The third level consists of neurons and ensembles of “situations” that simulate situations arising in a large system. And, finally, at the fourth level, we will place the ensembles of “precedents,” which are associated with the decisions on such precedents.

Between the levels, we create projective connections. They will transmit excitation from one level to another. The excitation of lower-level ensembles in the hierarchy by projective connections leads to the controlled excitation of the upper-level hierarchy ensembles. The connections between neurons and neural ensembles will be established and changed according to the results of learning. They can be either exciting (increasing the activity of neurons and ensembles) or inhibitory (reducing activity)

As a result, each concept is formalized by means of neural ensemble. At each level of hierarchy, the ensembles are identical in terms of structure (neurons which are linked by mutual exciting connections), yet different in terms of their meaning. The level of excitement of each ensemble depends on the importance of its influence on the ensembles in each consecutive level of hierarchy.

Connections between neurons and neural ensembles can be established and changed according to the results of training. They can be stimulating (increasing the activity of neurons and ensembles) or breaking (reducing the activity of neurons). The training procedure is as follows.

“Teacher” forms a variety of source data for neurons at the first hierarchical level. The excitation of the inputs of neurons and neural ensembles (the “parameters” of the first layer of the hierarchy) through the ensemble and projective connections initiates the process of excitation for the neural network. The excitement of the projective links of the first and second layers is transmitted to the “event” ensembles. Due to the connections within the ensembles and between the ensembles, the ensembles of the second layer are excited, and then, through the projective connections of the second and third layers, the “situation” ensembles of layer are excited. To each such ensemble at the third layer, the “precedent” ensemble is aligned at the fourth layer of the model hierarchy. The “precedent” ensembles are put in line with the decisions taken under given conditions and the consequences of such decisions. Initiating the excitation of the corresponding neurons and ensembles in the course of training, “teacher” can set new non-standard events that form previously unknown situations, create the necessary precedents and point out the right solutions in such situations with the aim of shaping the behavior of a large system in the required effective direction.

6. SITUATIONAL AWARENESS: FILLING OF INFORMATION

The neural model is located and functions in a certain "Internet-cloud". All elements of a large network-centric system have access to this source. Situational awareness formation here is the excitation process of a multilayer neural network based on the “parameter-characteristic-event-situation-precedent” principle, which runs sequentially as soon as information is received. Each element of a large system at each time transmits its current data to the model. The "current situation" ensemble, which is excited in the way described above under the "parameter" - "event" - "situation" scheme, is compared with ensembles that are in the "precedents" field and built on the learning outcomes or mark during the experience of system development. The type and name of the ensemble that is closest to the emerged situation are then determined. The decisions that were made in similar cases and the consequences of such decisions are also determined. The analysis of these consequences makes it possible to estimate the occurrence of problems for a given realization of the set of input parameters and initial data. This information is used for making the decision.

The neural model of situational awareness formation allows us to seek a solution in a neighborhood of the already known effective ones. For this purpose, an ensemble of "precedents" and the most effective solutions and satisfying consequences obtained in the process of learning is selected. A comparison between the characteristics of the input data vectors applied to the inputs of 1-st neurons level is made. The process of excitation again propagates through the neural network but with the modified input vector. A new “situation” ensemble is formed, and the ensembles are again compared.

It is assumed that the necessary knowledge of precedents and effective solutions will be developed as the knowledge base of situational awareness during large system functioning.

7. CONCLUSION

The paper has reflected only the general principles of neural model functioning for the analysis of relations between different states. Unfortunately, the limited format of a conference paper does not allow to give more details on many other important aspects of modeling. The problems of model training and other difficulties in its realization, such as the principles of coding for input information and decoding for output information, the issues of interpretation of modeling results, etc., have not been touched.

The idea of neural models application for situational awareness formation has become an efficient tool to describe the situational awareness processes, to choose most effective strategies and to predict the consequences of decisions based on situational awareness information.

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