ON SIMULATION OF COGNITIVE FUNCTIONS IN LANGUAGE INTERFACE DESIGN.

Mikhail A. Sharonov, Stanislav V. Mochenov

The Scientific Collaboration Research Centre:

"Information Technology and High Performance Computing"

of the Izhevsk State Technical University, Russia, 426069, Izhevsk, 30 Let Pobedy 2

Abstract

This paper describes an approach to the simulation of cognitive functions. The technological aspects of the technical implementation of adequate communication systems (ACS) are under review. The theoretical justification of the adequacy of the construction of semiotic systems based on neural structures is also provided.

Key words: *cognitive function, "human-machine" system, adequate communication system (ACS), physiological patterns, ACS main useful function (MUF).*

1. RELEVANCE OF RESEARCH AND PROBLEMS OF RESEARCH OF "HUMAN-MACHINE" SYSTEMS

Currently, there is a need for quality changes in the principles of interaction between humans and computer technology by switching to fundamentally new hardware and software that interpret commands in the natural language, which are known as adequate communication systems (ACS) [Sharonov 2011].

The need to switch to such systems is obvious, as the computational tools are increasingly used in everyday life and at work. The complexity of industrial, scientific, and information systems that employ the achivements of computer technology are constantly growing. At the same time, there are problems of management of such systems, of interaction with them, of provision of certain intelligent features to them, which features are usually carried out by humans.

We are talking about the availability of these systems to any user who has poor understanding of the internal organization of such a system. The main criteria are the simplicity of interaction with the system, ease of operation, possibility of using a computer system to solve any social problems. The machine should become socially oriented!

The key issues, the problematics of which should be developed in such a situation, can be summarized as follows. What should be the "human-machine" interaction system? What qualitative changes are needed in order to obtain an adequate level of interaction between humans and electronic computer technologies? What is adequate interaction? What are the quality of interaction and high-quality interaction? And similar questions.

Certainly, the answers lie initially in the explaination of the principles of interaction of the humans themselves, both among themselves and with the world around them. On this basis, we can talk about developing such interaction analogs with respect to the activity models [Korochkov, 2009] of "human-machine" systems.

The problematics associated with such modeling is related to the study of the phenomena of non-traditional fields of science and technology and has a direct analogy with the study of cognitive

activities of the human brain and of other phenomena of speech communication. The use of the methods and the means of technical sciences [Revenkov, 2009, Komarcova, 2002] may help disclose the answers to the questions about the nature of the principles of human nervous system functioning that perform cognitive activities.

The question arises as to the manner in which the use of ACS models will help make a transition to qualitatively new technologies and principles of interaction between humans and computer technology.

2. ANALYSIS OF PROBLEM SITUATIONS

This article focuses on the development of an ACS model, ACS language interface, and methods of ACS operation.

ACS main useful function (MUF) – "*interaction with the user in natural language"* (hereinafter, "*interaction"*) in order to improve the overall efficiency of the "human-machine" system.

In particular cases, this MUF can be made by a device representing a hardware-software complex (Fig. 1), including *specialized software*, *interfaces*, and *hardware*. The implementation of the ACS can also be based on the use of the open structure of the neural network.

ACS interfaces – software and hardware environment that implements, in general, two functions: internal and external. The external function provides interaction of the ACS interface with the user; the internal, interacts with the hardware part of the ACS.

Thus, ACS interfaces have external functions: the function of conversion of commands written in a natural language into control signals understandable to ACS hardware; and the function of conversion of control signals into the user-friendly natural language.

In addition, the ACS interfaces implement the following internal functions: selection of the actuator that distributes control signals between the ACS hardware actuators; delivery of the control signal to the ACS hardware actuator; delivery of the control signal of completion of the ACS hardware actuator activity.

ACS hardware part – a set of software and hardware that controls the cycles of the internal activity of the ACS, processes the input control signals from the ACS interface, and formation of the output control signals for the ACS interface in order to interact with the user and manage ACS resources.

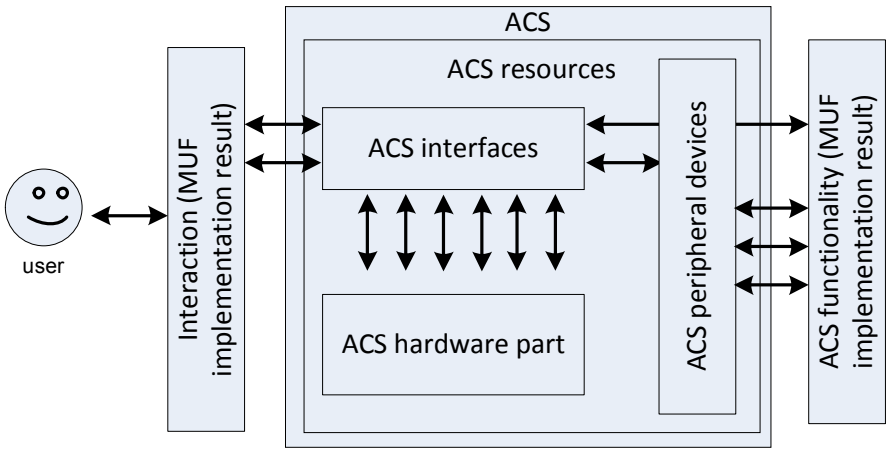


Fig. 1 - "Human-machine" block interaction diagram.

Thus, ACS basic functionality includes functions of both interfaces and hardware in the above interpretation. The MUF is represented by several auxiliary functions (refer to Fig. 2).

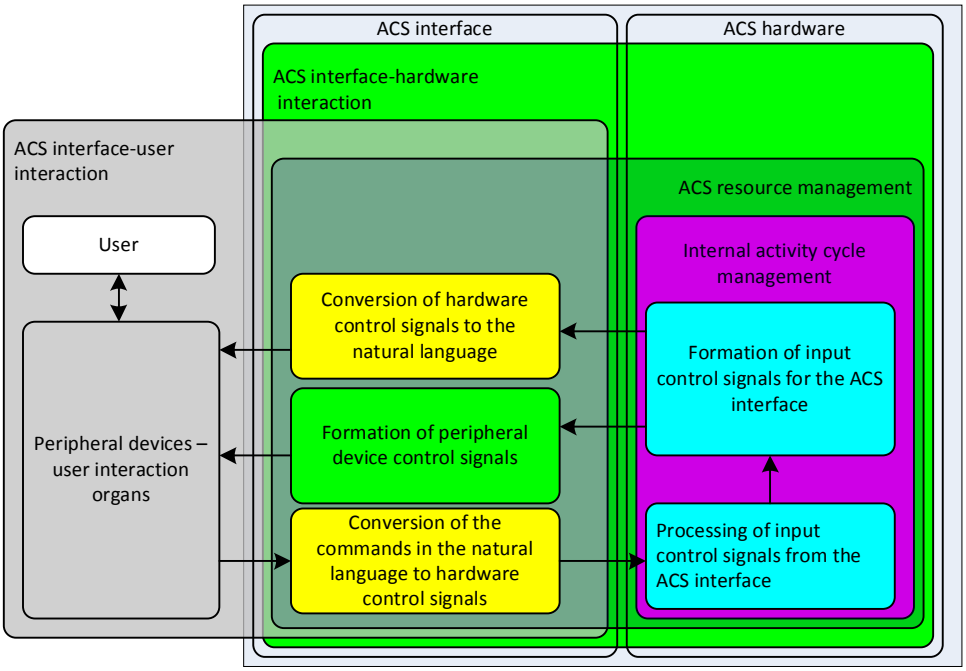


Fig. 2 – ACS MUF detailing

The considered main useful function is inherently an analog of the cognitive activity of the human brain. It is also similar to speech communication phenomena [Holl, 2007].

In our understanding, *cognitive function* is a function of consciousness or model of consciousness, which provides conversion of information or its properties in the transition from one level of the nervous system hierarchy to another. For humans, this corresponds to the transition from one state of the nervous system to another [Holl, 2007].

In this case, the cognitive function (ACS) is a variant of the excitation of a neural network that transfers the ACS from one known state to another, as a result of the impact of a particular input signal on it. Thus, the ACS MUF is to transform input data flows from the user into internal cognitive functions that activate various ACS target states. Similarly, we can assume that the inverse transformation is implemented in the similar way.

Thus, the essence of the existence of cognitive functions in humans is the need to convert one type of information to the other both inside and outside his or her body. Therefore, it is necessary to clarify the principles of information processing at different levels of the human nervous system, as well as to study the methods of impact of different methods of external objects on these levels.

3. ACS-USER INTERACTION MODEL

Without going into detail on the description of internal processes pertaining both to the ACS and to the user, it is possible to describe their interaction as follows (see Fig. 3).

For example, the user has a certain goal for the interaction with the ACS and expects of a particular result of the ACS. This goal is the motivating factor for the user's nervous system, which encourages him to interact with the ACS. To do so, the user uses his or her organs to produce target impact on the ACS interfaces.

In the course of the interaction of the hardware and software system, the ACS removes it from the equilibrium cycle of internal operations and the ACS with the use of available resources, performs certain activity connected with the performance of certain functions of the ACS that satisfies the specific purpose of the user. Following the implementation of the objective function, the motivational effect on the user's nervous system is terminated, and the cycle of interaction with the ACS is completed. The system then reverts to the equilibrium cycle of internal operations.

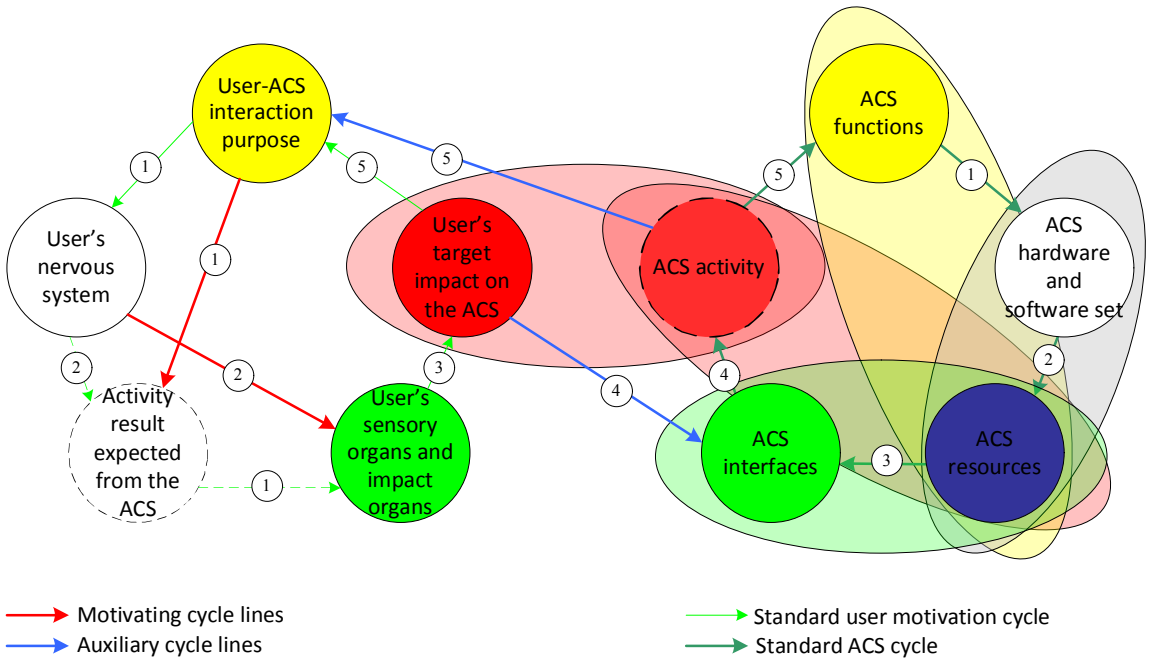


Fig. 3 – User-ACS interaction model.

This example illustrates the principle of interaction between the ACS and the user. The relationship between the internal processes in the ACS and the user are clearly defined.

To ensure adequate functioning of this theoretical model of interaction, it is necessary that the form of representation of the a certain possible command from the user interface be clearly perceived by the ACS interfaces. In other words, it is necessary to ensure full compatibility of the ACS and the user in terms of both the number of methods of transfer of information (for the user) and the number of communication interfaces that can handle this or that information flow generated by the user (for the ACS).

In a given situation, one can either reduce the number of methods of user interaction with the ACS or increase the number of ACS interfaces that can perceive certain kinds of information flows. Otherwise, the ACS must provide for such a structure of interfaces that will provide for the conversion of any information to be transmitted to the ACS at the input to the information that it can understand.

The set of user-generated commands either independently or through the ACS peripheral device systems must be converted into signals of the available ACS interfaces. With the help of its cognitive (information, recognizing) devices (neural systems), the ACS will be able to perceive them as a specific reference to a certain action (i.e., the excitation of certain environment, status, pattern in the ACS neural network).

4. BASIC ACS ORGANIZATION PRINCIPLES

There are two basic principles that are used in this paper. They are presented by B.T. Chuvin in his paper [Chuvin, 2006] by revealing the basic operation of the human nervous system. The first principle is the definition of information as the "data that is passed from one system to another in the process of interaction" [Chuvin, 2006: 30]. The second principle is the fact that "in order for *some data* to become information, it needs a system that perceives *this data* as information" [Chuvin, 2006: 30].

Guided by these principles, we find the only rule that can provide adequate performance of ACS in the course of user interaction. The rule is as follows: ***in the process of interaction with the user, the ACS must ensure the conversion of any information received at its inputs into information that can be understood both by the system itself and by the user***. This rule is a criterion of adequacy for the interaction between the user and the ACS; in the case of human interaction, it is the cause of the communication phenomenon.

Let us consider a simple information processing model (see Fig. 4) using the interaction of an external stimulus with the receptors of a certain simplest ACS that simulates the response to the stimulation, as an example. Such an ACS includes a receptor, a receptor neuron, a target state actuator neuron, and a target state actuator.

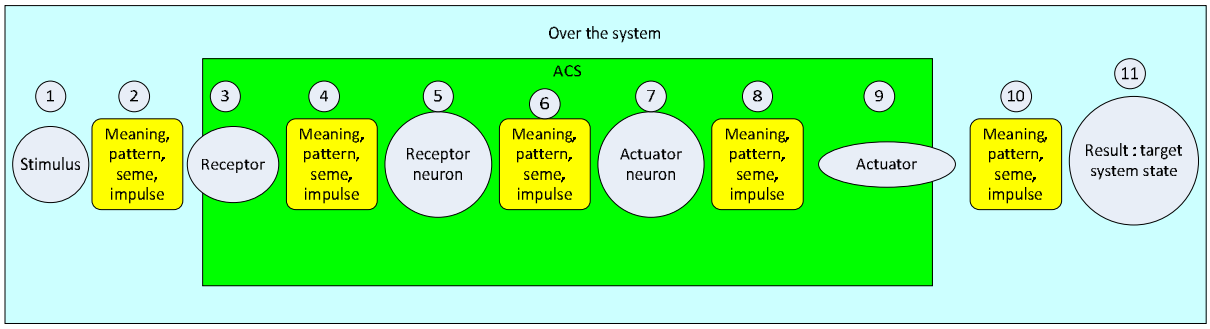


Fig. 4 - Information processing model in the course of interaction between two systems.

Let us consider, step by step, the chain of information transformation (pattern [Chuvin, 2006], seme [Plotkin, 1993, Osipov, 1992, Trubeckoi, 2000, Gorelov, 2009, Sharonov, 2011], meaning [Sharonov, 2011], impulse [Gorelov, 2009] etc.), as it is transferred from the supersystem into the ACS and back:

1. *The ACS* is at rest (i.e., fixated on the processing of the program of internal states).
2. *The external stimulus* creates *a stimulation pattern* (*in order to receive a target state from the ACS*).
3. *The stimulation pattern* impacts *the ACS receptor*.
4. *The ACS receptor* creates a *reaction pattern for stimulation*.

5. *The reaction pattern for stimulation* impacts *the receptor neuron.*
6. *The receptor neuron* creates *a sensation pattern.*
7. *The sensation pattern* impacts *the actuator neuron.*
8. *The actuator neuron* creates a *state invocation pattern.*
9. *The state invocation pattern* impacts *the target state actuator.*
10. *The target state actuator* creates an *ACS target state, which becomes a supersystem element.*

It should be noted that the patterns that are created in the process of conversion of the information are like "pictures" of signals with certain properties (characteristics, attributes). These properties share common features (for example, the same waveform) and, at the same time, bear certain similarity to the phenomena described by the following terms: sense, seme, impulse, signal, sensation, desire, feeling etc.

Let us consider more deeply the process of transformation of the pattern during the transition from the supersystem to the ACS at the following stages: 2, 3, and 4 (refer to Fig. 5).

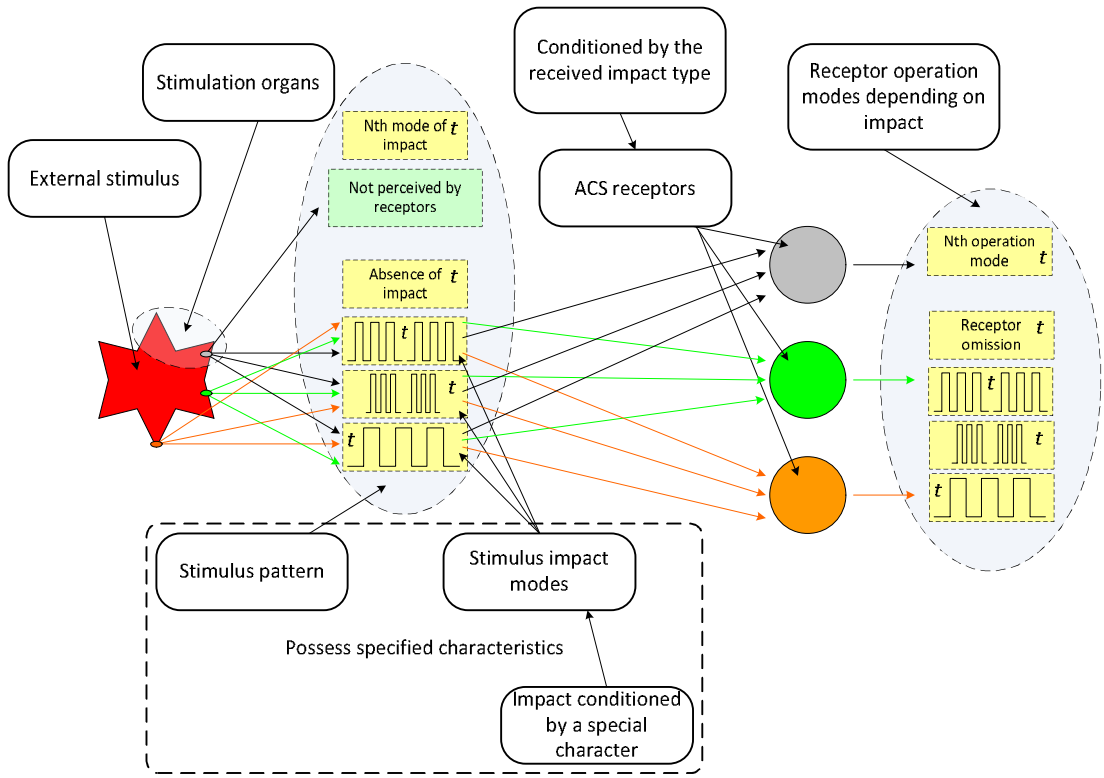


Fig. 5 – The conversion process of a pattern during the transition from the supersystem to the ACS.

When exposed to the ACS, the stimulus creates characteristic signals of irritation with the help of *N* stimulation organs available to it, each of which is characterized by the omissions of, or the ability to create, N' modes of impact. Modern physiology claims certain receptors in the human body to be

strictly oriented to the perception of a particular mode of impact (refer to Fig. 6). We will use a similar approach in the case of the ACS.

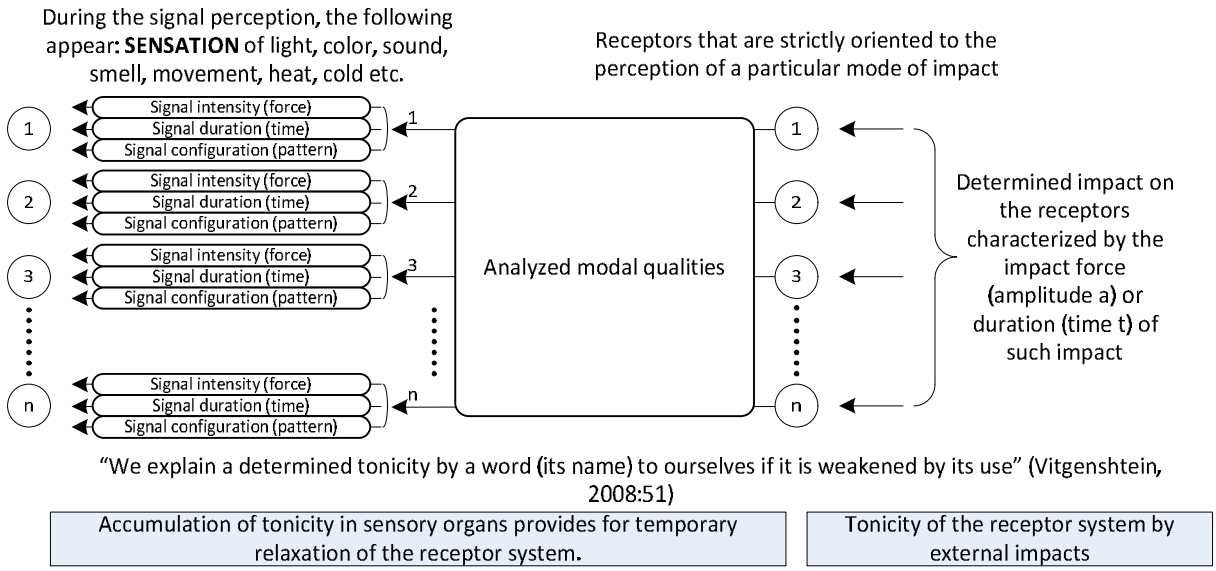


Fig. 6 – Vitgenshtein's explanation of the phenomenon of the name (word).

Figure 5 shows that each ACS receptor is able to capture N*N' modes of impact and establish, as per such number of modes, N*N' modes of operations that will be clearly perceived by the ACS.

In sum, the external stimulus signals will fill some of the big picture of the system stimuli, forming a certain level of abstraction of information therein. In this configuration of the overall stimulation picture, we will obtain a pattern of sensations (color, light, odor etc.) that possesses similar characteristics to the sum of the stimulation signals at the inputs of the system.

The signal that possesses a particular configuration (pattern), duration, and intensity will affect the receptors until the system produces sufficient capacity to transmit specific information to the next level of information abstraction. The operation will continue until the information reaches the maximum level of abstraction or is sent to the target state actuator.

It is worth paying attention to the fact that the ACS target state actuator can be either a particular element or a combination of operation or interaction of several elements. Semiotic signs and their systems can be considered a special case of complex target states. This effect makes it possible to build ACS models that operate a complex structure consisting of the simplest objects.

REFERENCES

1. Vitgenshtein L. Blue and brown books. Novosibirsk: Siberian University, 2008.
2. Gorelov I.N. Nonverbal communication components. M.: LIBROKOM, 2009.
3. Komarcova L.G., Maksimov A.V. Neurocomputers. M.: MSTU named after N.E. Bauman, 2002.
4. Korochkov A.V. Computer modeling of grapheme-phoneme conversion in English (based on traditional reading rules). Saransk: Mordovsky University, 2009.

5. Osipov B.I. Fundamentals of Russian phonetics (lectures on modern Russian). Omsk: Omsky University, 1992.
6. Plotkin V. Ya. Phonological quants. Novosibirsk: Nauka, 1993.
7. Revenkov A.V. Rezchikova E.V. Theory and Practice of Technical Task Solutions. M.: FORUM, 2009.
8. Trubeckoi N.S. Fundamentals of Phonology. M.: Apex Press, 2000.
9. Holl M. Bodenhamer B. Complete NLP Course, Spb.: Prime-EVROZNAK, 2007.
10. Chuvin B.T. Human nervous system and sensory organs: structure and functions. M.: Drofa, 2006.
11. Sharonov M.A. Mochenov S.V. Technology of structural and parametric synthesis of sense-forming components in the Russian language system. Journal of International Scientific Publications: Language, Individual & Society ISSN: 1313-2547, Volume 5, Part 1, viewed 30 January in 2012 <http://www.science-journals.eu/lis/5/isp-lis-5-1.pdf>, accessed September 2011