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NEW TRENDS IN NEUROCYBERNETICS

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Abstract

Many years ago neural networks were subject of scientific research conducted only for curiosity. The researchers pursue to better understanding of natural brain behaviour by means of forming of mathematical, electronic and simulation models. Unexpectedly as additional result of such research new computational tool occur, which very fast become huge popularity and high effectiveness. Now, when typical neural networks are used almost by everybody for almost everything – new progress in computational applications can come from new "cut end" research on neurocybernetics. The paper shows short survey of some most promising areas of current neurocybernetic research for inducting new possible technological inspirations.

Key words: neurocybernetics, networks, research

1. INTRODUCTION

Neuron networks have recently gained an established place among the tools that are readily and effectively used by engineers and scientists in order to solve various problems (Tadeusiewicz, 2009) and, therefore, it is worth having a look at the current prospects of the field of knowledge that created these networks. Presently, this field is commonly known as neurocybernetics. Its name combines the prefix *neuro-*, pointing to the biological sources of inspiration that are utilised, and *cybernetics*, which is a branch concerned with informational processes, initially and primarily connected with issues of control in systems with feedback mechanisms, and that has subsequently broadened in such a way that it currently concerns the entirety of the processes regarding the collection, processing, analysis, gathering and use of **information.** Numerous researchers study in this field for theoretical reasons, in which first and foremost the primary objective of their works (described fragmentarily hereunder in the present article) is to gain a better understanding of the biological aspects of brain function, as well as the psychological bases of cognitivism. To briefly present this, the researchers whose works are cited hereunder strive to achieve a goal that may seem to have rather little practical significance, namely achieving a better understanding of the nature of the human intellect.

However, experience (gained among others during the practical use of artificial neuron networks) shows and teaches us that each increment of progress that is attained in one of the subfields of neurocybernetics brings with it a result that is twofold in nature: apart from enriching pure knowledge, it contributes to the creation of successively new informational techniques. Thus, neurocybernetic research is keenly followed by information technology specialists - particularly those specialists whose activities are associated with applied information science, for it is highly probable that consecutive discoveries of this branch of knowledge will be processed into novel information technology tools and techniques,

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which in turn will be used to solve ever more complex practical problems with a ever greater level of autonomous artificial intelligence. This aspiration to develop further improvements is boundless, for in spite of the tremendous progress of information science, the human mind continues to predominate over the potential of computers in a great many fields. What is more, even if machines attain a level of efficiency that is equal to the human intellect, this development will not be stopped. The long-term task of artificial intelligence researchers is to create systems that will achieve a degree of competence that considerably exceeds human capabilities in various fields.

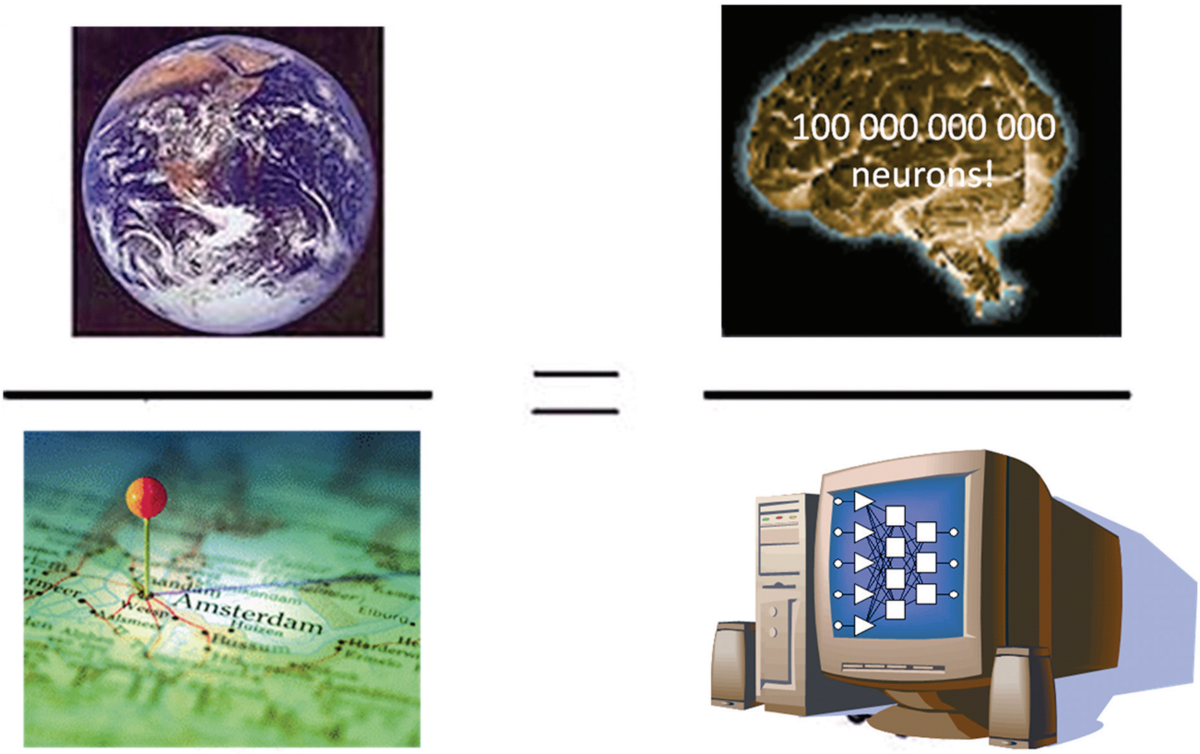

Fig. 1. The degree of complexity of the brain is many times greater than the degree of complexity of the objects that are researched by using neurocybernetic methods, as the volume of the terrestrial globe is greater than that of a pinhead.

One may doubt whether neurocybernetic research will indeed provide the knowledge needed by biology and engineering. These doubts are justified, for the present scale of objects that are researched by using neurocybernetic methods (for example, known neuron networks) is comparable in the size and level of complexity of the human brain as the volume of a pinhead to the volume of the terrestrial globe – figure 1.

This does not prevent, however, the obtaining of practically useful results in any way by means of the tools that are discovered and created by neurocybernetics. The fundamental objective of neurocybernetic research is to gain knowledge of, and to describe, the **principles of brain function** or, to put it more generally, the essence of the intellect as such. In this regard, not only is the scale effect not a hindrance, but it is rather helpful. Due to the complexity of the brain, the various types of knowledge that are gathered about it cannot be easily pieced together in order to form a clear whole (figure 2).

This specific "disassembly of the brain" by various fields of neurobiology in turn leads to an effect that may be best described by the colloquial statement: "you cannot see the forest for the trees". There are so many different results from observations and research available that it is practically impossible to create an overall picture on their respective basis. In this situation, the simplicity of neurocybernetic models is not a flaw, but rather an advantage (figure 3).

However, a doubt appears - will these simplified models not mislead us? Will we truly advance our knowledge of the brain (and intellect) as such by understanding a simple neurocybernetic model?

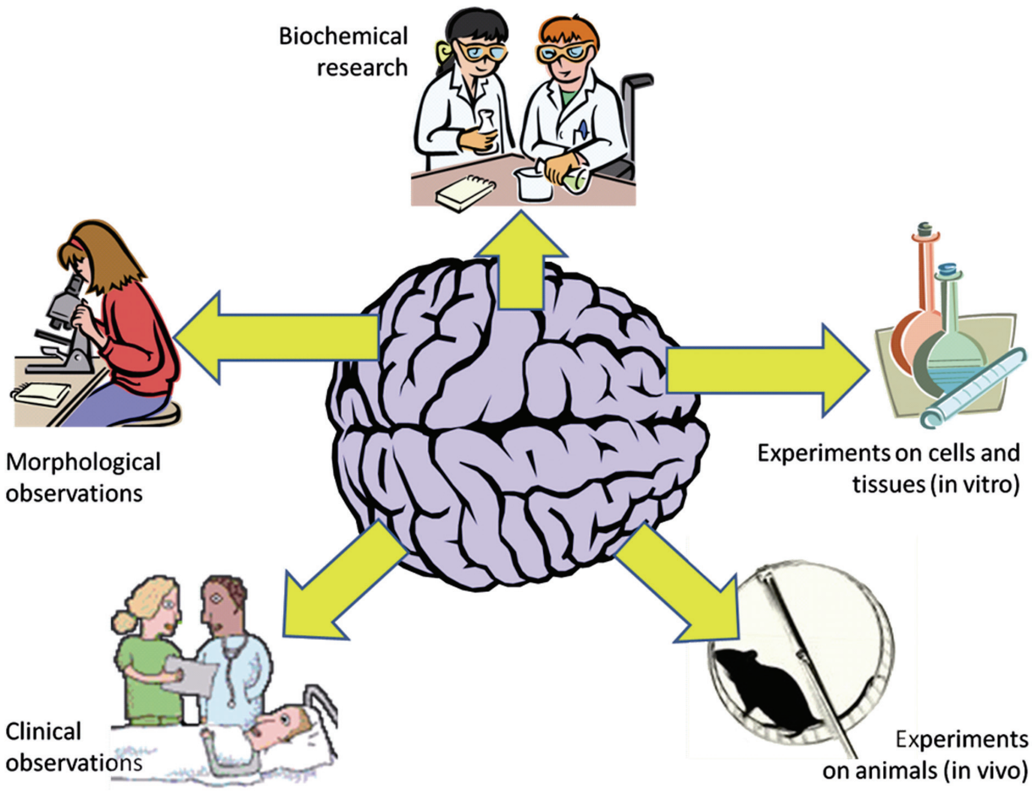

Fig. 2. *The fact that the brain is researched by using different methods makes it extremely difficult to bring the results of that research into a coherent whole*

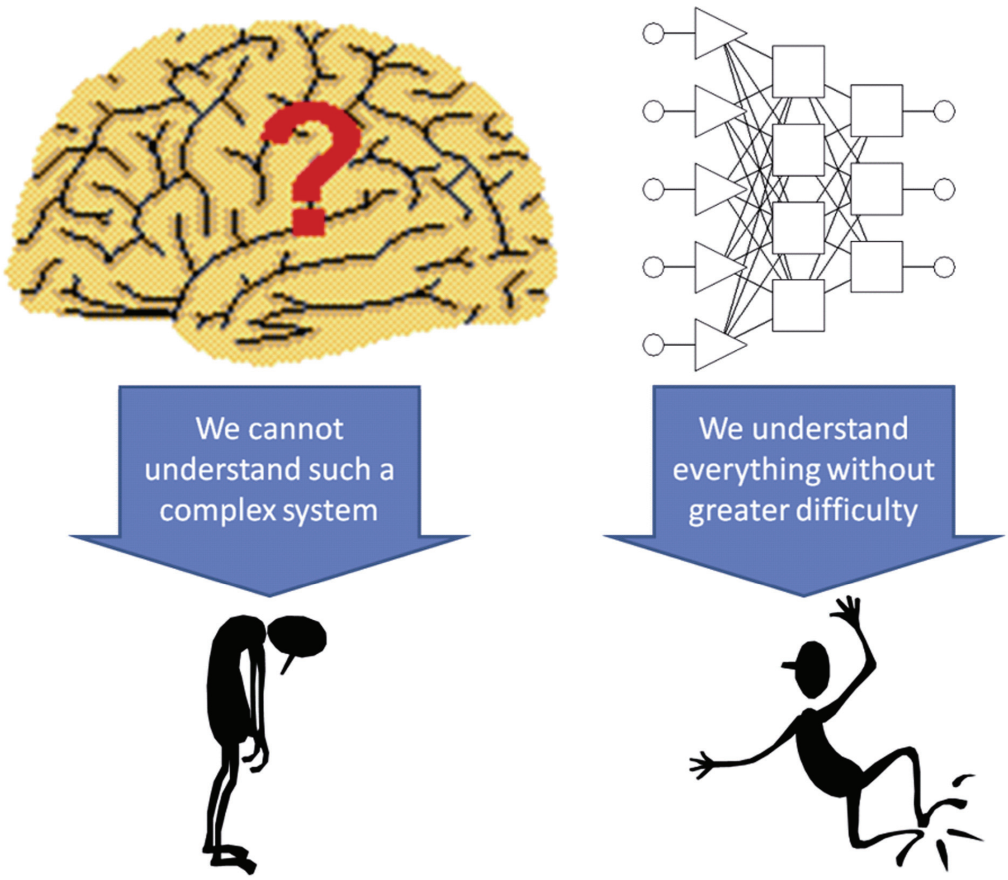

Fig. 3. *The simplicity of neurocybernetic models guarantees that we understand their functioning and, thereby, that of the brain as such, which in itself is too complex to be fully comprehended - even if we possess abundant information about it.*

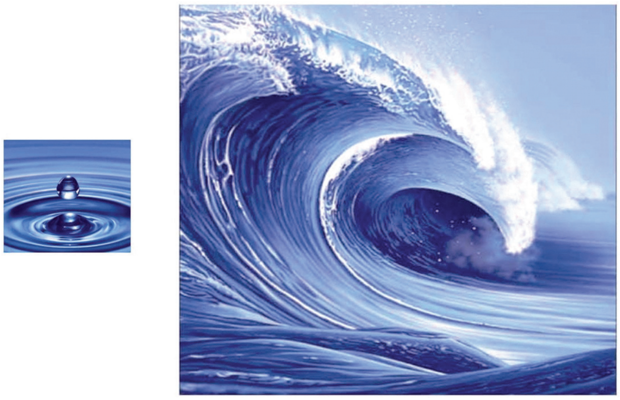

Fig. 4. Frequently, the veracity of scientific discoveries does not depend on scale. A phenomenon observed in a laboratory in a drop of water finds subsequent confirmation in a gigantic ocean.

The answer may be deduced based on figure 4. An experiment properly conducted on a model can provide us with noteworthy answers concerning the modelled - and considerably more complex - object. However, this requires the researcher to maintain particular diligence and a unique discipline of thought.

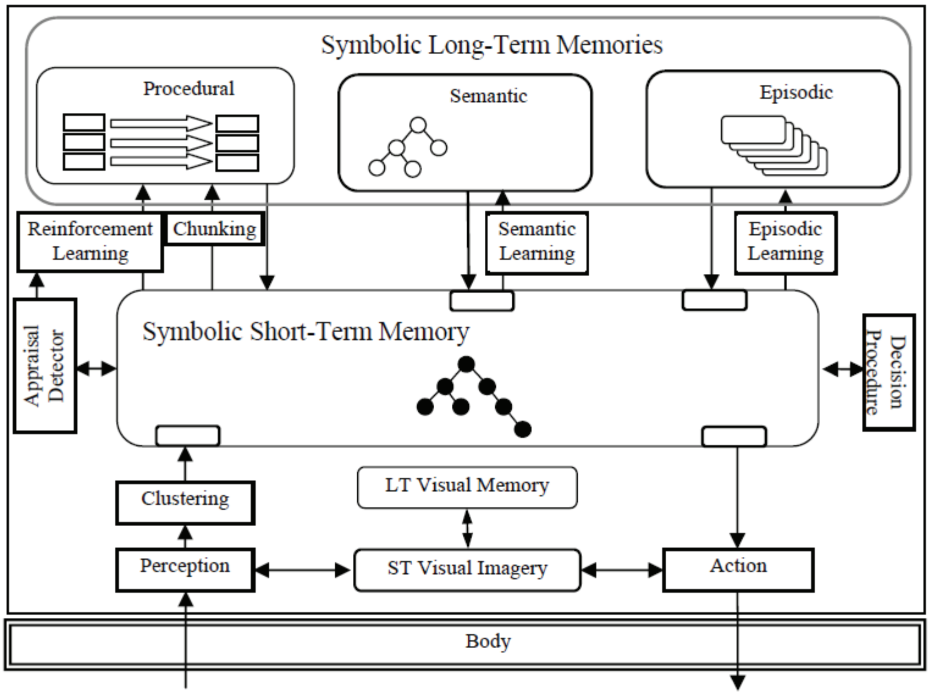

Fig. 5. The architecture of a neurocognitive SOAR-type system (Laird, 2008).

2. DIRECTIONS OF NEW RESEARCH

The new approach in neurocybernetic research, which is gradually replacing the traditional neuron networks, can be termed **neurocognitive information science**. Within this approach, we can discern a great many specific directions of research that in future may lead to very interesting solutions in turn advancing both the scientific knowledge of cognitive processes and the potential opportunities for technical applications. The first of these architectures is known as **SOAR** (its name comes from the terms *State, Operator And Result*). An example of the work performed in this field is the research that is described by Laird (2008). From his book, we have cited figure 5, which shows what contemporary SOAR systems look like, and of what elements they are constructed. This figure is not discussed in detail, instead any interested readers are referred to Laird's work. However, it is noteworthy that the architecture in question is considerably more developed than the traditional neuron network, a typical architecture of which is shown - among others - in figure 3.

Another novel neurocybernetic solution is the NARS (*Non-Axiomatic Reasoning System*). This constitutes an interesting attempt at approximating the cognitive architecture by means of non-standard logic. The NARS system is intended for inferring based on the language of the representation of knowledge in turn utilising semantics grounded in pragmatism (*experience-grounded semantics*). Non-axiomatic logic means that the veracity of logical statements is assessed based on the previous experience of the system with similar situations, and not based on a priori axioms. It may be used for adaptation in those situations where there is insufficient knowledge to make an unequivocal determination (Wang, 2009). This approach is clearly different from the typical neuron networks as regards its assumptions and implementation, but overall it results in similar opportunities for application. The author himself is convinced that this is the road that will lead to the construction of a thinking machine, as is signified - among others - by the title of his publication (Wang, 2007). When assessing the NARS concept in the present study in comparison with other neurocybernetic works, we are not inclined to ascribe it such great importance. The concept itself, however, is worth studying, for it may be the source of interesting solutions in areas of practical application.

Fig. 6. The logo of the adherents of "embodied intelligence"

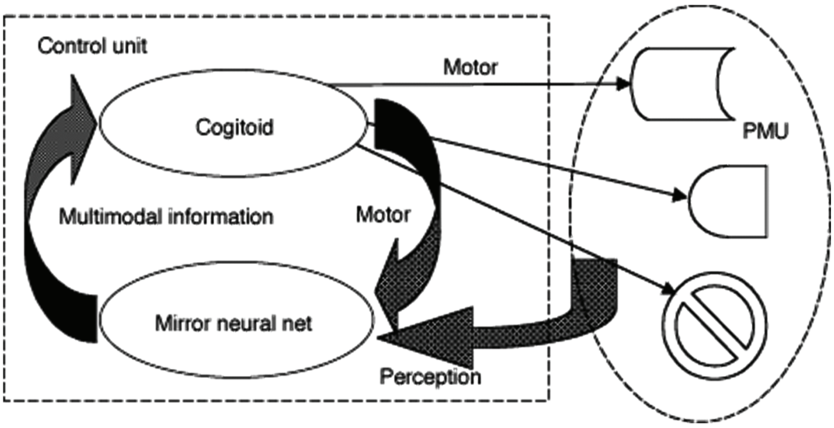

Fig. 7. One of the concepts of the implementation of "embodied intelligence" by use of active agents (Wiedermann, 2003)

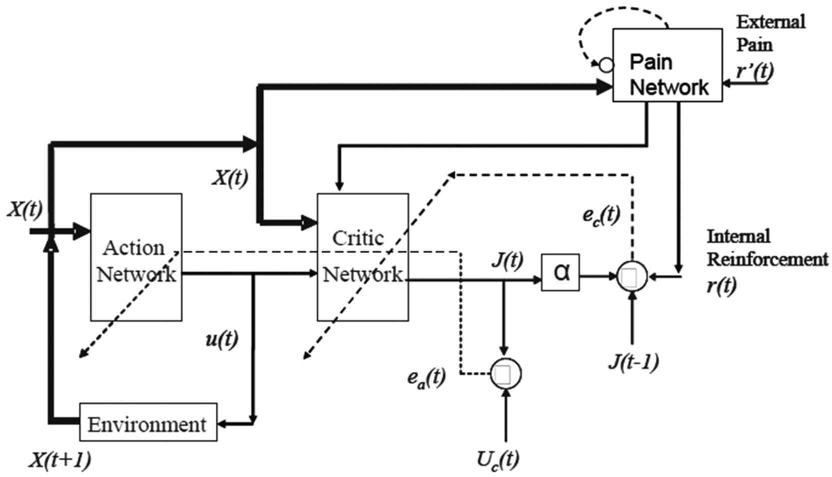

Fig. 8. The structure of the "embodied intelligence" system with built-in pain elements (Starzyk, 2008)

A very interesting path of development of modern neurocybernetics is the so-called "embodied cognition" and the enactivism concept (Barsalou, 2009). Adherents of this approach use a converted version of a well-known drawing by Leonardo da Vinci (figure 6) to argue that intelligence is shaped in action and, therefore, that we cannot construct effective artificial intelligence systems according to the principle that the mind alone will be computer modelled – it is necessary to supplement it with a functioning "body" (usually implemented in practice as a set of so-called active agents – figure 7). Some of the researchers further developing this field of neurocybernetics have gone as far as to discuss the pain "felt" by a system that is equipped with an *embodied intelligence*, in which they have presented mechanisms that assist in the avoidance of such pain (figure 8).

It is difficult to decisively state as to whether this approach will gain acceptance and whether it will truly lead to the much-heralded breakthrough in the field of artificial intelligence. Sceptics should be warned, however, that initially classic neuron networks were also treated with distrust and scepticism.

Since hereinabove we have presented a branch of artificial intelligence that aims to be "embodied", then by way of contrast we should also mention a current in artificial intelligence that is oriented towards the completely abstract implementation of a component of our mind, the importance of which we do not always fully comprehend, even though oftentimes it is of key importance. This concerns so-called *common sense*, as it is known by American researchers of the issue. It appears that this very factor (or, to be more precise, the lack of it) constitutes one of the most acute barriers to the development of certain applications of artificial intelligence. In order to surmount these limitations, Randall and Lenat (1982) elaborated a very ambitious project (as early as the mid-1980s!) for creating a system containing the encyclopaedic knowledge that is necessary to execute a computer equivalent of common sense. In Poland, this project usually arouses amusement on the part of those who hear of it for the first time, due to its name - CYC (from *enCYClopedic knowledge*) (in Polish, the word "cyc" means "tit" - translator's note). It is constructed based on complex structures known as frames. The ontology of the CYC system currently contains more than 300,000 terms and many million interconnecting facts (version 1.0 of OpenCyc had more than 3 million assertions concerning these terms, partially limiting and defining the mutual relations between 26,000 types), and more than 600 man-years of work have been devoted to its development. The system is being developed by Cycorp, the logo of which is shown in figure 9.

Fig. 9. *Logo of Cycorp, the company developing the CYC project.*

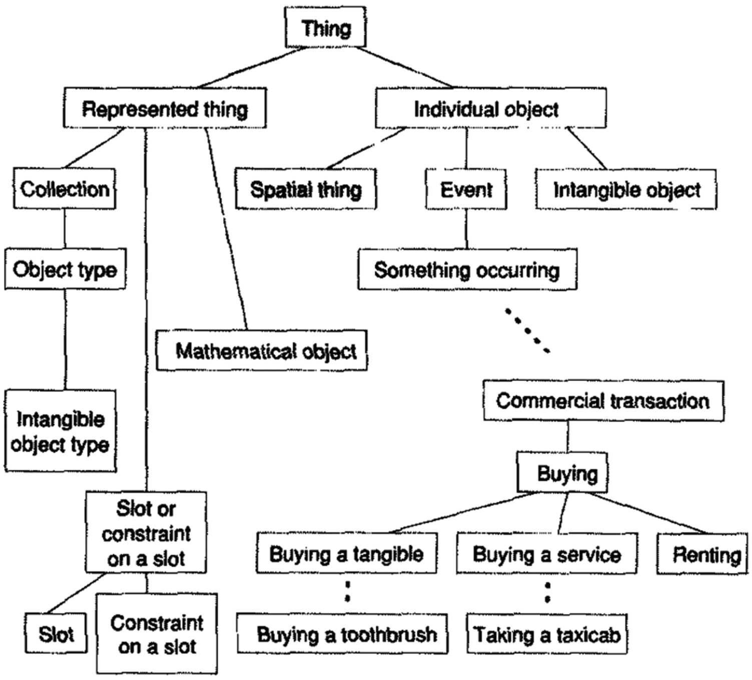

Fig. 10. *Exemplary method of knowledge representation in the CYC system. Illustration from Cycorp's website http://www.cyc.com/*

An exemplary fragment of knowledge representation in the CYC system is shown below in figure 10.

3. THE NEW CLASSIFICATION OF MEMORY

Neurocybernetic systems differ from the presently used general-purpose informational systems in many ways as well as from the point of view of different criteria. One of the aspects distinguishing neuro-like creations from classical computer tools is the method of collecting and storing data, which is the structure, principle of operation and method of utilisation of **memory.** In computers, as we all know, there are RAM, ROM and mass memories (the latter on magnetic disks, optical disks and Flash-type devices). In the brain, which also registers and reproduces various types of information, there are no equivalents of any of the above-mentioned categories. We can distinguish, however, a few other types of memory, which are made distinct by the roles that they fulfil (figure 11).

The simplest tasks are handled by the so-called **cognitive memory** (Duch & Pilichowski, 2007). This memory takes part in perception processes, makes it possible to identify and classify discerned objects, allows us to discover novelties in our surroundings, and - finally - makes it possible to protect ourselves against certain types of threats. Many traditional applications of neuron networks are connected with the memory thus defined, as well as with its learning processes.

A higher level of intellectual analysis of discerned objects, processes and phenomena is provided by **semantic memory (**Meeter & Murre, 2005). This memory systematises gathered information in such a way that it is possible to reach its semantic layer and disclose mutual relations. Memory of this type can be very useful in technical applications, for it can be used to create associations.

For the practical utilisation of observations that are filtered by the cognitive memory and knowledge that are created in the semantic memory, we have **episodic memory** (Tulving, 2005), which based on earlier experience and an assessment of the current situation allows us to control our present behaviour.

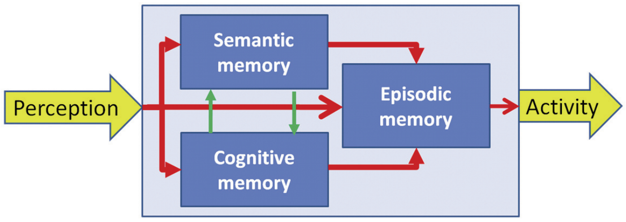

Fig. 11. *Types of memory in neurocybernetic systems*

4. SUMMARY

The present article discusses (very briefly) certain new research trends that have appeared lately in neurocybernetics. These trends are worth tracking and observing, for they give us hope that following the very successful, but by now considerably overused, paradigm of neuron networks, there will come into being (on their basis) a new tool for the intelligent analysis of data. Taking into consideration the still considerable distance that separates even the best computer systems from the efficiency of the human mind, each tool that enriches the resources of contemporary information science and enables us to solve problems that to date have proven difficult will be both valuable and noteworthy.

The list of new research areas of neurocybernetics that is set forth in the present work is not exhaustive. A more inclusive list - albeit outlined in greater brevity - can be found in the work by Duch (2009). Nevertheless, it is not important as to whether we mention more or fewer of these fields - of greater significance is the message that follows from the present article, namely:

Let us not content ourselves with the fact that we have neuron networks and know how to use them. It is definitely worth following the progress of neurocybernetics, for this field of research still has the potential to offer us numerous opportunities of improving computer data analysis processes and may yet hold a few pleasant surprises in store for us.

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NOWE TRENDY W NEUROCYBERNETYCE

Streszczenie

Wiele lat temu sieci neuronowe sieci neuronowe były przedmiotem badań prowadzonych głównie z pobudek teoretycznych. Celem tamtych, prowadzonych przez naukowców prac, było głównie lepsze poznanie biologicznych aspektów funkcjonowania mózgu, a także psychologicznych podstaw kognitywistyki, poprzez budowę matematycznych i elektronicznych modeli symulacyjnych. Niespodziewanym dodatkowym rezultatem tych badań było stworzenie nowych narzędzi obliczeniowych, które dzięki swojej wydajności bardzo szybko zyskały sobie olbrzymią popularność. Obecnie, kiedy sztuczne sieci neuronowe są używane przez niemal wszystkich do rozwiązywania najróżniejszych problemów, dalszy postęp w zastosowaniach obliczeniowych sieci może być osiągnięty poprzez zastosowania badań w zakresie neurocybernetyki. W niniejszej pracy przedstawiono krótki przegląd niektórych najbardziej obiecujących obszarów współczesnych badań w zakresie neurocybernetyki, inspirujących nowe możliwości technologiczne.

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