

RESEARCH STATEMENT



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Abstract. *My primary research interests include modeling of biological neurons and complex neural systems, including neural models for knowledge representation and automatic creation of appropriate neural structures. Moreover, my research is focused on artificial intelligence, computational intelligence, soft-computing, machine learning, data mining, knowledge discovery and knowledge engineering tasks. My study also includes associative memories, pattern and sequence learning, semantic learning, and associative learning. I specialize in the field of classification, construction of well-generalizing classifiers, construction of associative self-optimizing neural networks, associative neural graphs and artificial associative systems. My future research aims to develop new models of neurons, algorithms, architectures, and integrated artificial neural systems of biologically plausible associative mechanisms that can automatically form active representation of knowledge, aggregate data, consolidate sequences in a uniform neural structure. Furthermore, my future research will be focused on developing artificial intelligence and computational intelligence methods and theory to make automation of information processes possible in a brain-like way, automatically representing whatever relations between objects, their groups and sequences in uniform neural systems. I will apply for external funding for research to government agencies and strive for cooperation between industry and university.*

MOTIVATION AND OBJECTIVES

With raising awareness and deepening neurobiological knowledge of neural processes that take place in living creatures and the development of computational techniques, it is possible to build complex dynamic, reactive neural automatically reconfigurable associative systems for modeling real machine intelligence. Artificial intelligence can come into being only when appropriate representation of knowledge will be discovered and applied in reactive neural systems working alike biological brains. Artificial intelligence systems require further serious research on four major aspects:

1. biologically plausible associative mechanisms, representing knowledge in a uniform structure, including self-organization, dynamical learning, associative memory and self-control;
2. embodiment of machine intelligence hardware within systems that learn through interaction with environment with ability to automatically represent and associate classes of objects, their features, actions, relations, groups, and sequences;

3. developing dedicated hardware that is able to process data in a brain-like way, including asynchronous and synchronous parallelism and natural reactivity of biological neurons;
4. defining artificial needs that will automatically switch on and motivate artificial neural systems to act intentionally and to defined goals that can be defined and controlled by humans.

CURRENT RESEARCH

My current research directions involve:

1. Modeling of neurons (AS-NEURONS):

New currently developed and proposed models of neurons implement new biologically plausible mechanisms of automatic self-development accordingly to input stimuli influencing neurons. These models take into account not only direct connections but also an interneuronal space as a medium to spread information that enable neighbour neurons start plasticity processes, e.g. connecting. The new models emphasise the aggregative and associative properties of biological neurons. Each neuron can represent an infinite set of time-spread combinations of input stimuli. Such neurons automatically aggregate representation of many similar objects. They can also specialize by narrowing or widening class of represented objects due to their size, threshold and a number of other neighbour neurons involved in representation of input data. These models use various kinds of sensory fields with connected receptors like biological bodies. These receptors cooperating with neurons take a very important role in the process of automatic representation of input stimuli in developed by me new models of neural networks, e.g. Active Neural Associative Knowledge Graphs (ANAKG), Associative Self-Optimizing Neural Networks (ASONN), Associative Neural Graphs (ANG), and Artificial Associative Systems (AAS).

2. Development of Active Neural Associative Knowledge Graphs (ANAKG):

Appropriate representation of knowledge determines the ability to develop intelligent systems, because no intelligence is possible without automatic knowledge representation, its contextual use, and automatic generalization ability accordingly to a context of its use. The developed Active Neural Associative Knowledge Graphs are able to automatically aggregate representation of many groups of data and associatively consolidate and link many sequences of them. Thanks to aggregation and linking their representations together, we achieve new abilities of such neural networks that are able to bring back memories, generalize them, draw some conclusions, and even be creative.

3. Improvement of Associative Self-Optimizing Neural Networks (ASONN) for classification:

First generation of Self-Optimizing Neural Networks (SONN) did not use associative mechanisms at all, searching through the data for specific groups

of feature values that can be aggregated in neural representation and combined with other weighted groups of feature values to produce neural representation of group of objects of learned classes. Introduction of associative mechanisms made this task much easier because combinations of feature values can now be very quickly determined and used to build even better classifiers. Its generalization abilities position this approach at the top of known classification methods. Moreover, this method has a unique feature, which makes it able to automatically use the economically cheapest features of classified objects. This method will be further developed in order to minimize a number of necessary neurons, optimize fuzzified shape of classifying regions, and make the classification process more hierarchical in order to achieve the best classification results.

4. Modeling of human needs and personality:

Modeling of needs is the second important milestone in a way to artificial intelligence because a system that has no needs or goals has no motivation to develop. Needs evoke desire to act, develop and solve problems, so they should be modeled in artificial intelligence systems. In order for machines to interact with people they should understand human needs and personality and be able to cooperate with them and fulfil these needs. Moreover, people will treat artificial intelligence systems as intelligent since these systems will appropriately react to human needs like other people do. Thus, modeling of human needs and personality is an important and still developing aspect of artificial intelligence in my current study.

FUTURE DIRECTIONS

My future research aims to develop knowledge-based associative intelligent systems that are able to automatically form, self-organize, and generalize knowledge, recall memories as well as generalize them in new contexts of solved tasks, create, remember and use associations, and self-control to accomplish desired tasks or to fulfil built-in needs. This involves the research on different levels of algorithms, architectures, integrated systems design as well as collating various facts of neuroscience. To accomplish my research objective, I plan to develop a research laboratory for Knowledge-based Intelligent Artificial Associative Neural System (KIAANS) with the exiting research resources at University as well as possible external funding and industry cooperation. The short term and long term goals for this laboratory are:

Short-term goals:

1. Finalizing research and construction of multiclass associative self-optimizing neural networks (MASONN) for multi-classification tasks and semantic knowledge representation.
2. Further development and research in area of associative neural graphs (ANG and ANAKG) modeling and representing knowledge and constructing knowledge discovery mechanisms.

3. Focusing on study and development of artificial neural associative systems (AAS), automatic development of their structure into high-level representation of semantics between objects, features, actions, rules, episodes, and their groups in a hierarchical way.
4. Further development and creation of new model of neurons on the basis of previous study in order to equip artificial neurons with ability to automatically create associative brain-like structures, using artificial interneuronal space as a medium and developing methods for automatic conditional triggering of plasticity processes in such neurons.

Long-term goals:

1. Construction of associative neuronal systems able to represent knowledge in associative way with ability to generalize, summarize, draw conclusions and exhibit creativity in new contexts.
2. Construction of new methods for representing big data in an aggregated associative form of semantically linked classes of objects together with their context.
3. Construction and development of new associative data mining and knowledge discovery methods working on associative neural graphs and in artificial neural associative systems.
4. Construction of methods and theory of general artificial intelligence.
5. Development of cognitive systems and embodied artificial intelligence.

EXTERNAL FUNDING RESOURCES

Throughout my doctoral dissertation research and postdoctoral work, I contributed to Polish National Science Foundation (OSF OPI) and got funding for three scientific projects:

1. Research Project KBN 8 T11C 002 19, "*New methods of learning neural networks without feedback*", in years 2000 – 2001;
2. Research Project KBN 4 T11E 031 23, "*The use of artificial intelligence to assist the qualitative interpretation of biomedical acoustic signals*", in years 2003 – 2005;
3. Research Project KBN 4 T11C 025 24, "*Effective classification on the basis of a new type of ontogenic neural networks*", 2003 – 2006.

A next scientific project concerning construction of associative neural graphs for representing knowledge and intelligent reasoning is already being prepared.

External sources are very important to facilitate scientific research, development and implementation.

INDUSTRY COOPERATION

Since 2015 I established cooperation with Chinese industry (6D company) in the area of developing smart methods for medical robots. In the future, I would like to meet with industrial representatives to establish cooperation and make use of scientific research in industry. Industry can also be a valuable source of external resources and can support my research.