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PLACE AND ROLE OF INTELLIGENT SYSTEMS IN COMPUTER SCIENCE

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Abstract

General overview of the Artificial Intelligence area is presented with selected remarks about proper classification of research works as belonging to Artificial Intelligence or not belonging. Paper is treated as a general survey and not include new original scientific results. Nevertheless general idea of Artificial Intelligence area segmentation and systematization proposed in the paper can be useful for other researchers, especially these, who are novice in Artificial Intelligence applications.

Key words: computer science, artificial intelligence, machine learning, symbolic methods, holistic methods

1. INTRODUCTION

Fast and massive development of computer science and it popularity is evident. There are numerous applications of computer science, described in many books and papers. Almost every day bring new achievements and new publications in this area. Some of them are claimed as related to intelligent systems, but not every time this term is used properly. Many solutions and many system named "intelligent" are in fact typical computer applications and theirs connection with the intelligence is in fact reduced to the intelligence of the designers and programmers, not intelligence of the system itself. This remark concern also papers published in CMMS Journal, therefore in this paper we analyze place and role of intelligent systems in general computer science framework.

As was shown on figure 1, we have big number of common elements in computer science and in artificial intelligence, nevertheless are big area in which computer science is definitely something else than artificial intelligence (e.g. computer systems for accounting offices or engineering calculation in computer aided design) as well important part of artificial intelligence study is outside computer science (e.g. philosophical discussions about so called "strong" and "weak" artificial intelligence).

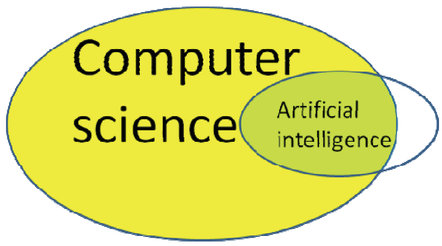

Fig. 1. *Relations between computer science and artificial intelligence.*

In this paper we give general overview of artificial intelligence in this area, where artificial intelligence can be described and discussed as a part of computer science. This overview and survey seem to be necessary because in numerous articles we can find name artificial intelligence when in fact prob-

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lems under consideration are based on different computer science methods not engaging in fact approaches leading to machine intelligence problems. Authors of these papers show sometimes the necessity of using various computational methods, but considered methods, named artificial intelligence methods, in fact are very far from intelligent systems building.

Off course almost every particular problem needs an individual solution and individual evaluation. Unique and "always proper" attempt to the artificial intelligence sure not exist. Every author search and find own path, thus we can meet in fact also many different intelligent systems studied in the literature. This paper is a kind of survey of variety particular systems given by the authors and different approaches presented in particular papers. The titles of papers will be not cited here, because the goal of this paper is not give critical assessment of particular papers, but we try to show the problem of abuse of artificial intelligence name without rational justification.

2. WHAT IS ARTIFICIAL INTELLIGENCE?

The role of this paper is to provide the reader with a bird's eye view of the area of intelligent systems. Before we explain what intelligent systems are and why it is worth to study and use them, it is necessary to comment on one problem connected with the terminology.

It seems that, problems of equipping artificial systems with intelligent abilities are, in fact, unique. We always want to achieve a general goal, which is a better operation of the intelligent system than one, which can be accomplished by a system without intelligent components. There are many ways to accomplish this goal and therefore we have many kinds of artificial intelligent systems. In general, it should be stressed, that there are two distinctive groups of researches working in these areas: the artificial intelligence community and the computational intelligence community. The goal of both groups is the same: we need artificial systems powered by intelligence. However, the way to accomplish this goal by every community is different (figure 2).

Artificial Intelligence (AI) researchers (Luger, 2005) focus on imitation of human thinking methods, discovered by psychology, sometimes philosophy and so called *cognitive sciences*. The main achievements of AI are traditionally rule based systems in which computers follow known methods of human thinking and try to achieve similar results as human. Mentioned below and described in detail in a separate chapter, expert systems are good examples of this Artificial Intelligence (AI) approach.

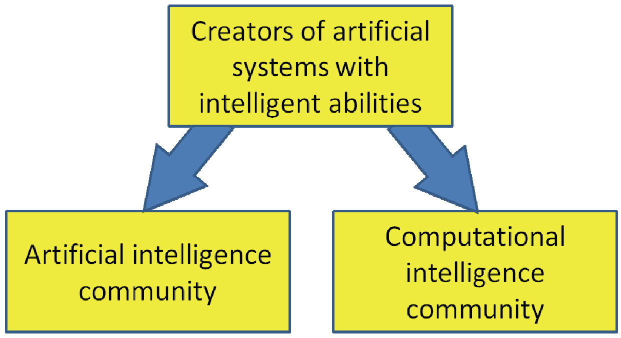

Fig. 2. *Two distinctive groups of researches working in Artificial Intelligence and Computational Intelligence.*

Computational Intelligence researchers (Poole et al., 1998) focus on modelling of natural systems, which can be considered as intelligent ones. The human brain is definitely the source of intelligence; therefore, this area of research focuses first on neural networks, very simplified but efficient in practical application models of small parts of the biological brain. There are also other natural processes, which can be used (when appropriately modeled) as a source of ideas for successful artificial intelligent systems. We mention for example swarm intelligence models, evolutionary computations and fuzzy systems.

The differentiation between Artificial Intelligence and Computational Intelligence, named also Soft Computing (Cios et al., 2005) is important for researchers and should be obeyed in scientific papers for its proper classification. However, from the point of view of applications in intelligent systems it can be disregarded. Therefore in the next parts of this paper we will simply use only one name (Artificial Intelligence) comprising both Artificial Intelligence and Computational Intelligence methods. For more precise differentiations and for tracing bridges between both mentioned approaches the reader is referred to the book (Rutkowski et al., 2008).

3. IS ARTIFICIAL INTELLIGENCE COMPACT PART OF KNOWLEDGE?

The term Artificial Intelligence (AI) is used in a way similar to terms such as Mechanics or Electronics but the area of research and applications that belong to AI is not as precisely defined as the other areas of Computer Science. The most popular definitions of AI are always related to the human brain and its emerging property: natural intelligence (figure 3).

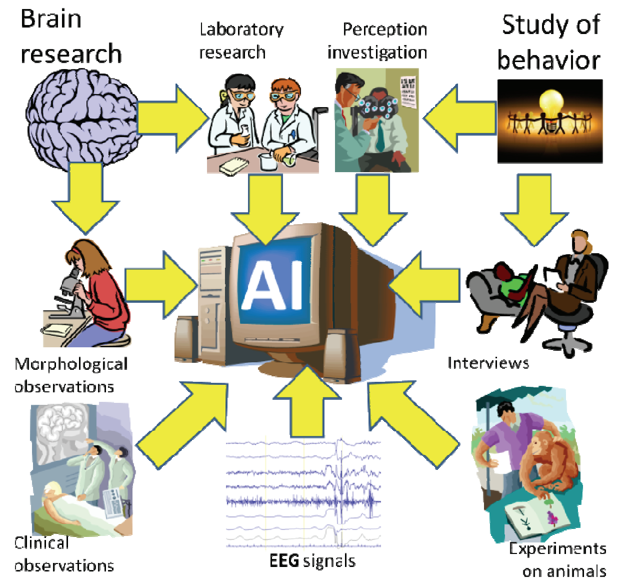

Fig. 3. Many sources of empirical knowledge are used as foundations of Artificial Intelligence (AI) concepts.

Valuable source of information and inspiration for Artificial Intelligence research are also psychological experiments and psychological observations. Taking into account human behavior in situations, when man must use his natural intelligence (figure 4) and follow introspective rapports registering way of thinking (figure 5) we can also obtain foundations for development of Artificial Intelligence methods.

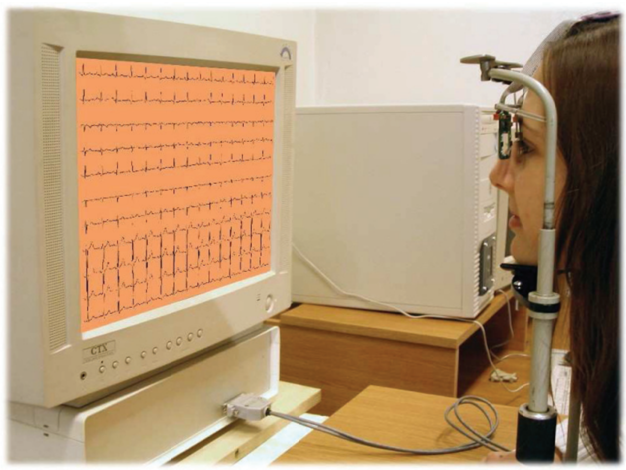

Fig. 4. Psychological research as a source of Artificial Intelligence development.

At times it was fashionable to discuss the general definition of Artificial Intelligence as follows. ***Is AI at all possible or not?*** Almost everybody knows Turing's answer to this question (Turing, 1950), known as "Turing test", where a human judge must recognize if his unknown to him partner in discussion is an intelligent (human) person or not. Many also know Searle's response to the question, his "Chinese room" model (Searle, 1980). For more information about these contradictions the reader is referred to the literature listed at the end of this paper (a small bibliography of AI), as well as to a more comprehensive discussion of this problem in thousands of webpages on the Internet. From our point of view it is sufficient to conclude that the discussion between supporters of "strong AI" and its opponents is still open – with all holding their opinions.

Fig. 5. Analysis of introspective thinking rapports is also valuable source of inspiration for Artificial Intelligence researchers.

For the readers of this paper the results of these discussions are not that important since regardless of the results of the philosophical roll outs – "intelligent" systems were built in the past, are used contemporarily, and will be constructed in the future. It is because intelligent systems are very useful for all, irrespective if they believe in "strong AI" or not. Therefore in this paper we do not try to answer the fundamental question about the existence of the mind in the machine. We just present some useful methods and try to explain how and when they can be used. This detail knowledge can be found in the book quoted above (Rutkowski et al., 2008). In this paper only general outline of this problem will be presented for proper classification in the future which method or system can be named artificial intelligence tool, an which not.

General map of the Artificial Intelligence area is presented on figure 6. Now we describe very short particular parts of these map, next (in sequent chapters) we will discuss step by step some interesting details.

General view of the map show, that big and important part of Artificial Intelligence is connected with machine learning systems. In fact learning ability is one of most important factors for every intelligent system and most intelligent activities must be based on collecting and using knowledge. Inside machine learning systems area we can find neural networks – most known and most valuable learning systems. Let consider that not all neural network area is covered by learning systems area – it is because of some neural networks, which work without learning process. Inside machine learning area we can find also pattern recognition systems (which can be realized sometimes as neural networks) and learning decision trees.

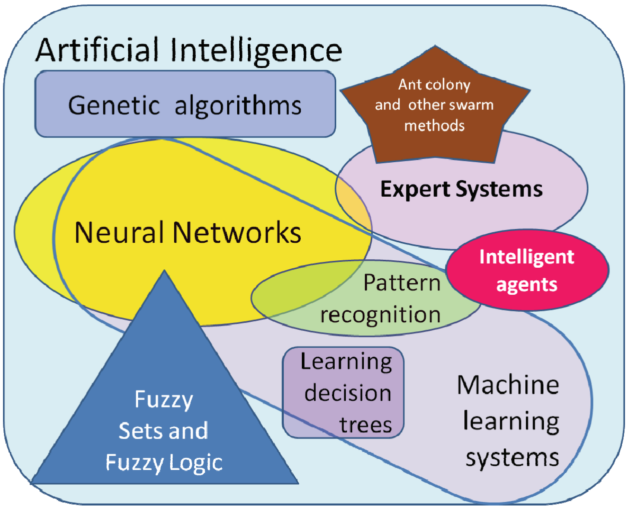

Fig. 6. General map of the Artificial Intelligence area.

Special part of artificial intelligence methods are Fuzzy Set and Fuzzy Logic system. Considered systems can be combined with Neural Networks (as so called neuro-fuzzy solutions) and sometimes also may be learned. Special parts of Artificial Intelligence area are Expert Systems, Intelligent agents and Genetic algorithms, and most strange part of Artificial Intelligence are Ant colony methods and in general so called Swarm methods.

Now we go to the details.

4. NEURAL NETWORKS – FIRST ARTIFICIAL INTELLIGENCE TOOL

This paper is not meant to be a history of Artificial Intelligence or Neural Networks because the users are interested in exploiting of mature systems, algorithms, or technologies, regardless of long and difficult ways of systematic development of particular methods as well as serendipities that were important milestones in AI's development. Nevertheless, it is good to know that the oldest systems, solving many problems by means of AI methods, were neural networks. This very clever and user-friendly technology is based on the modeling of small parts of real neural system (e.g., small pieces of the brain cortex) that are able to solve practical problems by means of learning. The way leading form brain research to neural networks discovery and development is shown on figure 7. In upper part of this figure we see mysterious brain studied by biologist and neurocybernetic researcher, who collect results of biological research converting them to the mathematical model form (below). In lower part of figure we see how mathematical model of the brain activity is converted to computer program – artificial neural network, used next as Artificial Intelligence tool.

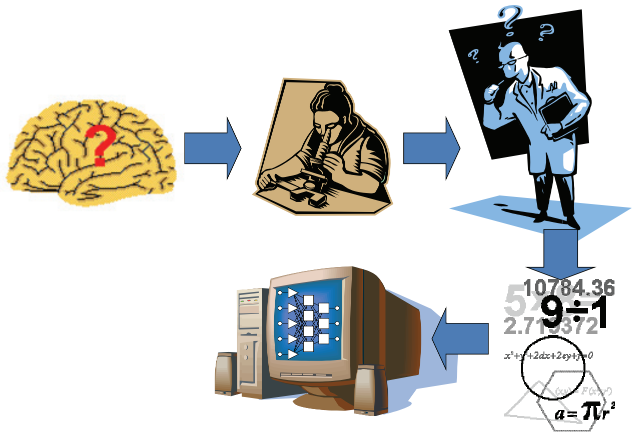

Fig. 7. Way leading form brain research to neural networks discovery and development.

The neural network theory, architecture, learning and methods of application was be discussed in many papers published before (e.g., Tadeusiewicz, 2009 or Tadeusiewicz, 2010), therefore here we only provide a general outline.

One was mentioned above: neural networks are the oldest AI technology and it is still leading technology of one counts number of practical applications. When the first computers were still large and clumsy, the neurocomputing theorists (McCulloch & Pitts, 1943), thus laying foundations for the field of artificial neural networks. This paper is considered as the one that started the entire Artificial Intelligence area. Many books written earlier and quoted sometimes as heralds of AI were only theoretical speculations. In contrast the paper just quoted was the first constructive proposition on how to build artificial intelligence on the basis of mimicking brain structures. It was a fascinating and breaking idea in the area of computer science.

During many years of development neural networks became the first working AI systems (Perceptron by Rosenblatt, 1957), which was underestimated and it lost "steam" because of (in) famous book (Minsky & Papert, 1988), but returned triumphantly as an efficient tool for practical problem solving with discovery of backpropagation learning method (Rumelhart & McClelland, 1986). Neural networks are assessed as the best computational tool for solving complex problems with total lack of information about rules governing the problem (figure 8).

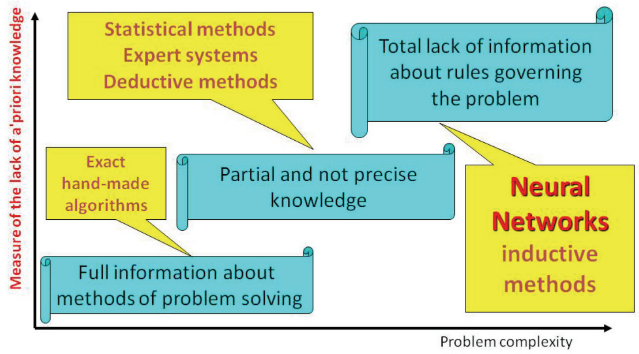

Fig. 8. Localization neural network application area.

Since the mid-eighties of the 20^{th} century the power and importance of neural networks permanently increased, reaching now a definitely leading position in all AI applications. However, its position is somehow weakened because of the increase in popularity and importance of other methods belonging to the so-called soft computing. But if one has a problem and needs to solve it fast and efficiently – one can still choose neural networks as a tool that is easy to use (figure 9), with lots of good software available.

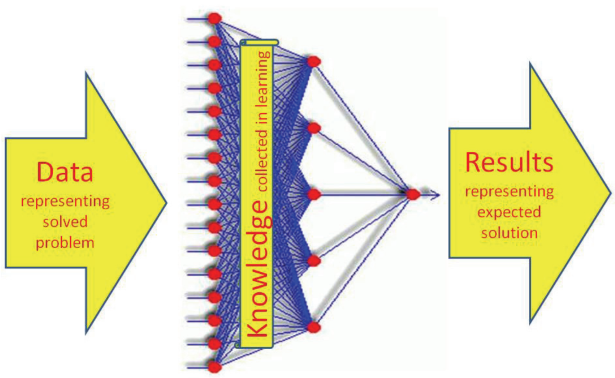

Fig. 9. General scheme of the neural network use.

The above comments are the reason we pointed out neural networks technology in the title of this sub-chapter with the descriptive qualification "first". From the historical point of view neural networks was the first AI tool. From the practical viewpoint, it should be used as the first tool, when practical problems need to be solved. It is great chance that the neural network tool you use turns out good enough and you do not need any more. Let me give you advice, taken from years of long experience in solving hundreds of problems with neural networks applications. There are several types of neural networks elaborated on and discovered by hundreds of researchers. But the most simple and yet successful tool in most problems is the network called MLP (Multi-Layer Perceptron by Haykin, 1999). If one knows exactly the categories and their exemplars one may use this network with a learning rule such as the conjugate gradient method. If, on the other hand, one does not know what one is expecting to find in the data because no prior knowledge about the data exists, one may use another popular type of neural network, namely, the SOM (Self-Organizing Map), also known as Kohonen network, which can learn without the teacher (Kohonen, 1995). If one has an optimization problem and needs to find the best solution in a complex situation, one can use the recursive network, known as the Hopfield network (Hopfield, 1982). Experts and practitioners can of course use also other types of neural networks, described in hundreds of books and papers but it will be a kind of intellectual adventure, like off-road expedition. Our advice is like signposts pointing towards highways; highways are boring but lead straight to the destination. If one must solve a practical problem often there is no time for adventures.

5. HUMAN KNOWLEDGE INSIDE THE MACHINE – EXPERT SYSTEMS

Neural network discussed in the previous section are very useful and are effective tools for building intelligent systems but they have one troublesome limitation. There is a huge gap between the knowledge encoded in the neural network structure during the learning process, and easy for human understanding knowledge presented in any intelligible form (mainly based on symbolic forms an natural language statements). It is very difficult to use knowledge which is captured by the neural network during its learning process, although sometimes this knowledge is the most valuable part of the whole system (e.g., in forecasting systems, where neural networks sometimes are – after learning – a very successful tool, but nobody knows how and why).

The above mentioned gap is also present when going in the opposite way, e.g. when we need to add man's knowledge to the artificial intelligent system. Sometimes (and in fact very often) we need to have in an automatic intelligent system some part of this knowledge embedded, which can be obtained from the human expert. We need to insert this knowledge into an automatic intelligent system because it is often easier and cheaper to use a computer program instead of constantly asking humans for expert opinion or advice.

Such design with computer-based shell and human knowledge inside it is known as an Expert System (Giarrantano & Riley, 1989). Such a system can answer the questions not only searching inside internal knowledge representation but can also use methods of automatic reasoning for automatic deriving of conclusions needed by the user. The Expert system can be very helpful for many purposes, combining the knowledge elements extracted from both sources of information: explicit elements of human expert wisdom collected in the form of the knowledge base in computer memory, and elements of user knowledge hidden in the system and emerged by means of automatic reasoning methods after questioning the system (figure 10).

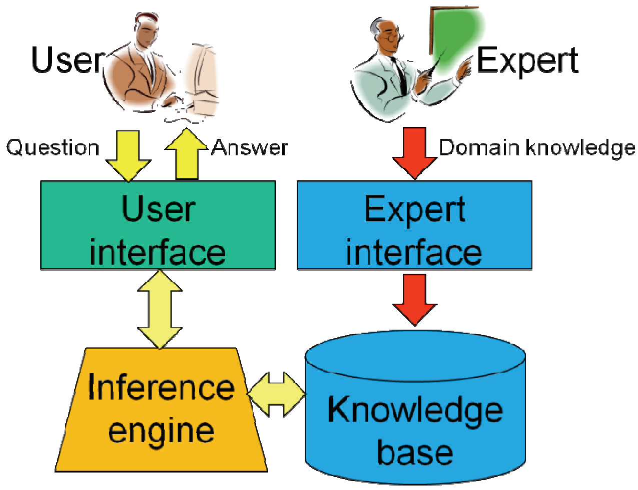

Fig. 10. *Simplified model of the expert system.*

The main difference between the expert systems and neural networks is based on the source and form of knowledge, which is used in these two AI tools for practical problem solving. In neural networks the knowledge is hidden and has no readable form but can be collected automatically on the base of examples forming the learning data set. Results given by neural networks can be true and very useful but never comprehensible to users, and therefore must be treated with caution. On the other hand, in the expert system everything is transparent and intelligible (most of such systems can provide explanations of how and why the particular answer was derived) but the knowledge used by the system must be collected by humans (experts himself or knowledge engineers who interview experts), properly formed (knowledge representation is a serious problem) and input into the system's knowledge base. Moreover, the methods of automatic reasoning and inference rules must be constructed by the system designer and must be explicit to build it into the system's structure. It is always difficult to do so and sometimes it is the source of limitations during the system's development and exploitation.

6. SYMBOLIC OR HOLISTIC SYSTEMS?

There are various approaches to intelligent systems but fundamental difference is located in following distinction: the methods under consideration can be described as symbolic versus holistic ones (figure 11).

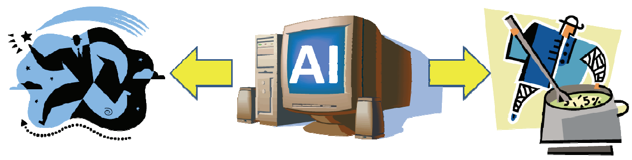

Fig. 11. *Methods used in AI can be described as holistic (intuitive) finding of proper solutions (left) or diligent processing of symbolic knowledge representation (right).*

In general the domain of Artificial Intelligence (very wide and presented in this paper only as a small piece) can be divided or classified using many criteria. One of the most important divisions of the whole area can be based on the difference between the symbolic and holistic (pure numerical) approach. This discriminates all AI methods but can be shown and discussed on the basis of only two technologies presented here – neural networks and expert systems. Neural networks are technology definitely dedicated toward quantitative (numerical) calculations. Signals on input, output and most importantly – every element inside the neural network - are in the form of numbers even if its interpretation is of a qualitative type. It means that we must convert qualitative information into quantitative representation in the network. This problem is out of the scope of this paper, therefore we only mention a popular way of such a conversion, called "one of N". The merit of this type of data representation is based on spreading one qualitative input to N neurons in the input layer, where N is a number of distinguishable quantitative values, which can be observed in a considered data element. For example, if a qualitative value under consideration is "country of origin" and if there are four possible countries (let's say the USA, Poland, Russia, Germany) we must use for representation of this data four neurons with all signals equaling zero, except one input, corresponding to the selected value in input data, where the signal is equal one. In this representation 0,1,0,0 means Poland, etc. The identical method is used for representation of output signals in neural networks performing a classification task. Output from such a network is in theory singular, because we expect only one answer: label of the class to which a classified object belongs given the input of the network at this moment. But because the label of the class is not a quantitative value – we must use in the output layer of the network as many neurons as there are classes – and the classification process will be assessed as successful when an output neuron attributed to the proper class label will produce a signal much stronger than other output neurons (figure 12).

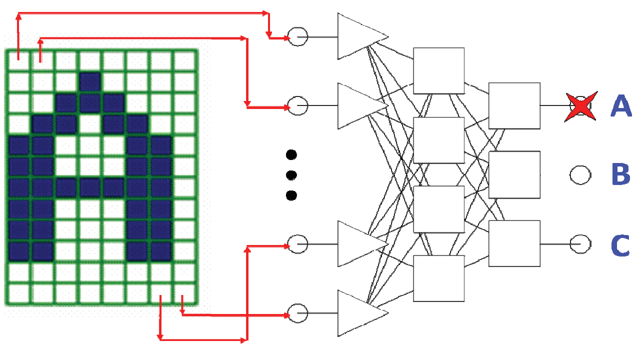

Fig. 12. *Holistic neural network tool (neural network) producing symbolic answer.*

Returning to the general categorization of AI methods: qualitative versus quantitative we point out expert systems as a typical tool for processing of qualitative (symbolic) data. The source of power in every expert system is its knowledge base, which is constructed from elements of knowledge obtained from human experts. Such elements of knowledge are different from the merit point of view because the expert system can be designed for solving different problems. Also, internal representation of the human knowledge in a particular computer system can be different, but always in its symbolic form (sometimes even linguistic (natural language sentences)).

The methods of symbolic manipulations were always very attractive for Artificial Intelligence researchers because the introspective view of human thinking process is usually registered in a symbolic form (so-called "internal speech"). Thus, in our awareness almost every active cognitive process is based on symbol manipulations. Also, from the psychological point of view the nature of activity of the human mind is defined as analytical-synthetical. What is especially emphasized is the connection between thinking and speaking (language), as the development of either of these abilities is believed to be impossible to exist in separation one from another.

Therefore "founding fathers" of AI in their early works massively used symbolic manipulations as tools for AI problem solving. The well-known example of this stream of works was the system named GPS (General Problem Solver) created in 1957 (Newell et al., 1959). It was a famous example, but we stress that a lot of AI systems based on symbolic manipulations and applying diverse approaches have been described in the literature. They were dedicated to automatic proving of mathematical theorems, playing a variety of games, solving well formalized problems (e.g., Towers of Hanoi problem), planning of robot activities in artificial environments ("blocks world") and many others. Also early computer languages designed for AI purposes (e.g., LISP) were symbolic.

The differentiation between symbolic manipulations (as in expert systems) and holistic evaluation based on numerical data (like in neural networks) is observable in whole Artificial Intelligence technology. It must be taken into account by every person who strives for enhancement of designed or used electronic systems powering them by Artificial Intelligence supplements.

We note one more surprising circumstance of the above discussed contradiction. Our introspection suggest a kind of internal symbolic process, which is accompanied with every metal process inside the human brain. At the same time, neural networks that are models of the human brain are not able to use symbolic manipulation at all!

7. AI SOLUTIONS CONNECTED WITH PATTERN RECOGNITION

Artificial Intelligence methods and tools are used for many purposes but one of the most important areas, where AI algorithms are used with good results, are problems connected with pattern recognition. The need of data classification is very popular because if we can classify the data we can also better understand the information hidden in the data streams and thus can pursue knowledge extraction from the information.

In fact, for using in Artificial Intelligence automatic classification methods we must take into account two types of problems and two groups of methods used for problem solution.

The first one is a classical pattern recognition problem with many typical methods used for its solving. At the start of all such methods we have a collection of data and – as a presumption - a set of precisely defined classes. We need a method (formal algorithm or simulated device like neural network) for automatic decision making as to which class a particular data point belongs (figure 13).

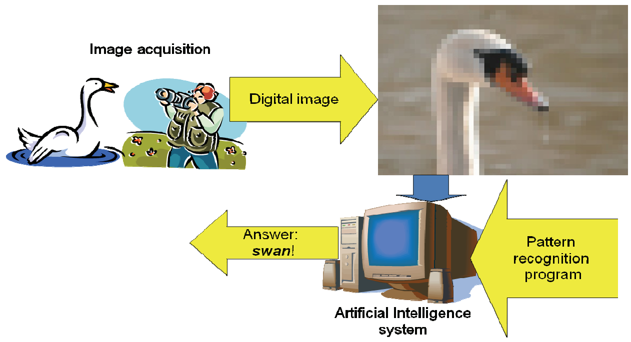

Fig. 13. Pattern recognition system.

Pattern recognition is always based on features of recognized objects. Figure 14 shows an example how the features (property of face images in considered example) can be categorized.

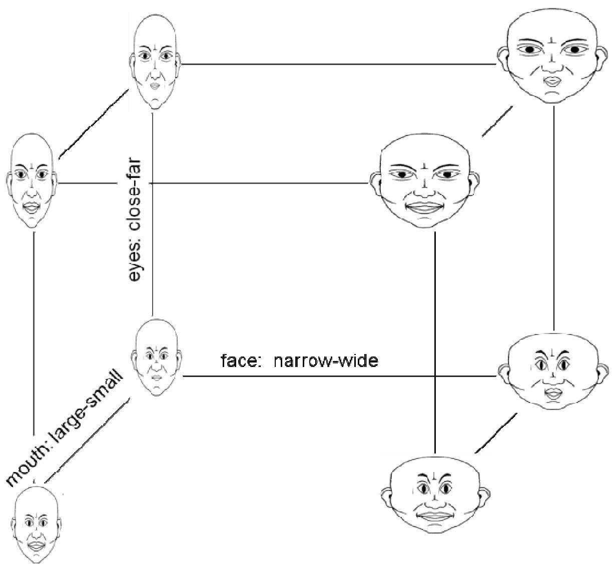

Fig. 14. Example features which can be used for categorization and recognition of faces.

The face can be wide or narrow, can have large or small mouth, and eyes can be close or far. Once these categories are selected then each image of a face can be considered as a point in the three dimensional space as shown in figure 15.

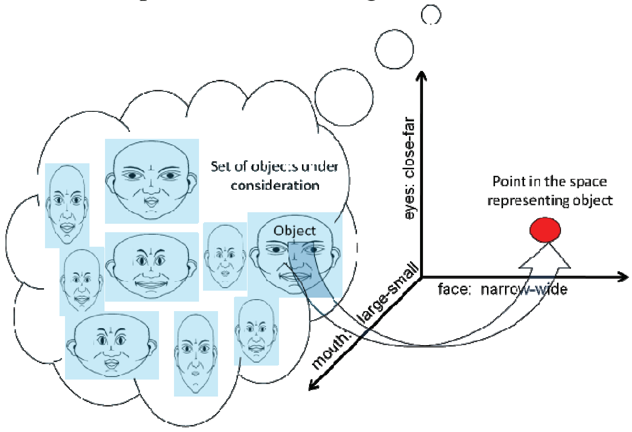

Fig. 15. Relation between image of face and point in three dimensional space.

Of course often in the object we can distinguish more than just three properties and this would be a point in multidimensional space. Fuzzy systems may handle well the classifications when dimensionality they are limited to three. For problem with larger dimensions neural networks have a significant advantage.

The problem under consideration is important from a practical point of view because such classification-based model of data mining is one of the most effective tools for discovering the order and internal structure hidden in the data. This problem is also interesting from the scientific point of view and often difficult to solve because in most pattern recognition tasks we do not have any prior knowledge about classification rules. The relationship between data elements and the classes to which these data should be classified is given only in the form of collection of properly classified examples. Therefore all pattern recognition problems are examples of inductive reasoning tasks and need some machine learning approach that is discussed in next chapter (Theodoridis & Koutroumbas, 2009).

8. KEY ELEMENT OF AI - MACHINE LEARNING

Most non-trivial applications of Artificial Intelligence methods are related to machine learning process. Machine learning methods can be divided into two general parts. First part is based on the supervised learning while second part is related to unsupervised learning called also self-learning or learning without teacher.

Example of supervised learning is presented on figure 16. Learning system (represented by computer with learning algorithm inside) receive information about some object (e.g. man's face). The information about the object is introduced throw the system input when teacher guiding the supervised learning process prompt proper name of the class, to which this object should be numbered among. The proper name of the class is "Man" and this information is memorized in the system. Next another objects are shown to the system and for every object teacher gives additional information, to which class this object belongs. After many learning steps system is ready for exam and then new object (never seen before) is presented. Using knowledge completed during the learning process system can recognize unknown object (for example as a man).

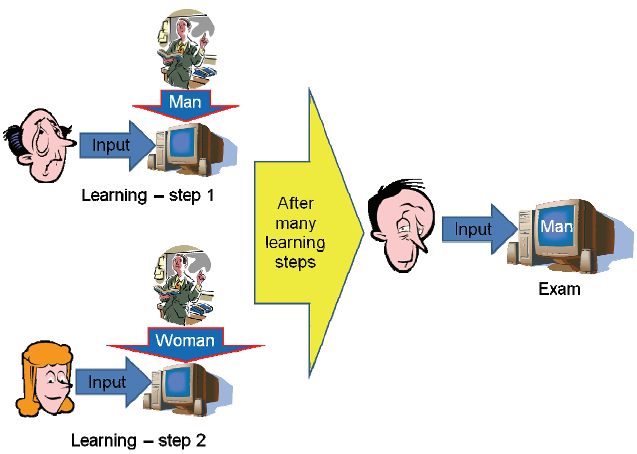

Fig. 16. *Pattern recognition problem with supervised learning used.*

In real situations special database (named learning set) is used instead of human teacher. In such database we have examples of input data as well as proper output information (results of correct recognition). Nevertheless the general scheme of supervised learning, shown on figure 16 is fulfilled also in this situation.

Methods used in AI for pattern recognition vary from simple ones, based on naïve geometrical intuitions used to split data description space (or data features space) into parts belonging to different classes (e.g., k-Nears Neighbor algorithm), through methods in which the computer must approximate borders between regions of data description space belonging to particular classes (e.g., discriminant function methods or SVM algorithms), up to syntactic methods based on structur or linguistics, used for description of classified data (Duda et al., 2001).

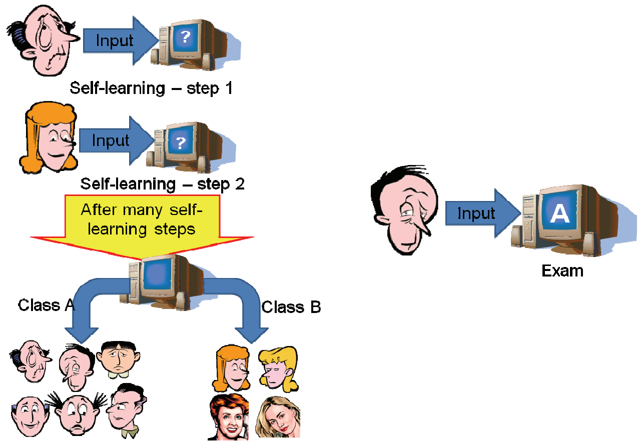

Fig. 17. *Classification problem with unsupervised learning used.*

A second group of problems considered in AI and related to the data classification tasks is cluster analysis (Aldenderfer & Blashfield, 1984). Characteristics of these problems are symmetrical (or dual) to the above mentioned pattern recognition problems. Where in pattern recognition we have predefined classes and need a method for establishing membership for every particular data point into one of such classes, in cluster analysis we have only the data and we must discover how many groups are in the data (figure 17). There are many interesting approaches to solving clustering problems, and this problem can be thought of as the first step in building automatic systems capable of knowledge discovery, not only learning (Cios et al., 2007).

Let us discuss unsupervised learning scheme used for automatic solving of classification problems. During self-learning learned algorithm also receive information about features of the objects under consideration, but in this case this input information is not enriched by accompanying information given by the teacher – because teacher is absent. Nevertheless self-learning algorithm can perform classification of the objects using only similarity criteria and next can recognize new objects as belonging to particular self-defined classes.

9. FUZZY SETS AND FUZZY LOGIC

One of the differences between the human mind and the computer relates to the nature of information/knowledge representation. Computers must have information in precise form, such as numbers, symbols, words, or even graphs, however, in each case it must be an exact number, or precisely selected symbol, or properly expressed word or graph plotted in a precisely specified form, color, and dimension. Computers cannot accept a concept such as "integer number around 3", or "symbol that looks like a letter", etc.. In contrast, human minds perform very effective thinking processes that take into account imprecise qualitative data (e.g., linguistic terms) but can come up with a good solution, which can be expressed sharply and precisely.

There are many examples showing the difference between mental categories (e.g., "young woman") and precisely computed values (e.g., age of particular people). Definitely, the relation between mathematical evaluation of age and "youngness" as a category cannot be expressed in a precise form. We cannot precisely answer the question, at which second of a girl's life she transforms to a woman, or which exact hour begins her old age?

In every situation, when we need to implement in an intelligent system a part of human common sense, there is a contradiction between human fuzzy/soft thinking and the electronic system's sharp definition of data elements and use of precise algorithms. As is well known the solution is to use fuzzy set and fuzzy logic methods (Zadeh, 1965). Fuzzy set (for example the one we used above, "young woman") consists of the elements which for sure (according to human experts) belongs to this set (e.g. 18 years old graduate of high school), and the elements that absolutely do not belong to this fuzzy set (e.g. 80 year old grandma), but take into account the elements that belong to this set only partially. All elements that have degrees of membership different from zero belong to this particular fuzzy set. Some of them have membership function with values of 1 – they belong to the set unconditionally. Elements with membership function have values of 0 – they are outside of the set. For all other elements the value of membership function is a real number between 0 and 1. The shape of membership function is defined by human experts (or sometimes from available data) but for practical computations the preferred shapes are either triangular or trapezoidal (figure 18).

Fuzzy logic formulas can be dually expressed by ***if… then … else …*** statements but they are expressed by means of fuzzy formulas. It is worth mentioning that fuzzy logic came to being as an extension of Lukasiewicz's multi modal logic (Lukasiewicz, 1970).

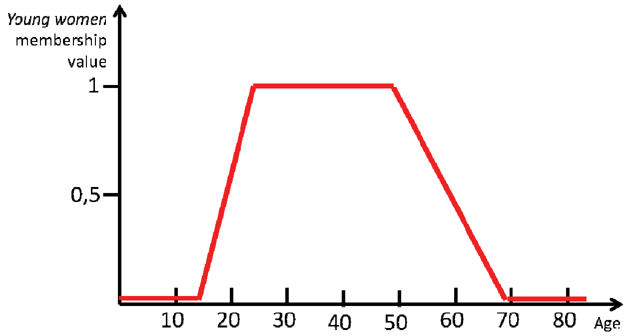

Fig. 18. *Example fuzzy set membership function.*

It is worth mentioning here a gap between rather simple and easy to understand key ideas, used in fuzzy data representation as well as simple fuzzy logic reasoning methods and rather complex practical problems solved in Artificial Intelligence by means of fuzzy systems. It can be compared to walking in high mountains – first we go through a nice flowering meadow but after a while the walk transforms into extreme climbing.

Not all AI researchers like fuzzy methods. A well known AI expert commented that this approach can be seen as "*fuzzy theory about fuzzy sets*". But in fact the advantages of using fuzzy methods are evident. Not only the knowledge-based systems (i.e., expert systems) broadly use fuzzy logic and fuzzy representation of linguistic terms but the fuzzy approach is very popular in economic data assessment, in medical diagnosis, and in automatic control systems. Moreover, their popularity increases because in many situations they are irreplaceable.

10. GENETIC ALGORITHMS, EVOLUTIONARY COMPUTING AND OTHER BIOLOGICALLY BASED METHODS

While describing neural networks, which are popular AI technology, we stressed their biological origin as a crude model of a part of a brain. Thanks to this fact artificial neural networks exhibit brain-like behavior: they can learn and self-organize, generalize, and be used as predictors/classifiers, arrange information on the base of auto-associative and hetero- associative criteria, perform holistic and intuitive analysis of complex situations, are robust, etc. On the basis of the neural network example we show the effectiveness of translating the biological knowledge into technological applications. Neural networks are obviously not a unique example of such biology-to-technology transmission of ideas. Another very well known example are evolutionary computations (Mitchell, 1996).

The biological theory of evolution in many details (especially connected with the origin of humans) is still the area of hot discussions but no one questions the existence of evolution as a method of natural species optimization. In technology we also seek for ever-better optimization methods. Existing optimization algorithms can be divided (freely speaking) into two subgroups. The first subgroup is formed by methods based on goal-oriented search (like fastest decrease/increase principle); an example is gradient descend algorithm. The second group is based on random search methods; an example is Monte Carlo method.

Both approaches to optimization suffer serious disadvantages. Methods based on goal- oriented search are fast and efficient in simple cases, but the solution may be wrong because of local minima (or maxima) of the criteria function. It is because the search process in all such methods is driven by local features of the criterion function, which is not optimal in the global sense. There is no method, which can be based on local properties of the optimization functionality and at the same time can effectively find the global optimum. On the other hand, the methods which use random searches can find proper solutions (optimal globally), but require long computational times. It is because probability of a global optimum hit is very low and is increased only by means of performing a large number of attempts.

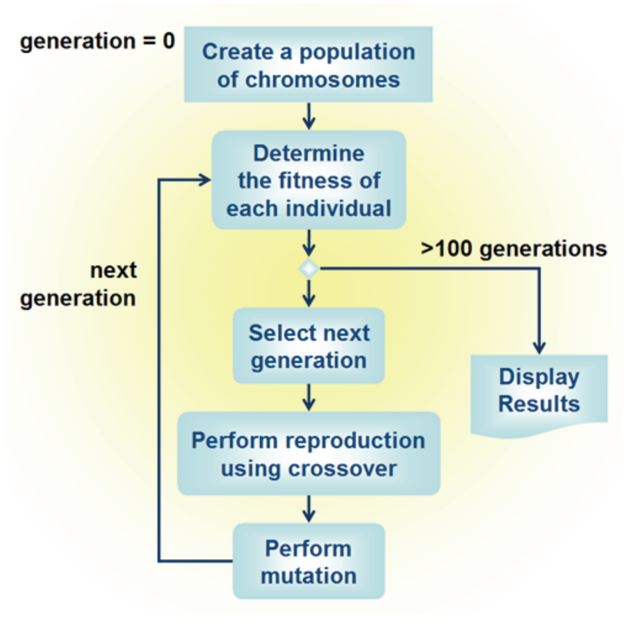

Fig. 19. Example of artificial evolution process.

AI methods based on evolutionary computations combine random searches (because of using cross-over and mutation) with goal-oriented searches (maximization of the fitness function, which is a functional to be optimized). Moreover, the search is performed simultaneously on many parallel paths because of several individuals (represented by chromosomes) belonging to every simulated population. The main idea of the evolutionary computing is based on defining all parameters and finding their optimal values. We generate (randomly) initial value for chromosomes (individuals belonging to the initial population) and then artificial evolution starts. During every step such artificial evolution fitness of each individual (measure of quality of solution given by this individual according to it chromosome) is determined and the best individuals are selected for producing next generation. Reproduction is connected with crossover process (exchange parts of genetic material between “parent” individual) and the mutation is applied. Artificial evolution stops after selected number of generations and the best individual is treated as solution of considered problem.

It is worth to remember that evolutionary computing is a more general term than, for example, genetic algorithms. Every user of genetic algorithms is doing evolutionary computing (Koza, 1992), but some evolutionary computing are not genetic algorithms.

In the title of this paragraph we mentioned that there exists other biologically inspired methods for problem solving. We note below just two that are very popular.

The first one is the ant colony optimization method that is used for solving many optimization problems, and is based on the ant’s behavior. Like the neural network it is a very simplified model of a part of the human brain, while genetic algorithms work on the basis of evolution, the ant’s calculations use simplified model of the social dependences between ants in an ant colony. Every particular ant is a primitive organism and its behavior is also primitive and predictable. But the total ant population is able to perform very complicated tasks like building of the complex three dimensional structure of the ant-hill or finding the most efficient way for transportation of food from the source to the colony. The most efficient way can sometimes be equivalent to the shortest path; it takes into account structure of the ground surface for minimizing the total effort necessary for food collection. Intelligence of the ant colony is its emerging feature. The source of very clever behavior observed sometimes for the whole ant population is located in rather simple rules controlling behavior of each particular ant and also in the simple rules governing relations and "communication" between ants. Both elements (e.g. mechanisms of single ant activity control as well as communication schemes functioning between ants) are easily modeled in the computer. Complex and purposeful behavior of the entire ant population can be then converted into an intelligent solution of a particular problem by the computer (Colorni et al., 1991).

The second (too previously discussed) bio-inspired computational technique used in Artificial Intelligence is artificial immune systems methodology. The Natural immune system is the strongest anti-intruder system that defend living organisms against bacteria, viruses and other alien elements, which try to penetrate the organism. Natural immune systems can learn and must have memory, which is necessary for performing the above mentioned activities. Artificial immune systems are models of this biological system that are able perform similar activities on computer data, programs, and communication processes (de Castro & Timmis, 2002).

11. INTELLIGENT AGENTS

Over many years of development of Artificial Intelligence algorithms dedicated to solving particular problems there was a big demand (in terms of computer calculation power and in memory). Therefore, programs with adjective "intelligent" were hosted on big computers and could not be moved from one computer to the other. An example is Deep Blue – a chess-playing computer developed by IBM, which on May 11, 1997, won the chess world championship against Garry Kasparov.

In contemporary applications artificial intelligence, even the most successful, located in one particular place is not enough for practical problem solving. The future is distributed Artificial Intelligence, ubiquitous intelligence, which can be realized by means of intelligent agents.

Agent technology is now very popular in many computer applications, because it is much easier to achieve good performance collaboratively, with limited costs by using many small but smart programs (agents) that perform some information gathering or processing task in a distributed computer environment working in the background. Typically, a particular agent is given a very small and well-defined task. Intelligent cooperation between agents can lead to high performance and high quality of the resulting services for the end-users. The most important advantage of such an Artificial Intelligence implementation is connected with the fact that the intelligence is distributed across the whole system and is located in these places (e.g. websites or network nodes) when necessary (Alonso, 2002).

Artificial Intelligence methods used on the base of agent technology are a bit similar to the ant colony methods described above. But an intelligent agent can be designed on the base of neural networks technology, can use elements taken from expert systems, can engage pattern recognition methods as well as clustering algorithms. Almost every earlier mentioned element of Artificial Intelligence can be used in the intelligent agent technology as a realization framework.

The best known applications of distributed Artificial Intelligence implemented as a collection of cooperating but independent agents are in the area of knowledge gathering for Internet search machines. The second area of intelligent agent applications is related to spam detection and computer virus elimination tasks. Intelligent agent technology is on the rise and possibly will be the dominating form of Artificial Intelligence in the future.

12. OTHER AI SYSTEMS OF THE FUTURE: HYBRID SOLUTIONS

In the previous paragraphs we tried to describe some "islands" from the "AI archipelago". Such "islands", like neural networks, fuzzy sets, or genetic algorithms are different in many aspects: their theoretical background, technology used, data representation, methods of problem solving and so on. However, many Artificial Intelligence methods are complementary, not competitive. Therefore many modern solutions are based on the combination of these approaches and use hybrid structures, combining the best elements taken from more than one group of methods for establishing the best solution. In fact, AI elements can be combined in any arrangement because they are flexible. The very popular hybrid combinations are listed below:

- Neuro-fuzzy systems, which are based on fuzzy systems intuitive methodology combined with neural networks power of learning;
- Expert systems powered by fuzzy logic methods for conclusion derivations;

– Genetic algorithms used for selection of the best neural network structure

Hybridization can be extended to other combinations of Artificial Intelligence elements that when put together work more effectively than when used separately. Known are hybrid constructions combining neural networks with other methods used for data classification and pattern recognition. Sometimes expert systems are combined not only with fuzzy logic but also with neural networks, which can collect knowledge during its learning process and then put it (after proper transformation) as an additional element in the knowledgebase powered expert system. Artificial Immune Systems can cooperate with cluster analysis methods for proper classification of complex data (Corchado et al., 2008).

Nobody can foretell how Artificial Intelligence will develop in the future. Perhaps AI and Computational Intelligence will go towards automatic understanding technologies, developed by the author and described by Tadeusiewicz et al. (2008). This paper was meant to provide a general overview of AI and electronic engineering, and enriched with this information the reader can hopefully be better suited to find proper tools for specific applications.

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MIEJSCE I ROLA SYSTEMÓW INTELIGENTNYCH W INFORMATYCE

Streszczenie

W pracy zaprezentowano ogólny przegląd metod i technik sztucznej inteligencji, przywiązując wagę do odróżnienia systemów informatycznych zaliczanych do dziedziny sztucznej inteligencji oraz takich, które do tej dziedziny zaliczane być nie powinny. Dodatkowo dokonano przeglądu oraz klasyfikacji istniejących metod sztucznej inteligencji, wskazując na istniejące w tej dziedzinie powinowactwa jednych metod oraz nie dające się pogodzić sprzeczności innych. Praca ma charakter przeglądowy i nie zawiera nowych rezultatów naukowych, jednak ze względu na zaproponowaną systematyzację wiedzy na temat systemów sztucznej inteligencji praca może być użyteczna dla wielu badaczy, szczególnie tych, którzy są nowicjuszami w stosowaniu sztucznej inteligencji do rozwiązywania różnych praktycznych problemów.

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