Applying Neuro-fuzzy Systems in Hospital

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***Abstract*—Neuro-fuzzy systems are widely used in both applied and experimental medicine and are one of the most modern subjects of today's Medical Informatics. Despite the initial refuse of their use due to informatical, economical, educational and other reasons, these systems are widely accepted in medical institutions operating in all levels of healthcare. The accuracy of some up-to-date neuro-fuzzy systems today matches or even surpasses the diagnostic abilities of physicians, thus holding an important role in risk-assessment and diagnostics in medicine. This work deals with newer applications of these systems in medicine along with the possibility of their implementation in the region of Central Europe.**

I. NEURO-FUZZY SYSTEMS IN MEDICAL SCIENCES

Medical diagnostics, despite the wide use of international Latin nomenclature and disease classification systems, is a field of evaluation of vague, human-like categories. Risk assessment requires high degree modeling, but on the same time must provide the necessary environment of interaction with the human factor.

To establish objective quality control the process must be monitored by a multi-level feedback system operated by a team of experts preferably of medical informatics, social medicine, epidemiology and by a committee for verifying the accuracy of the established diagnoses. These factors are important not solely for the purpose of satisfying the principles of Good Clinical Practice (GCP), but also the terms defined by social medicine and the country`s main development program.

These systems will need to be changeable as clinical considerations may alter the existing categories. The frequent lowering of tolerance levels for LDL cholesterol provides us with excellent example. These changes are often unforeseen in medical sciences so the speed of changing these systems will come to foreground. In the previous example the interaction of business interest of antihyperlipemic drug manufacturers and changing medical aims – among others – resulted in frequent changes of these values.

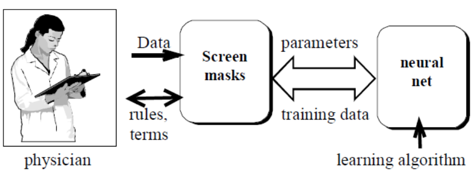

Figure 1. Neuro-fuzzy information feedback system

II. THE ROLE OF NEURO-FUZZY SYSTEMS IN MEDICAL DIAGNOSTICS

Neuro-fuzzy systems, among other requirements, have to meet not only the standards and expectations of physicians, but their patients as well. An ample example for this is the use of neuro-fuzzy systems by a group of prominent scientists of the Annamalai University. Their work, published in 2005 is titled "An investigation of neuro-fuzzy systems in psychosomatic disorders" in which they state the possibility of interpreting the vague, human-like symptoms of the hospitalized as well as appropriately diagnose their psychic condition. I might recollect that this is one of the most ambitious examples of the efficacy of neuro-fuzzy systems, since it was able to validly simulate the understanding of complex pathophysiological laws to the extent of valid diagnoses with its effectiveness approved physicians. It is for the first time that a system that is based on artificial neural networks actually used directly for the evaluation of function of a real neural network.

Mental diseases and psychosomatic disorders are closely determined with the structural architecture and the conductive abilities of this biological network. In the age of examining the human brain the simulation of such a system becomes imperative as medical ethics greatly hinders the possibilities of legal experiments on humans. The electric charge in the neurons is generated by a sodium influx and potassium efflux which depolarizes the cell. Complex, additional biochemical reactions make possible the flow of this current. The speed of current propagation as well as its strength and other properties are now clearly defined, opening the path for making appropriate models. Current conduction by chemical synapses and the properties of the certain neurotransmitters is also a subject of knowledge. The number of possible connections if billion times billion, but the histological and neurological properties of the human brain still provide ample ground for modeling purposes. Many mental disorders are mostly due to abnormal production or lack of certain neurotransmitters or their quantitive proportions. In these examples no higher structural analysis is required. On the other hand in epilepsy the abnormal excitation of pathologic neuron groups provide the clinical picture. Since these phenomena can be measured by EEG the neuro-fuzzy system can be filled up with data intervals necessary to classify vague signals. Epilepsy can be triggered with many external influences which patients can describe only subjectively and therefore not precisely. These effects could be intense or rapidly changing visual or auditive impulses.

The role of simulation becomes evident in the so-called surgical simulators too. Surgeons use these simulators to practice new surgical methods before actually applying them on patients. Apart from realistic 3d modeling they also need to recreate the feel and consequences of manipulating with elastic tissue. The tissue`s level of elasticity was often left without simulation creating an unreal practicing environment. In the modern surgical simulators the modeling and realization is achieved using neuro-fuzzy systems. The Institute for Medical Informatics, Technical University of Braunschweig, and Institute for Knowledge and Language Processing, University of Magdeburg together developed the plan for such a sytem [2,1998].

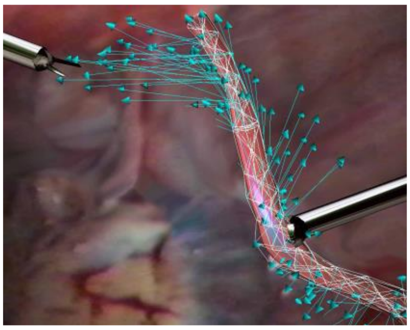

Figure 2. Surgical simulator: virtual laparoscopy

It is also desirable that the modeling respects at least the main histological layers of these organs, required for example at microsurgical or some gynecologic or otorhinolaryngological operations. During these procedures the physician is using a sort of microscope and usually interferes with the integrity of very thin histological layers, leaving more healthy tissue intact. The evolution of these multi-layer systems is at the stage of planning, but with the speed of evolution of this branch of medical informatics it is considered soon to be realized. There is on the other hand some concern that these simulations require more expensive computers. The most important and the most common aspects of possible application of neuro-fuzzy systems are in primary health care.

Besides the anamnesis and physical examination, laboratory diagnostics is usually among the most often diagnostic method in the inventory of a general practitioner, but is essential part of any preventive branch of medicine. The anamnesis and physical examination is written in the patient's records and their interpretation and control is relatively objective. The laboratory results on the contrary only contain the measured value and the intervals in which these values are to be regarded as physiological. The patient is deprived from any insight of his condition, while doctors can also interpret them sometimes too deliberately (since often there are many proposed interpretations in medical literature). Nevertheless this system cannot be also effectively integrated in a bigger, modern neuro-fuzzy based one for diagnostics or risk assessment.

A possible solution was provided for numerous values by the J.W. Goethe University of Frankfurt [5,2000]. Among others fuzzy categories where defined for the following: mean corpuscular erythrocyte volume, alkalic phosphatase, glutamat-pyruvat-transaminase in serum, glutamat-oxalacetat-transaminase in serum gammaglutamyltranspeptidase, and for the number of daily consumed alcohol portions. The significance of this research is pointed out in the Proceedings of European Symposium on Artificial Neural Networks, ESANN 2000, Elsevier Publ., 2000, pp. 201-206 with these words: "The decision and diagnostic power of neural networks are needed in many tasks of everyday life. Successful example applications show that especially in medicine human diagnosis abilities are significantly worse than those of neural diagnosis systems."

The electrocardiogram is also a common device in diagnostics and cardiovascular risk evaluation in all levels of healthcare. The proper interpretation of the electrocardiogram is time consuming for every physician since there are 12 leads to consider, not to mention their comparison, becoming impractical for many branches of healthcare like intensive care units, coronary care units, ambulance or any physician providing life support. Many successful attempts have been made for that matter to construct an ECG device which also establishes a diagnose. These ECG devices are using fuzzy logic and are relatively common in Serbia. The disadvantage of these systems is their reliability which varies from manufacturer to manufacturer, and therefore cannot be trusted by physicians. The great responsibility of administrating the proper drug in certain acute situations and the general flaws of these devices prompt doctors toward manual diagnosis making regardless of the situation. This is one of the compelling reasons why diagnosing ECG devices are not significantly preferred to the ones who do not use fuzzy logic.

Many groups of authors recently published works independently on the possibilities of applying neuro-fuzzy systems to enhance the capabilities of artificial ECG interpretation. It is encouraging that these studies are conducted even in this region like in the Dept. of Applied Electronics and Information Engineering, Polytechnic University, Bucharest, Romania [6,2003]; providing possibilities for Serbian scientists possibilities of collaboration in this field. Romania published its results under the title: "A Neuro-Fuzzy Approach to Classification of ECG Signals for Ischemic Heart Disease Diagnosis". They state that the rate of correctness for ECG interpretation for Ischemic Heart Diseases is already 100% in the examined number of patients.

In 2007 a group of scientists from various Chinese universities discussed the possibility of describing complex hormonal regulation mechanisms using the neuro-fuzzy technology. Endocrinology is a particularly complex branch of medicine, since the adjustment of the desired hormonal status is the function of many organ systems, the brain, the numerous endocrine glands, blood hormone levels, the concentration of sodium in the blood or osteopoesis are only a few from the various interacting elements.

A typical neuroendocrine mechanism can be described with the following generalized algorithm, the knowledge of which is the basis of making efficient neuro-fuzzy systems in endocrinology. The hypothalamus produces releasing hormones which are transported to the glandula pinealis. The glandula pinealis releases a so called endocrine gland stimulating hormone. This stimulating hormone influences gland cell behavior and biochemical processes, allowing the gland to produce the desired product. The so produced hormones are directly injected in the blood flow and travel to the target cells.

In certain diseases the hormone could get blocked while residing in the blood flow. The presence of certain receptors on the target cells are usually microscopically connected with certain proteins and/or induce biochemical chain reactions altering the host's metabolism. The presence, absence or quality of these receptors is the main factor in many widely common diseases such as Diabetes type II, from which approximately 8% of the population suffers. There are many feedback mechanisms that inform the various members of hormonal homeostasis of the hormonal status, lowering or otherwise adjusting their function. All of this is underlined with a firm histological basis, but the scope of this discussion doesn`t permit further discussion on it, nevertheless the presented system is also sufficiently applicable for modeling. Frequently tumors of the neuroendocrine organs alter this fine-tuned regulation profoundly, which – due to the high prevalence of these neoplasms - is also should be part of a more sensitive neuro-fuzzy based simulation.

Neuro-fuzzy systems are more and more accepted in interpreting the results of ophthalmological examination. Since ophthalmology a largely visual branch of medical science, various interpretations and judgments are possible for certain conditions. The universities of Madrid and Tenerife have worked together to make a neuro-fuzzy system for automatic interpretation of the visual field [3, 2001]. The scientists stated that it achieved high accuracy and was generally able to substitute the physician in the examined cases. Similarly to these examples, almost every medical field in principle that requires any sort of interpretations of vague, human-like categories is open for introducing neuro-fuzzy interpretators.

There is a vast field of possibilities in introducing these systems in the process of physical therapy and rehabilitation of patients. As an example of such a use of neuro-fuzzy system a particular experiment will be demonstrated. Scientists from the University of Malaya tried to objectively express the strength of human grip as a means of a more precise evaluation of the progress of rehabilitation as well as neural damage [1, 2006]. Test results clearly showed that an Adaptive Network-based Fuzzy Interference System is "a robust and adaptive tool to recognize human hand grip strength patterns. ". This system has also an immensely accurate tool for diagnostic purposes, mainly diseases of the musculoskeletal system, for example almost all the forms of myopathias. The professors are constantly improving the recognition accuracy; it is currently about 85%. This solution is also a valid tool for post-operative monitoring and healthcare. It is also important that the signals are "calibrated, filtered and stored in a database for retrieval and querying purposes.", and that these data are presented in an acceptable way to the physician.

The strength of the hand grip is detected using strain gauges, and then an electrical is produced, registered by the Labview software. Then it is transferred to the data classification unit. Personal computers enable practical storage of the data, thus creating a comprehensive patient record and enables comparison – so monitoring the effectiveness of treatment in the function of time. A brief schematic block diagram of this computational hand grip assessment tool is given below. I leave out the particular technical details, because there are other prominent projects for the evaluation of human hand grip strength, which achieve similar results by using different specifications.

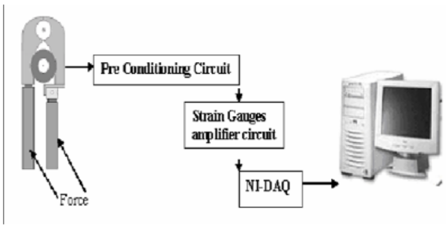

Figure 3. Schematic block diagram of the computational hand grip assessment tool

III. CHALLENGES AND FRONTIERS OF NEURO-FUZZY SYSTEMS

The hand grip assessment tool`s significance is clear from the fact that many authors on the application of neuro-fuzzy systems agree that this point of communication is one of the most problematic and controversial in these systems. This problem lies mostly in the complexness of medical, international Latin terminology and language which can be hardly generated by artificial intelligence. The debates were mostly centered about what the nature and detail of the presentation of the collected data should be. Artificial intelligence often presented these data by a not precise computer generated language or in a way that was understandable only for the technicians, therefore not practical. This was one of the main reasons of refusal by the professional healthcare staff.

One of the most comprehensive medical textbooks on the subject of neuro-fuzzy systems nowadays is "Fuzzy and Neuro Fuzzy Systems in Medicine" edited by Horia-Nicolai Teodorescu et al. In this textbook, apart of defining the current challenges and status of this technology, the author also presents us case-studies based on medical experiments [4,1991]. In the following lines I mention some of the biggest and most ambitious projects besides the ones I already elaborated in this work. Though their mention is more due to a simple list, it still validly represents in which branches of medical science was the adaptation of neuro-fuzzy systems was most wide.

There was, as I mentioned before, many attempts to understand the brain as a fuzzy system and modeling its functions; identifying its state or forecasting acute pathology. Brain surgery was performed and segmentation of neural tumors this way. Many experiments were conducted on diagnosis and treatment for diseases of the myocardium (mostly for ischemic heart disease) or blood pool. The establishment of an expert system in intensive care diagnostics (for addressing conditions such as heart failure or shock) has reported to be effective in lowering patient mortality. Many practical methods are proposed for this purpose, but according to Teodorescu they are of "comparable complexity and have similar performances".

Analyzing EEG signals in neurology is now possible using various technical solutions: time frequency analysis, multiscale decomposition by the fast wavelet transform, multichannel model based and decomposition by matching pursuit. Their classification is usually conducted by one of the following methods: by an unsupervised optimal fuzzy clustering algorithm or the weighted fuzzy k-means algorithm.

Combination of neuro-fuzzy systems with wavelet analysis brought many possibilities to exist among various branches of medical imaging technology. SPECT of the ventricular myocardium is one of the most stunning examples of successful practical implementation of this combination. MR image analysis is also a prominent example for the use of neuro-fuzzy systems in medical imaging, tested for unsupervised brain tumor segmentation and labeling. The edge of the tumor mass could be determined more precisely then with other pre-existent method, allowing more precise data for surgical purposes. This system is tuned by the most possible accuracy (since it is for surgical purposes) on two levels, similar to other neuro-fuzzy systems: on the level of physicians and on the fuzzy categories which is also called "fine tuning".

So far we have discussed strictly the medical applications of neuro-fuzzy systems, although it is interesting that stomatology also began to benefit from them. Stomatology is closely interwoven with a branch of medical science, maxillofacial surgery and therefore its worth to mention that occlusion analysis and analysis of masticatory function is already realized using this technology. Besides maxillofacial surgery, a pediatric advantage is defined, namely the reducing of the necessary amount of X-ray examination of children, that way lowering the accumulation of radiation.

Hemodynamic control during anesthesia by a neuro-fuzzy system has proved to be a problem which solution is among the future challenges of medical informatics. High level of uncertainty, the complexity of control and constantly changing physiological parameters did not allow successful results.

While many attempts have been made to design a system that could work without medical supervision, these systems prove themselves not stable and still have to be controlled by physicians.

CONCLUSIONS

The preferred spelling of the word "acknowledgment" in America is without an "e" after the "g." Try to avoid the stilted expression, "One of us (R.B.G.) thanks ..." Instead, try "R.B.G. thanks ..." Put sponsor acknowledgments in the unnumbered footnote on the first page.

Despite promising results, the use of neuro-fuzzy systems in medicine still faces certain general problems regardless of the field of medical science. It is already mentioned that many of these systems (surgical simulators for example) require more sophisticated and therefore more expensive hardware, therefore must be subject to evaluation by social medicine. The use of these systems provide many, but different advantages on all three levels of healthcare, as well as for those institutions operating on multiple levels, therefore it must be controlled by the countries healthcare development program mainly from economical perspective.

Hardware minimization or optimization between architecture and design of these devices are also listed among the most discussed problems. Most authors agree that the main constrains of investigation of the effectiveness of a neuro-fuzzy system is evaluation of the systems autonomy, reliability and the precision of computation.

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