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Applications of soft computing to medical problems

Ahmet Yardimci
Vocational School of Technical Sciences Department of Industrial Automation
Akdeniz University, Antalya-Turkey
yardimci@akdeniz.edu.tr

Abstract

The medical industry requires new engineering technologies, to assess information objectively. While recent developments in medical engineering have been achieved by state-of-the-art of intelligent computing techniques including computer-aided diagnosis, computer-aided radiography, developments in computational techniques including soft computing (SC), information processing and data mining hold new premises in this field. SC methods are becoming indispensable for to sport modern medical practice. SC combines Fuzzy Logic (FL), Neural Networks (NN), and Genetic Algorithms (GAs) methodologies. The aim of this paper is to introduce briefly the various SC methodologies and to present various applications in medicine between the years 2000 and 2008. The recent published knowledge about use of SC in medicine is researched in MEDLINE. According to MEDLINE database searches, the rates of preference of SC methodologies in medicine were found as 68% of FL-NN, 27% of NN-GA and 5% of FL-GA.

1. Introduction

SC is a consortium of methodologies which works synergistically and provides, in one form or another, flexible information processing capability for handling real life ambiguous situations. Its aim is to exploit the tolerance for imprecision, uncertainty, approximate reasoning and partial truth in order to achieve tractability, robustness and low-cost solutions. SC's includes Fuzzy Logic (FL), Neural Networks (NN), and Genetic Algorithms (GAs) methodologies. SC combines these methodologies as FL and NN (FL-NN), NN and GA (NN-GA) and FL and GA (FL-GA). Recent years have witnessed the phenomenal growth of bio-informatics and medical informatics by using computational techniques for interpretation and analysis of biological and medical data. Among the large number of computational techniques used, SC, which incorporates neural networks, evolutionary computation, and fuzzy systems, provides unmatched utility because of its demonstrated strength in handling imprecise information and providing novel solutions to hard problems. Although computers were already used in medicine, the early medical systems appeared at about the same time as the seminal article by Zadeh - almost four decades ago - there was little communication between these research fields for many years [1,2]. But for the last two decades the situation has changed. A major transformation has occurred in the field of knowledge engineering and also medicine has been affected by this transformation. Many researchers had a bold vision of the way knowledge engineering would revolutionize medicine, and push the frontiers of technology forward. There are now numerous systems that use fuzzy logic, neural networks, genetic algorithm, and other techniques in approximate reasoning.

Today the importance of knowledge for medicine as a task requiring computer support in routine clinical situations receives a lot less emphasis. The strict focus on the medical setting has now broadened across the healthcare spectrum, and instead of artificial intelligence systems, it is more typical to describe them as clinical decision support systems. Intelligent systems today are thus found supporting medication prescribing, in clinical laboratories and educational settings, for clinical surveillance, or in data-rich areas like the intensive care setting. Soft computing is a branch of computer science capable of analyzing complex medical data. Their potential to exploit meaningful relationship set in a data set can be used in the diagnosis, treatment and prediction of the outcome in many clinical scenarios. SC combines more than one the technologies, either as part of an integrated method of problem solution, or to perform a particular task that is followed by a second technique, which performs

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some other task. For example, neuro-fuzzy controllers use NNs and FL for the same task, i.e. to control a process, whereas in another SC system a neural network may be used to derive some parameters and a GA might be used subsequently to find an optimum solution to a problem.

2. Literature Review

The goal of this paper is to survey the use of SC in medicine. Searches are based on MEDLINE medical and engineering database. The candidate papers of this survey have been retrieved through a computerized search on EBSCOhost database service using appropriate keywords. EBSCOhost gives a chance to reach several databases including MEDLINE. Furthermore, EBSCOhost's interface users have a chance to use conjunctions between the keywords. The main aim was here to make first filtering SC based studies in medicine and make classification to put them to the correct FL-NN, NN-GA and FL-GA classes. After this step the search results were checked and examined several times to find their correct SC areas.
The keywords used to search were based on the logical linguistic pattern;

1. "fuzzy logic *and* neural networks *and* biomedical *or* medicine"
2. "fuzzy logic *and* genetic algorithm *and* biomedical *or* medicine"
3. "neural networks *and* genetic algorithm *and* biomedical *or* medicine"
4. "fuzzy logic *and* neural networks *and* genetic algorithm *and* biomedical *or* medicine".

These linguistic patterns are suitable to find publications which contain SC methodologies. By using these patterns we also classify the publications in accordance to their methodologies. The search results show us popularity and applicability of the methodology combinations. To compare the using of SC methodologies in medicine with the using of separately methodologies in medicine, "fuzzy logic *and* biomedical *or* medicine", "neural network *and* biomedical *or* medicine" and "genetic algorithms *and* biomedical *or* medicine" logical linguistic patterns are also searched under MEDLINE and results are evaluated in results and discussion section and presented in a separate graphics.

Before the year 2000 researchers mostly used a single artificial intelligence technique, did not combine them. Observing the previous studies which surveyed the use of AI methodologies in medicine, the database search was restricted to the last decade. Especially the last eight years should be the main focus, since the articles of Abbod et al.[3,4] and Mahfouf et al.[5] have a good coverage for the use of fuzzy logic, smart and adaptive engineering systems in medicine until the year 2001. As per Mahfouf et al. [5] the total numbers of FL based papers that had been published until the year of 2000 for conservative disciplines, invasive medicine, regionally defined medical disciplines and radiology science is 55,67,14 and 98 respectively. The trends indicated from comparing this result with ours, the use of SC methodologies are being gradually assimilated into medicine. The use of SC methodologies has been increasing for the last decade. So, this paper mainly focused on examining what happened after 2000. The database search covers the papers that had been published until December 2007.

2.1 NN-FL applications

These applications will be in two types; NN controlled by FL or FL controller tuned by NNs. Fuzzy logic enables us to easily translate our qualitative knowledge about the problem to be solved, such as resource allocation strategies, performance evaluation, and performance control, into an executable rule set. As a result, fuzzy rule bases and fuzzy algorithms have been used to monitor the performance of NNs and modify their control parameters. FL controllers usually use to control the learning rate of NNs. The studies which use ANFIS are included to second type of NN-FL applications. ANFIS consists of a six layers generalized network. The first and sixth layers correspond to the system inputs and outputs. The second layer defines the fuzzy partitions on the input space, while the third layer performs a differentiable T-norm operation. The evaluation of the left-hand-side of each rule is normalized in the fourth layer. The polynomial coefficients in the right-hand-side of each Takagi-Sugeno rule are computed in the fifth layer.

2.2 NN-GA applications

In general NNs are used as learning systems and GAs as optimization systems. NNs and GAs can be combined in a number of different ways to generate highly successful adaptive systems. Schaffer and co-workers [6], have noted that these combinations can be classified into one of two general types; supportive combinations in which the NN and GA are applied sequentially, and collaborative combinations in which they are applied simultaneously. In a supportive approach the most common combination is to use a GA to pre-process the data set that is used to train a NN.

When we look to the use of collaborative approach the GA and NN are integrated into a single system in which a population of neural networks is evolved to find the optimal NN solution. A GA can be applied to optimizing a NN in a variety of ways; the first GA can be used as the learning rule of the NN and, the second to select general structural parameters and the neural learning is used separately to train the network and determine its fitness. Collaborative combinations of NNs and GAs have sparked the interest of a great number of biomedical researchers because of their obvious analogy to natural systems. A wide variety of systems have been developed.

2.3 FL-GA applications

Like NN-FL applications, FL-GA applications will be in two types; GAs controlled by FL and FL controller tuned by GAs. As we mentioned in the NN-FL application section the use of FL to translate and improve heuristic rules has also been applied to manage the resource of GAs during their transition from exploration to exploitation. This management gives the algorithm an adaptability that improves its efficiency and convergence speed. In the second type of application of FL-GA studies we meet various FL controller systems which are partly or completely tuned by GAs. Such as, use of GAs to modify the membership functions in the termsets of the variables used by the fuzzy controller (FC), directly tuned each rule used by FC, tuned both rules and termsets used by FC [7]. In all studies to aim of the use the GAs is to provide better generated rule base. In most of studies it is noticed that membership functions is tuned to get the best rule base.,

3. Soft computing in medicine

Medicine is a diverse field. It consists of various specialized sub-branches. Roughly we can divide it into four broad fields as follows: basic science, diagnostic science, clinical science and surgical science. Each of these fields can be further sub-classified. In the following sections, a brief description is given of key contributions which soft computing methodologies have made in each of the sub topics which have been identified in the literature search. Table 1 shows all soft computing studies as FL-NN, NN-GA and FL-GA, on medicine field. If we compare the rate of the use of SC methodologies in medicine FL-NN methodology is the significantly most used one with its 68% rate, NN-GA methodology is in the second rank with its 27% rate, and FL-GA methodology is the last one with its only 5% rate. It is easy to say, the FL-NN applications have taken big interest from all sub-branches of medicine in the last eight years. Distribution percentages of FL-NN applications to broad fields are as follow; clinical science 58%, basic science 25%, diagnostic science 17%. NN-GA applications has most preferred by basic sciences with 62% of use. The rates of rest of the studies which are distributed to clinical sciences and diagnostic science are 23% and 15% respectively.

3.1 Basic science

According to MEDLINE database search results the use of SC methodologies in basic science of medicine is increasing. Basic science is very suitable to all SC methodologies. For example, in biochemistry field there is a variety of phenomena with many complex chemical reactions, in which many genes and proteins affect transcription or enzyme activity of others. It is difficult to analyze and estimate many of these phenomena using conventional mathematical models. So, NNs, Fuzzy NNs, and the NN-GAs, have been applied to analysis in a variety of research fields. Especially biochemistry, biostatistics, genetics, physiology and pharmacology branches have applied to use of SC methodologies. Cytology, histology and pathology are the other branches which have applied to SC in their studies.

3.2 Diagnostic science

Diagnostic science mainly includes clinical laboratory sciences and radiology sciences. Database search results show that the almost SC application studies done in radiology especially for interventional radiology. Interventional radiology is concerned with using imaging of the human body, usually from CT, ultrasound, or fluoroscopy, to do biopsies, place certain tubes, and perform intravascular procedures. The most useful approach for reducing deaths due to diseases is to treat these diseases in the early stages. Early treatment requires early diagnosis, which requires an accurate and reliable diagnostic procedure. Medical image processing plays a pivotal role in early diagnosis. The medical imaging studies include ultrasound (US), computed tomography (CT), magnetic resonance imaging (MRI) and angiography. If we compare to the use of SC methodologies in diagnostic science area we clearly see that FL-NN applications is the first and nearly unique. There are some applications which were done with NN-GA but these are very few when compare them to FL-NN applications. Image segmentation is one of the most important steps leading

to the analysis of digital images, its main goal being to divide an image into parts that have a strong correlation with objects or areas of the real world. SC has proved to yield promising results in digital image processing and understanding when missing, ambiguous or distorted data is available. Image segmentation is an indispensable process in the visualization of human tissues, particularly during clinical analysis of magnetic resonance (MR) images. But, MR images always contain a significant amount of noise caused by operator performance, equipment, and the environment, which can lead to serious inaccuracies with segmentation. Shen et al. [8] Meyer-Baese et al. [9] and Wismuller et al. [10] have used FL-NN methodology in their recent studies to solve magnetic resonance imaging (MRI) problems. These studies are also good examples to use FL-NN and NN-GA methodologies.

3.3 Clinical disciplines

MEDLINE database search results showed that the clinical sciences are the most popular and suitable area for the SC methodology applications in medicine. So far, 48% of SC methodology applications were done for clinical science disciplines. Although the studies shows a regular dispersion to all sub-branches of clinical science, according to search results evaluation it is obvious that the cardiology, neurology, critical care medicine, anesthesiology and physical medicine and rehabilitation are the most preferred disciplines. When we compare to preference of SC methodologies we clearly see that the FL-NN methodology is significantly the most preferred one. This result also shows parallelism with a result of the preference of SC methodologies in medicine. ICA). Their comparison results showed that the unsupervised clustering outperforms ICA in terms of classification but requires a longer processing time then the ICA methods. In the other study Wismuller adapted a NN-GA network for analyzing fMRI data and compared it to Kohonen's self-organizing map. In spite of conventional model-based or statistical analysis methods for fMRI are easy to implement and are effective in analyzing data, they are not applicable in situations in which patterns of neural response are complicated and when fMRI response is unknown. The most important findings in this study is that both Neural GAs and the fuzzy clustering technique outperform Kohonen's map in terms of identifying signal components with high correlation to the fMRI stimulus.

3.4 Surgical disciplines

In medicine, surgery is a medical specialty that uses operative manual and instrumental techniques on a patient to investigate and/or treat a pathological condition such as disease or injury, to help improve bodily function or appearance, or sometimes for some other reason. MEDLINE database search results showed that surgical science is not consisting suitable areas to the researchers for SC applications. There is no record is shown in Table 1 for this discipline of medicine. The reason is easy; there is a common opinion about surgery is mostly related by surgeon's skills.When the literature is checked, it is possible to find a few studies which are related with surgical science but none of them related directly in an application from surgical science. In fact, surgical procedures are mostly depends to the surgeon's ability even though modern surgery is often done in an operating room using surgical instruments and other equipments.

4. Results and Discussion

An overview of different SC techniques is presented in this paper according to our previous study [11]. The proficiency of SC techniques has been explored in almost every field of medicine. Based on this study future developments of SC technology in medicine can be tentatively forecast. Although the literature search was not exhaustive and restricted with only MEDLINE, it is sufficient to illustrate to use of SC and its methodologies in medicine. According to all search results summarizes the Figures 2 and 3 have been prepared. Figure 1 gives the numbers of applications of SC methodologies in medicine on a yearly basis. The results of studies which use only FL, NN and GA methods are also given in Table 1. FL, NN and GA based search results are given here to help reader understand the situation. As shown by Table 1 and Figure 2 the number of articles using only FL, NN and GA are 2-8 times higher than soft computing approach. However, please note that these results may include soft computing studies in combination. When we made searches by using FL, NN and GA keywords, Medline gives us all studies including FL, NN and GA. It is almost impossible to sort papers that are based on the methods used with Medline database tools. For example, if we use "not" conjunction and made a search such as "Fuzzy logic and medicine or biomedical not neural networks not genetic algorithm", it gives us the studies which were only using FL application in medicine. But in this case we lost some

FL studies which has some comparison with the two other artificial intelligence methodologies. The best way is to obtain all results and after studying carefully on each of them to make correct classification. To produce the results for Table 1 this approach was preferred.

Table 1. The number of applications of SC methodologies in medicine on a yearly basis.

	Publication year									Total
	1995 - 1999	2000	2001	2002	2003	2004	2005	2006	2007	
*FL	184	41	81	44	45	58	42	44	34	573
NN	641	160	171	172	192	239	194	211	186	2166
GA	43	20	18	17	14	28	29	40	36	245
FL-NN	29	6	23	13	14	8	14	21	16	144
NN-GA	17	2	5	5	6	6	8	11	9	56
FL-GA	3	1	-	1	1	1	-	4	-	11
FL-NN-GA	1	-	-	1	1	1	-	1	-	5

*FL: Fuzzy logic, NN: Neural networks, GA:Genetic algorithms,

The number of FL-NN, NN-GA, FL-GA, and FL-NN-GA addressed studies in medicine are illustrated in Figure 1 on a yearly basis. In this graphic FL-NN studies made a peek in 2001. After this peek the numbers of FL-NN based papers go down and up between the years 2002 and 2007. On contrast of FL-NN studies, NN-GA studies have followed an increasing line between the years 2001 and 2007. The situation for FL-GA studies is completely different from the other SC combined methodologies. There are a few FL-GA based studies were found in medicine in same period. For comparison with SC, Figure 2 is presented which shows the number of FL, NN and GA based studies which were used separately in medicine. FL, NN and GA shows a stable state on yearly based. While the numbers of NN studies have a range between 160 and 240, the numbers of FL and GA studies have a range between 40 and 60, 14 and 40 respectively. Mainly FL-NN and NN-GA combined studies contributes SC in medicine. According to Figure 1 and 3, the combination rate of FL-NN is obtained nearly %50. If we compare the studies which used separately GA with NN-GA based studies, nearly %25 of GA studies has found a chance to combine with NN methodology. FL-NN based studies mostly were applied to interventional radiology, cardiology, oncology and neurology areas while NN-GA based studies were applied biochemistry, genetics and pharmacology. Radiology and neurology disciplines mostly used to SC methodologies for classification and diagnosis studies. It should be noted that radiology, imaging and diagnosis studies are always related to other disciplines of medicine such as neurology, dermatology, pulmonology and oncology. All publications were examined carefully to avoid repeating one publication in two areas.

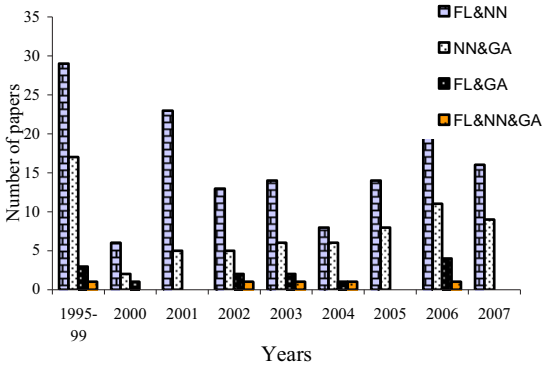

Figure 1. Comparison of the numbers of SC methodologies based published papers between the years 1995-2007

The preference percentage of SC methodologies in medicine is as follows: The mostly used methodology is FL-NN 68% then NN-GA 27% and FL-GA 5%. As far FL-NN methodology is significantly used in clinical science of medicine. 58% of cited FL-NN studies are related clinical science while %62 of cited NN-GA studies are related basic science. On the other hand NN-GA and FL-GA methodologies were mostly preferred by basic science of medicine. Clinical science has the 48% of all cited SC studies while basic science has 36% and diagnostic science 16%.

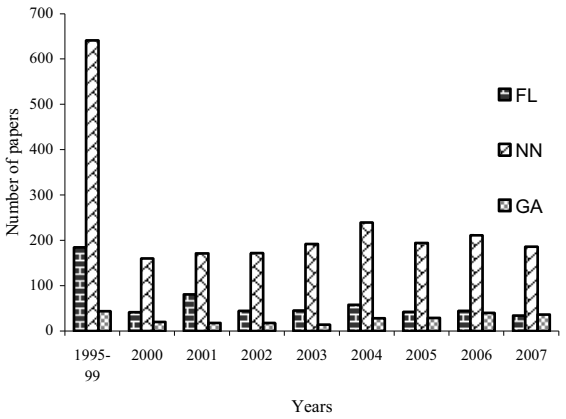

Figure 2. Comparison of the numbers of FL, NN and GA methodologies based published papers between the years 1995-2007.

The preference percentage of SC methodologies in medicine is as follows: The mostly used methodology is FL-NN 68% then NN-GA 27% and FL-GA 5%. As far FL-NN methodology is significantly used in clinical science of medicine. 58% of cited FL-NN studies are related clinical science while %62 of cited NN-GA studies are related basic science. On the other hand NN-GA and FL-GA methodologies were mostly preferred by basic science of medicine. Clinical science has the 48% of all cited SC studies while basic science has 36% and diagnostic science 16%. Another message emerging from this survey is that FL-GA methodology has not applied well enough to medicine yet. Most of the researchers preferred to use NNs with FL and GA techniques. The number of FL-NN and NN-GA publications proves this decision. All information gathered in this study retains their time value. The papers were arranged on a time scale. This means that dynamic process of the information spread in each sub-branch of medicine can be determined. The trends indicated from the tables and the survey that all SC methodologies are being gradually applied into medicine. When we look to changing of the use of methodologies as far, on a yearly basis while NN-GA methodology based studies follows a rising line while FL-NN based studies show wavy change. FL-GA, FL-NN-GA based studies show very weak progress. We should note that SC technologies are relatively young when compared with 1959 originated NNs, 1965 originated FL and 1975 originated GAs. This will be the reason of the poor progress in the use of FL-GA and FL-NN-GA methodologies in medicine. The main findings of the study are:

a. In genetics, physiology, interventional radiology, anesthesiology, cardiology, and neurology disciplines there are undeniable interest in studying SC methodologies. It proves to be very fruitful to study SC in these disciplines.
b. In the field of clinical laboratory science and surgical science, there are no specific applications to date.
c. SC methodologies give birth to new studies in neighboring disciplines in medicine.

In addition to c, the problems of medicine give also birth to SC methods. Instead of just applying existing SC methods there is a tendency of developing revised SC methods.

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10. References

[1] Zadeh LA, "Fuzzy Sets", Information and Control, 8, (1965), 338-353

[2] Akay M, Cohen M, Hudson D, "Fuzzy sets in life science", Fuzzy Sets and Systems, 90, (1997), 219-224

[3] Abbod MF, Diedrich GK, Linkens DA, Mahfouf M, "Survey of utilization of fuzzy technology in Medicine and Healthcare", Fuzzy Sets and Systems, V.120, (2001),331-349

[4] Abbod MF, Linkens DA, Mahfouf M, Dounias G, "Survey on the use of smart and adaptive engineering systems in medicine" Artificial Intelligence in Medicine , 26, (2002), 179-209

[5] Mahfouf M, Abbod MF, Linkens DA, "A survey of fuzzy logic monitoring and control utilization in medicine", Artificial Intelligence in Medicine, V.21, 1-3, (2001), 27-42

[6] Schaffer RD, Whitley D, Eshelman LJ, "Combinations of Genetic Algorithms and Neural Networks: A survey of the State of the Art", *International Workshop on Combinations of Genetic Algorithms and Neural Networks COGANN-92,* (1992), 1-37

[7] Bonissone PP, "Soft computing: the convergence of emerging reasoning technologies", Soft Computing, V.1, (1997), 6-18

[8] Shen S, Sandham W, Granat M, Sterr A, "MRI fuzzy segmentation of brain tissue using neighborhood attraction with neural-network optimization" *IEEE Transactions on Information Technology In Biomedicine*, V.9, 3, (2005), 459-467

[9] Meyer-Baese A, Wismueller A, Lange O, "Comparison of two exploratory data analysis methods for fMRI: unsupervised clustering versus independent component analysis" *IEEE Transactions on Information Technology in Biomedicine*, V.8, 3, (2004), 387-398

[10] Wismuller A, Meyer-Baese A, Lange O, Auer D, Reiser MF, Sumners DW, "Model-free functional MRI analysis based on unsupervised clustering" *Journal of Biomedical Informatics*, V.37, 1, (2004), 10-18

[11] Yardimci A, "Soft computing in medicine", *Applied Soft Computing*, V.9, 3, (2009), 1029-1043