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Artificial Intelligence Techniques in Medicine and Health Care

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INTRODUCTION

Now-a-days, researchers are increasingly looking into new and innovative techniques with the help of information technology to overcome the rapid surge in health care costs facing the community. Research undertaken in the past has shown that artificial intelligence (AI) tools and techniques can aid in the diagnosis of disease states and assessment of treatment outcomes. This has been demonstrated in a number of areas, including: help with medical decision support system, classification of heart disease from electrocardiogram (ECG) waveforms, identification of epileptic seizure from electroencephalogram (EEG) signals, ophthalmology to detect glaucoma disease, abnormality in movement pattern (gait) recognition for rehabilitation and potential falls risk minimization, assisting functional electrical stimulation (FES) control in rehabilitation setting of spinal cord injured patients, and clustering of medical images (Begg et al., 2003; Garrett et al., 2003; Masulli et al., 1998; Papadourokis et al., 1998; Silva & Silva, 1998).

Recent developments in information technology and AI tools, particularly in neural networks, fuzzy logic and support vector machines, have provided the necessary support to develop highly efficient automated diagnostic systems. Despite plenty of future challenges, these new advances in AI tools hold much promise for future developments in AI-based approaches in solving medical and health-related problems. This article is organized as follows: Following an overview of major AI techniques, a brief review of some of the applications of AI in health care is provided. Future challenges and directions in automated diagnostics are discussed in the summary and conclusion sections.

ARTIFICIAL INTELLIGENCE TECHNIQUES

There have been a number of artificial intelligence (AI) tools developed over the past decade or so (cf., Haykin, 1999; Keckman, 2002). Many of these have found their applications in medical and health-related areas. Commonly applied AI techniques can be listed as:

- Neural Networks
- Fuzzy Logic
- Support Vector Machines
- Genetic Algorithms
- Hybrid Systems

In the following, we give a brief overview of neural networks, fuzzy logic and the relatively new support vector machines.

Neural Networks

Artificial neural networks work much like the human brain and have the ability to learn from training data and store knowledge in the network. In the learning phase, it maps relation between inputs and the corresponding expected outputs. During the learning phase, knowledge is acquired and stored in the network in the form of synaptic weights and biases. This knowledge is used to make future predictions in response to new data or inputs during the testing phase. Usually, the network has one input and one output layer, and one or more hidden layers depending on the complexity of the problem. Learning can be supervised; that is, the network is provided with both the inputs and their desired outputs during the leaning process, or it can be unsupervised or self-organizing learning. There are a number of learning algorithms available (Haykin, 1999), and among them back-propagation learning algorithm is the most widely used. In this method, an error signal based on the difference between network-generated output (g_i) and desired output (d_i) is propagated in the backward direction to adjust the synaptic weights according to the error signal. During the learning process, the aim is to minimize an objective function such as the mean-squared error (E),

$$E = \frac{1}{n}\sum_{i=1}^{n}(d_i - g_i)^2$$

Neural networks are frequently used as diagnostics, and therefore it is important to have good generalization ability, that is, good performance in predicting results in response to unseen data. One limitation of neural networks is the possibility of being stuck in local minima during training rather than converging to the global minimum. To overcome this the network is usually trained several times with random initial weights to avoid converging to the local minima. Neural networks have found the majority of their applications in pattern recognition, time-series prediction, signal processing and financial forecasting.

Fuzzy Logic

Fuzzy sets were introduced by Zadeh (1965), and they deal with imprecise and uncertain information or data. Naturally, this has been found suitable for many medical and health-related problems, as it relates to the way humans think. Since the early work of Zadeh, there has been an exponential rise in the number of scientific papers applying fuzzy sets in biology, medicine and psychology areas (Teodorescu et al., 1998).

Support Vector Machines

Support vector machines are a relatively new machine learning tool and have emerged as a powerful technique for learning from data and solving classification and regression problems. This has been particularly effective for binary classification applications. SVMs originate from Vapnik's statistical learning theory (Vapnik, 1995). SVMs perform by nonlinearly mapping the input data into a high dimensional feature space (by means of a kernel function) and then constructing a linear optimal separating hyperplane by maximizing the margin between the two classes in the feature space.

For *m* training data with input-output pairs $(y_1,\mathbf{x}_1),\ldots,(y_m,\mathbf{x}_m)$ where each input data $\mathbf{x}_i \in \Re^N$ belongs to a class $y_i \in \{-1,+1\}_{i=1,\ldots,m}$, the decision function for a new data $(\mathbf{x}_i)$ can be given by the sign of the following function (Gunn, 1998):

$$\mathrm{f}(x) = sign(\sum_{i \in SVs} \alpha_i y_i \mathrm{K}(x_i, x) + \mathrm{b})$$

where, a_i is a nonnegative Lagrange multiplier corresponding to $\mathbf{x}_i$, $K(.)$ is a kernel function and b is the bias. The Lagrange multipliers are obtained as the solution of a convex quadratic programming problem. The data points $\mathbf{x}_i$s corresponding to $a_i>0$ are called support vectors. Such $\mathbf{x}_i$s are the only data points in the training set relevant to classification since the decision surface is expressed in terms of these points alone (support vectors, SV). For linearly separable problems, the number of SVs and the hyperplane are determined by a subset of the training set only. For nonlinearly separable problems, a_i in SVs are constrained by an upper bound C, which is regarded as a regularization parameter. This parameter makes a trade-off between margin maximization and minimization of classification errors in the training data set (Gunn, 1998).

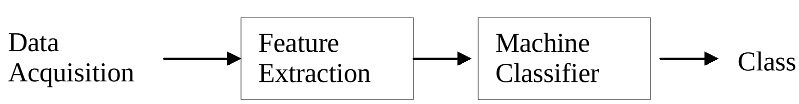
Hybrid Systems

Recently, researchers have started looking into ways of combining various AI tools in order to maximize performance of the AI system. The main idea behind this is to offset limitation of one system by cascading with another AI tool. As a result, hybrid systems like Neuro-Fuzzy (neural networks and fuzzy logic), Neuro–SVM (neural networks and support vector machines) and Fuzzy-SVM (fuzzy logic and support vector machines) systems have evolved. Hybrid systems have been applied in many applications, including some biomedical areas (Teodorescu et al., 1998).

APPLICATIONS IN HEALTH CARE AND MEDICINE

In addition to applications in medical diagnostic systems, AI techniques have been applied in many biomedical signal-processing tasks, including analysis of ECG, EEG and human movement data (Nazeran & Behbehani, 2001). Neural network models have played a dominant role in a majority of these AI-related applications in health and medicine. Many of these applications are for pattern recognition or classification. A typical classification application usually has a number of steps or procedures as shown by the flow diagram (see Figure 1). This involves feature extraction from the input data before feeding these features to the classifier for designing and developing

Figure 1. Stages of a typical pattern recognition task



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