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Fuzzy logic in the gravitational search algorithm for the optimization of modular neural networks in pattern recognition

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ABSTRACT

In this paper the main challenge is to find the optimal architecture of modular neural networks, which means finding out the optimal number of modules, layers and nodes of the neural network, with the fuzzy gravitational search algorithm for a pattern recognition application and in addition provide a comparison with the original gravitational approach. The proposed method is applied to the recognition of medical images. One of the most common methods for detection and analysis of diseases in the human body, by physicians and specialists, is the use of medical images. In this case, we are using a database of echocardiograms, which contains images of disease and healthy patients to test the proposed approach. The optimally designed modular neural networks produce simulation results that are able to show the advantages of the proposed approach.

1. Introduction

In recent years, the interest in algorithms inspired by natural phenomena has grown considerably. It has been shown by different researchers that these algorithms are well suited to solve complex problems, for example Genetic Algorithms (GAs) are inspired on Darwinian evolutionary theory (Tang, Man, & Kwong, 1996), Ant Colony optimization (ACO) mimics the behavior of ants foraging for food (Dorigo, Maniezzo, & Colorni, 1996), Particle Swarm Optimization (PSO) simulates the behavior of flock of birds (Bergh & Engelbrecht, 2006; Kennedy & Eberhart, 1995), Simulated Annealing (SA) is designed by using the thermodynamic effects (Kirkpatrick, Gelatto, & Vecchi, 1983), the Artificial bee colony algorithm (ABC) is an optimization algorithm based on the intelligent foraging behavior of a honey bee swarm (Karaboga & Basturk., 2012), and the Bat algorithm (BA) is inspired by the echolocation behavior of microbats (Yang, 2010), etc. The gravitational search algorithm (GSA) is a heuristic optimization method based on the laws of gravity and mass interactions. This algorithm is based on Newtonian gravity: "Every particle in the universe attracts every other particle with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them" (Rashedi, Nezamabadi-pour, & Saryazdi, 2009). There exists different works concerning the gravitational search algorithm, but only the most important and relevant for this paper will be considered (Dowlatshahi, Nezamabadi, & Mashinchi, 2014; Mirjalili, Mohd, & Moradian, 2012; Yazdani, Nezamabadi, & Kamyab, 2014). There exists a previous proposal of a fuzzy gravitational search algorithm (FGSA), for optimal design of multimachine power system stabilizers (PSSs). The FGSA based-PSS design is validated for two multimachine systems: a 3-machine 9-bus system and a 10-machine 39-bus. Therefore, fuzzy logic is used to speed up the final stages of the process and find the accurate answer in a shorter time, even for very large problems. In the proposed GSA the fuzzy-based mechanism and fitness sharing are employed to aid the decision maker to choose the best compromise solution from the Pareto front (Ghasemi, Shayeghi, & Alkhatib, 2013). However, we have proposed a new fuzzy gravitational search algorithm (FGSA) to dynamically change the alpha parameter and give a different gravitation and acceleration values to each agent in order to improve its performance, which is presented in Sombra, Valdez, and Melin (2013). This approach is now considered here in this paper to design optimal modular neural networks (MNNs) for pattern recognition, which has not been considered previously in other works.

Research in medical imaging has grown in the last years as it is normally a non-invasive method of diagnosis. Therefore, we are considering the application of the FGSA to design the optimal architecture of this type of MNNs, which means finding out the optimal number of modules, layers and nodes of the neural

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network designed for echocardiogram recognition. In this case, we are using a database of echocardiograms that contains images of disease and healthy patients. This paper focuses on the field of nature inspired computation and several approaches have been previously proposed for the optimization of modular neural networks (Martinez, Melin, & Castillo, 2005; Melin, Sánchez, & Castillo, 2012; Pandey & Garg, 2013; Tsai & Lin, 2011; Valdez, Melin, & Castillo, 2014; Valdez, Melin, & Parra, 2011), a modular neural network for medical diagnosis is presented in Das, Turkoglu, and Sengur (2009) and Rodriguez , Martín, Lafuente, Muguerza, and Pérez (1996), a MNN for pattern recognition is also shown in Gaxiola, Melin, and López (2010) and Melin, Mendoza, and Castillo (2011), preprocessing and segmentation techniques of medical images are presented in Vikram and Yongmin (1997) and Zong, Laine, and Geiser (1998) and finally some medical applications using echocardiograms are shown in Ahmed, Ungprasert, Srivali, Cheungpasitporn, and Bischof (2013), Chao, Wang, and Chan (2012), Crow, Hannan, Grandits, and Liebson (1996) and Strzelecki, Materka, Drozdz, Krzeminska, and Kasprzak (2006).

The main problem in these medical applications is that normally there are many speckle noise points on the ultrasound images. So the resulting images are contaminated with this noise that corrodes the borders of the cardiac structures (Beymer, Kumair, Tanveer, & Wang, 2010). This characteristic turns difficult to perform image processing, and even more achieving the level of accuracy for pattern recognition needed in the applications. Besides this kind of noise, other factors influence the outcome of ultrasound image recognition. However, the disease recognition problem is complicated by the heart's non-rigid motion. Furthermore, the poor imaging quality of 2D echo videos due to low contrast, speckle noise, and signal dropouts, also cause problems in image interpretation (Kang & Hong, 2002).

We show in Fig. 1 (right), the image of a heart with Cardiac amyloidosis, which is a myocardial disease characterized by extracellular amyloid infiltration throughout the heart. The Cardiac amyloidosis has a wide spectrum of clinical manifestations, but the most frequent presentation is heart failure. We also show in Fig. 1 (left) the image of a healthy heart.

This paper presents an approach using fuzzy logic in the Gravitational Search Algorithm (FGSA) for optimal architecture design of MNNs, which means finding out the optimal number of layers and nodes of the neural network for Pattern Recognition, to recognize if the image corresponds to a person with a heart disease or is an image of a person with a normal heart. The FGSA method was originally applied to fifteen benchmark mathematical functions (Sombra et al., 2013) and now it is applied in pattern recognition using MNNs. In this paper, as a difference to other papers in which they use an active shape model (ASM) to model shape and texture information in an echo frame, we use modular neural networks to perform this task. The motion information derived by tracking ASMs through a heart cycle is then projected into the Eigen-motion feature space of the viewpoint class for matching (Beymer, Tanveer, & Wang, 2008).

The rest of the paper describes this approach in detail and is organized as follows. In Section 2, we describe some of the works related to image recognition echocardiography and basic concepts related to this subject. In Section 3 we describe the modular neural network architecture and the database of echocardiograms for recognition and the pre-processing of the databases that are used. In Section 4 the experimental results are presented. Finally, in Section 5 the conclusions of this work are offered.

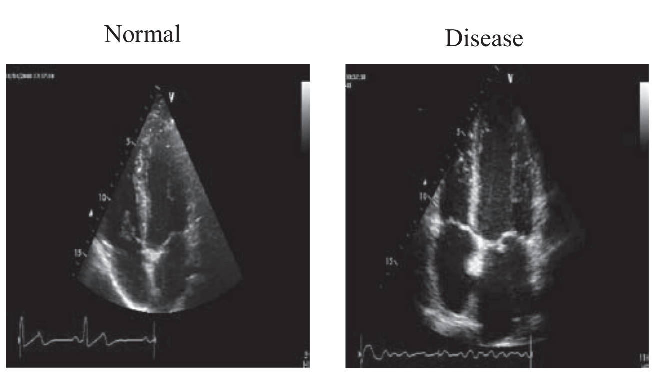

Fig. 1. (Left) Echocardiographic frames from normal; (right) motions of the heart for disease patients.

2. Background and basic concepts

There are different recent works about Echocardiograms (Bailes, 1996; Suhling, Arigovindan, Jansen, Hunziker, & Unser, 2005; Unser, Pelle, Brun, & Eden, 1989), but only the most important and relevant for the subject of this paper will be mentioned here as related work.

2.1. Previous work

In the first automatic cardiac view recognition system, Ebadollahi et al. (Shahram, Shih-Fu, & Wu, 2004) proposed a constellation-of-parts based method. They used a generic heart chamber detector (Bailes, 1996) to locate heart chambers, and they represented the spatial arrangement of the chambers using a Markov Random Field (MRF) based relational graph. The final classification of a test image is performed using a Support Vector Machine on the MRF network output. This method suffers from sensitivity of the chamber detection method to frequently present noise in the echocardiogram images while demonstrating limited robustness to basic image transformations.

Shahram et al. proposed an approach for the automatic identification of the views of the heart from the content of the echocardiogram videos. In this approach the structure of the heart is represented by the constellation of its parts (chambers) under the different views. The statistical variations of the parts in the constellation and their spatial relationships are modeled using Markov Random Field models. A discriminative method is then used for view recognition, which fuses the assessments of a test image by all the view-models (Shahram et al., 2004).

Jacob et al. (Banning, Behrenbruch, Kelion & Jacob, 2002) and Sugioka et al. (Sugioka, 2003) proposed a method using patterns to detect cardiac structures using active contours (snakes) in echocardiographic images. In another work, Comaniciu (Comaniciu, Krishnan, & Zhou, 2004) proposed a methodology for tracking cardiac edges in echocardiographic images using several information extract of the images.

Wu, Bowers, Huynh and Souvenir (2013) proposed a method of echocardiogram view classification using low-level features. This work presents a view classification method for 2D heart ultrasound information. The method uses low-level image features to train a frame-level classifier, which unlike related approaches, does not require an additional pixel-level classification of heart structures. By employing kernel-based classification, the algorithm can classify images from any phase of the heartbeat cycle and efficiently incorporate information from subsequent frames without re-training the model (Wu et al., 2013).

Dowlatshahi and Nezamabadi-pour (2014) proposed a method called GGSA: A Grouping Gravitational Search Algorithm for data clustering. The proposed algorithm, which is called Grouping GSA (GGSA), differs from the standard GSA in two important aspects. First, a special encoding scheme, called grouping encoding, is used