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Medical image fusion based on hybrid intelligence

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ABSTRACT

Medical image fusion combines complementary images from different modalities for proper diagnosis and surgical planning. A new approach for medical image fusion based on the hybrid intelligence system is proposed. This paper has integrated the swarm intelligence and neural network to achieve a better fused output. The edges are an important feature of an image and they are detected and optimized by using ant colony optimization. The detected edges are enhanced and it is given as the feeding input to the simplified pulse coupled neural network. The firing maps are generated and the maximum fusion rule is applied to get the fused image. The performance of the proposed method is compared both subjectively and objectively, with the genetic algorithm method, neuro-fuzzy method and also with the modified pulse coupled neural network. The results show that the proposed hybrid intelligent method performs better when compared to the existing computational and hybrid intelligent methods.

1. Introduction

Medical image fusion (MIF) combines images to provide accurate and reliable information. The images can be from different modalities like PET, CT, SPECT, MRI, etc., or from the same modality obtained at different times. The MIF is used to improve confidence in diagnosis, to provide structural and functional information in the same image, to increase the reading efficiency, to quantify the difference between scans, to plan radiation therapy and much more [1].

The computational intelligent systems (CIS) play a crucial role in the field of medicine [2]. CIS like fuzzy logic, neural networks, machine learning, swarm intelligence and genetic algorithms are applied to different medical problems and domains like neurology, oncology, gynecology, cardiology, radiology and ophthalmology [3,4]. The CIS are applied widely for the fusion of medical images [5–13].

In the recent years, many algorithms based on hybrid intelligent systems (HIS) are developed for medical diagnosis and computer assistance, patient monitoring and patient care [14–17]. HIS is a combination of intelligent tools and techniques that make sense in a theoretical and practical basis for performing in a competitive way when compared to simple intelligent techniques. It can be framed either by integrating two or more intelligent systems, which maintains the identity of each methodology, or by fusing one system into another or by transforming the knowledge representation of one intelligent system into another form with the characteristic of the another intelligent system. The different hybrid soft computing architectures are given in the literature [18]. The performance of HIS depends not only upon the choice of the intelligent systems but also on the architecture of the hybrid intelligent systems. The right components need to be selected for building a good hybrid system. A very few research works using the HIS has been carried out in the field of the MIF. The algorithms are developed by combining the neural network and fuzzy logic, generally known as neuro-fuzzy [19–23].

Many algorithms using the CIS have been applied to the MIF [5–13]. In the literature [6], authors have fused CT and MRI images by using Mamdani-type minimum-sum-mean of maximum (MIN-SUM-MOM) algorithm. The fuzzy implication operation has used MIN algorithm and SUM was applied for calculating the membership functions of total output set. In order to defuzzify, the MOM algorithm was used. The fusion algorithms using pulse coupled neural network (PCNN) were developed in the past decade [8–11]. The feeding input which is applied to the modified PCNN (m-PCNN) in the application of image fusion [8] used the normalized gray value of the input image. In most of the MIF work with PCNN, the normalized value of the single pixel intensity in spatial or transform

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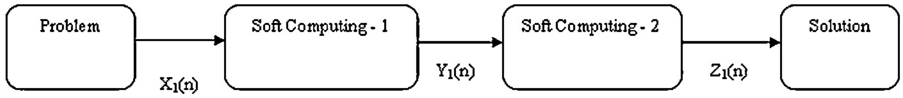

Fig. 1. The hybrid soft computing architecture.

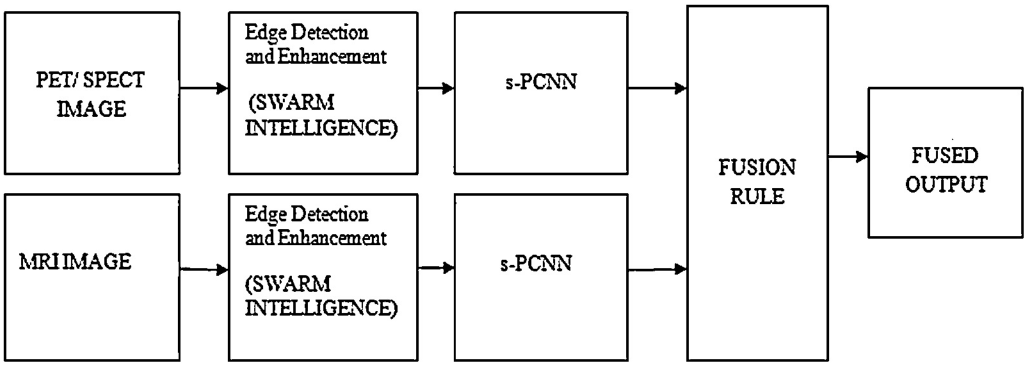

Fig. 2. The proposed HIIF architecture for MIF.

domain of the input image is used as the feeding input of the neuron [7–10]. In the transform domain, the image coefficients which are negative are normalized by considering the absolute value of the coefficients. This leads to the loss of directional details. In literature [11], for fusing CT and MRI images, the modified spatial frequency of the high frequency region in the discrete ripplet transform domain is given as input to the PCNN. In literature [24], for fusing multifocal images, the focus measure is given as an input to the m-PCNN. These methods which are applied to the PCNN are not effective as the edge and the directional information are lost.

To overcome the above limitation of the PCNN method, suitable modification is carried out in the feeding input and in the linking field of the PCNN and it is represented as simplified PCNN (s-PCNN) in this paper. The integration and synergetic effects of swarm intelligence and neural network is proposed. This method utilizes one of the hybrid soft computing architecture discussed in the literature [18] and it is shown in Fig. 1. In this paper, the swarm intelligence of ant colony is used to detect and optimize the edges. The output of the ant colony optimization (ACO) is enhanced and it is given as the feeding input to the neural network. The proposed MIF based on the HIS technique is named as hybrid intelligence image fusion (HIIF) scheme. The datasets of PET and MRI, SPECT and MRI are taken to study the effectiveness of the HIIF method and the fused output is compared quantitatively and qualitatively with the existing method.

2. Materials and methods

2.1. Proposed HIIF architecture

The proposed HIIF architecture for MIF is shown in Fig. 2. Here, the intelligent systems are cascaded to get the fused output. An optimization technique to use in the neural network is proposed for getting accurate and precise information of the input images from a single fused image.

2.1.1. The algorithm

The various steps of the HIIF fusion scheme are:

- The perfectly registered datasets are given as input to the HIIF fusion scheme.
- The edges of the input images are optimized using ACO and enhanced.
- The enhanced edge images are applied as feeding input to s-PCNN which produces the firing maps for both the images.
- Then maximum fusion rule is applied which results in the fused output.

2.2. Datasets

Two types of datasets are taken for testing the performance of the proposed algorithm. Type-I consists of PET and MRI images and Type-II consists of SPECT and MRI images [25]. Five datasets from each type are used for testing. The size of the image is $256 \times 256 \times 3$ with intensity values ranging from 0 to 255. Two sets of input images are shown in Fig. 3(a)–(d). The remaining eight datasets are given in Appendix.

Fig. 3(a) shows the PET-FDG image of a person suffering from Astrocytoma and (b) shows the MR-GAD image of the same person. Fig. 3(c)–(d) shows SPECT-Tc and MR-T2 image of a person suffering from chronic subdural hematoma.

2.3. Edge detection and enhancement

Edges are the points where discontinuities or sharp changes in intensity occur. They play an important role in understanding the content of the image clearly. For maximizing the information content of the image, enhancement of the image is required. In the proposed HIIF method, a new technique for image enhancement is carried out by applying the enhancement criteria only to the edgels. The edgels are detected and optimized using the ant colony optimization (ACO) technique.

2.3.1. Edge detection using ACO technique

ACO technique is an optimization algorithm inspired by the natural collective behavior of the ant species. Number of ants are utilized to evolve on a 2D image and to construct the pheromone matrix. This matrix represents the edge information at each pixel based on the path followed by the ants. The ant colony moves to the neighboring pixels based on the image intensity values and follows the path where the intensity of the pixel varies [26–28]. The various process involved are initialization, construction, update and decision.

Let the input images be I_1 and I_2 and let the size of each input image be $M \times M$.