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A hybrid Wavelet Neural Network and Switching Particle Swarm Optimization algorithm for face direction recognition

Yang Lu [a,b,*], Nianyin Zeng [c], Yurong Liu [d,e], Nan Zhang [a]

[a] College of Information Technology, Heilongjiang Bayi Agricultural University, Daqing 163319, PR China
[b] Intelligent System & Biomedical Robotics Group, School of Computing, University of Portsmouth, Portsmouth PO1 3HE, UK
[c] Department of Mechanical and Electrical Engineering, Xiamen University, Xiamen, Fujian 361005, PR China
[d] Department of Mathematics, Yangzhou University, Yangzhou, Jiangsu 225002, PR China
[e] Communications Systems and Networks (CSN) Research Group, Faculty of Engineering, King Abdulaziz University, Jeddah 21589, Saudi Arabia

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ABSTRACT

Face direction recognition is an important research issue in human–computer interaction. In order to improve recognition accuracy, a novel hybrid approach called Switching Particle Swarm Optimization–Wavelet Neural Network (SPSO–WNN) is presented. In this model, we employ the recently proposed Switching Particle Swarm Optimization (SPSO) algorithm to optimize the parameters of weights, scale factors, translation factors and threshold in Wavelet Neural Network (WNN). The proposed SPSO–WNN method has fast convergence speed and higher learning ability than conventional WNNs. Especially, a mode-dependent velocity updating equation with Markovian switching parameters is introduced in SPSO to overcome the contradiction between the local search and the global search, which makes it easy to jump the local minimum. The experiment results of the recognition for face direction show the feasibility and effectiveness of the proposed method. Compared with Particle Swarm Optimization–Wavelet Neural Network (PSO–WNN), Genetic Algorithm–Wavelet Neural Network (GA–WNN) and WNN, the proposed method has much better performance over them.

1. Introduction

Face recognition, as a complex pattern recognition problem, has been extensively studied and widely used in many fields over the past decades. Many new methods have been developed and adopted for this issue, and greatly enriched and broadened the pattern recognition field. Recently, researchers have paid much attention on the face recognition, detection, tracking, and also the feature positioning technology. Face recognition is one of the important steps in the human–computer interaction and the purpose is to segment the face region that background is not included from the image. Because of irregularities of face shape as well as diversity of lighting and background conditions, the existing algorithms can only be used to handle some specific problems under certain experimental environments, such as the location and status of the human face. However, in practical applications, the direction and angle of rotation and the position of the faces are not fixed in lots of images and video sources, which greatly increase the difficulty of the face recognition. Also, the face direction represents the direction of human attention and the declaration of intent in the human facial expression. Therefore, the estimate on human face direction is critical in face recognition application.

In the field of face recognition, few researchers have been involved in face direction estimation. In previous studies, Hongo et al. [15] applied a linear discriminant analysis to the face direction estimation. Some other researchers improved the method by removing adverse effects of the facial horizontal rotation on the recognition process [3,4,14]. However, the problem of the face direction estimation is much more complex in practice. Therefore, the human face direction estimation and recognition will be a very meaningful and challenging work.

The last few decades have witnessed successful applications of artificial neural networks (ANNs) in various fields including pattern recognition, image processing, fault diagnosis, etc. The study of neural networks has therefore gained persistent research interests from the early 1980s, see [4,21,23,27–31] and the references therein. ANNs, as both predictors of dynamic non-linear models and pattern classifiers for evaluation, have been suggested as a possible technique to cope with the face direction recognition. Instead of requiring an accurate mathematical model of the process, these approaches only need representative training data. However, owing to some inherent defects in ANNs, such as existence of local minima and difficulty in choosing the proper size of network, many researchers have proposed wavelet neural networks (WNNs) for the face direction recognition [32]. WNN has widely been

* Corresponding author.
E-mail address: luyanga@sina.com (Y. Lu).

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applied to the face direction recognition field due to its strong advantages in dealing with nonlinear mapping capacity to solve complex nonlinear estimating problem. Meanwhile, WNN inherits the merits from the wavelet analysis in expanding and contracting basis function, which makes it to have stronger self-learning and classification capacity than conventional neural network. WNNs are inspired by the feed-forward neural networks and wavelet decomposition theories. Since such WNNs are based on multi-resolution analysis (MRA) of wavelet transforms, wavelet decompositions provide a useful basis for localized approximation of uncertainty with any degree of regularity at different scales. Incorporating the time-frequency localization properties of wavelets and the learning abilities of ANNs, WNNs have shown their advantages over the regular ANN systems, which can dramatically improve the convergence speed [5,13,16].

In most of the existing literatures concerning WNNs, different wavelet techniques such as the wavelet packet decomposition, have been applied to extract typical information, i.e., features, characterizing the signals of the images. Among which, only a few contributions have been made to dealt with the application of wavelet analysis to process face direction recognition. Although WNNs have been successfully applied in facial expression recognition [1,3], there still exist some challenging issues such as how to optimize the structure and parameters of WNNs? and how to select the wavelet bases?

On the other hand, the particle swarm optimization (PSO) algorithm proposed by Kennedy and Eberhart [18,19] is a simple and effective stochastic global optimization technique due primarily to its attractive properties, i.e., easy implementation and no gradient information required. In previous research results [2,17,20], variations of PSO algorithms have been utilized to a wide range of different optimization problems, such as training ANNs and solving the function minimization problem. On the other side, the converge speed of WNNs is faster than the Back Propagation (BP) algorithm. However, the PSO algorithm has some disadvantages such as easily falling into local minima, slow convergence speed and poor accuracy. In order to overcome these drawbacks, we try to train the WNNs with a new SPSO algorithm. The SPSO algorithm [25,33] has been developed that introduces a mode-dependent velocity updating equation with Markovian switching parameters in order to overcome the contradiction between the local search and the global search. The proposed SPSO algorithm can not only avoid the local search stagnating in a local area and wasting more time on an invalid search but also lead the swarm to move to a more potential area quickly. Therefore, the SPSO algorithm can greatly improve the ability of WNNs because of its advantages such as the improved particle diversity and the good global search ability.

On the basis of an analysis of the structure and parameters of WNNs, the SPSO algorithm can be applied to determine the number of wavelet nodes and related parameters such as initial values. A new pattern recognition method called SPSO–WNN is proposed for the face direction recognition. To implement this method, preprocessed and selected input–output face direction data are first used to train the SPSO–WNN algorithm. After that, the SPSO algorithm is applied to refine the SPSO–WNN parameters. The experiment results of the recognition for face direction show the feasibility and effectiveness of the proposed method. As far as we know, to date, no research work has been published that combining SPSO with wavelet artificial neural network for face direction recognition with multiple parameters of the input image. The objective of this research is to explore the hybrid SPSO–WNN method for face direction recognition and to make comparison with other WNN methods. The main contribution of this paper is mainly twofold. (1) A novel hybrid approach called Switching Particle Swarm Optimization–Wavelet Neural Network (SPSO–WNN) is proposed to the issue of the face direction recognition. Note that the proposed algorithm can correctly and effectively recognize the face direction. (2) Experiment results show that the proposed algorithm can not only improve the convergence speed while training the parameters of the WNN but also obtain a higher recognition accuracy than other WNN models that are optimized by (1) standard PSO algorithm; (2) genetic algorithm (GA) or; (3) WNN that all the parameters are randomly initialized.

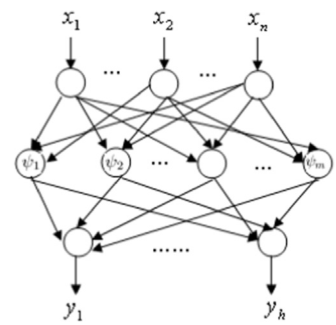

Fig. 1. The structure of the WNNs.

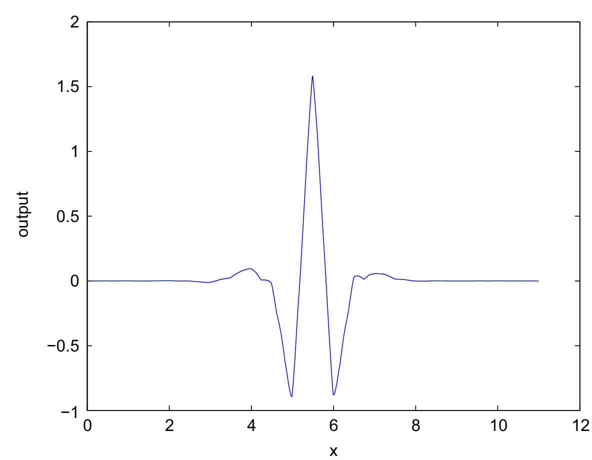

Fig. 2. Mexican Hat wavelet function.

Table 1
Pseudocode of the SPSO.

Step	Pseudocode of the SPSO
1:	*Parameter* ← SwarmParaInitialization()
2:	While not satisfying the terminal condition do
3:	for $i=1$ to swarm numbers S do
4:	evaluate Fitness(x_i)
5:	update Particle Best()
6:	update Swarm Best()
7:	if $Div(k) < threshold$ then
8:	increase the x of $\Pi^{(k)} = ()$
9:	end if
10:	if $Div(k) < threshold$ then
11:	increase the χ of $\Pi^{(k)} = \begin{pmatrix} \chi & 1-\chi \\ \chi & 1-\chi \end{pmatrix} (\chi \in [0.4, 0.8])$
12:	end if
13:	if $P_{best} < threshold$ then
14:	$\Pi^{(k)} = \begin{pmatrix} \nu & 1-\nu \\ \nu & 1-\nu \end{pmatrix} (\nu \in [0.04, 0.3])$
15:	end if
16:	Calculate new Velocity() of the Particle by Eq. (6)
17:	Calculate new Position() of the Particle by Eq. (6)
18:	end for
19:	end while

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