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Multi-size patch based collaborative representation for Palm Dorsa Vein Pattern recognition by enhanced ensemble learning with modified interactive artificial bee colony algorithm

Sandip Joardar[a], Amitava Chatterjee[a,*], Sanghamitra Bandyopadhyay[b], Ujjwal Maulik[c]

[a] Electrical Engineering Department, Jadavpur University, Kolkata 700032, India
[b] Machine Intelligence Unit, Indian Statistical Institute, Kolkata 700108, India
[c] Department of Computer Science and Engineering, Jadavpur University, Kolkata 700032, India

A R T I C L E I N F O

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A B S T R A C T

This paper proposes a novel method, Multi-Size patch based Collaborative Representation based Classification (CRC) strategy by Enhanced Ensemble Learning, for palm dorsa vein pattern (PDVP) based human recognition employing thermal imaging. This thermal PDVP imaging based human recognition methodology has been specifically employed to encounter the challenging crisis of intrusion posed by imposters. To address the Small Sample Size (SSS) problem, intrinsic to many biometric applications, each image is transformed into multiple patches, leading to an increase in the total number of samples. In a bid to make the classification strategy less sensitive to the choice of patch-size, the present paper proposes a new *enhanced ensemble learning* for the patch based CRC (PCRC) algorithm, where margin maximization is carried out using *exponential squared loss minimization*. This work also proposes how this loss minimization can be achieved by a stochastic optimization algorithm and solves this problem using artificial bee colony (ABC) algorithm. In this context, a new ABC variant, called *modified interactive artificial bee colony* (MI-ABC) algorithm, has also been proposed, which has been demonstrated to outperform the basic ABC and its several modern variants. The proposed methodology has been implemented on a well–structured real database, developed in our laboratory using real subjects, and the results obtained in implementation phase clearly demonstrate that our proposed method could outperform its several competitors and achieve substantially high classification rates, for the problem under consideration.

1. Introduction

The Palm Dorsa Vein Pattern (PDVP) is a comparatively new biometric feature with respect to other human physiological features that have been used extensively for biometric applications, like fingerprint, palm-print, face, and iris images. The Palm Dorsa Vascular structure of a human hand is shown in Fig. 1 (Dorsal metacarpal veins). The thermal images of the palm dorsa vein pattern can be acquired using infrared (IR) imaging technology, which has been recently demonstrated to be an interesting potential means for human authentication/identification (Michael et al., 2011).

One of the significant advantages of IR imaging a biometric feature is that the dependence on illumination conditions can be completely eliminated, thereby, achieving high degree of detailing in the biometric feature even when imaging is carried out in complete absence of light. The hygienic aspect of the PDVP biometric feature is that the data acquisition, both for training and testing, is of the non-contact type. Moreover, if contact type sensor is used for data acquisition, then the latent hand print, that persist on the surface for some time, can be copied and used illegitimately (Putte and Keuning, 2000). Cognizant of the deception posed by imposters, the PDVP, as a biometric feature, is considerably safer as the complex vascular structure resides underneath the skin, in the human body, which cannot be altered or restructured without surgery. Moreover, the complex palm dorsa vascular structure of a certain person is distinct from another (Jain et al., 2002), and remains unchanged for a prolonged period of time, provided there is no surgical intervention.

In recent times, *Sparse Representation based Classification* (SRC) has emerged as an interesting classification methodology where a query sample can be coded as a sparse linear combination of all training samples pertaining to different classes (Elad, 2010). However, in spite of the initial success of SRC, the stringent requirements of Sparse Representation, i.e., formulation of the testing sample as an underdetermined system of linear equations, and an over-complete (dimen-

* Corresponding author.
E-mail address: cha_ami@yahoo.co.in (A. Chatterjee).

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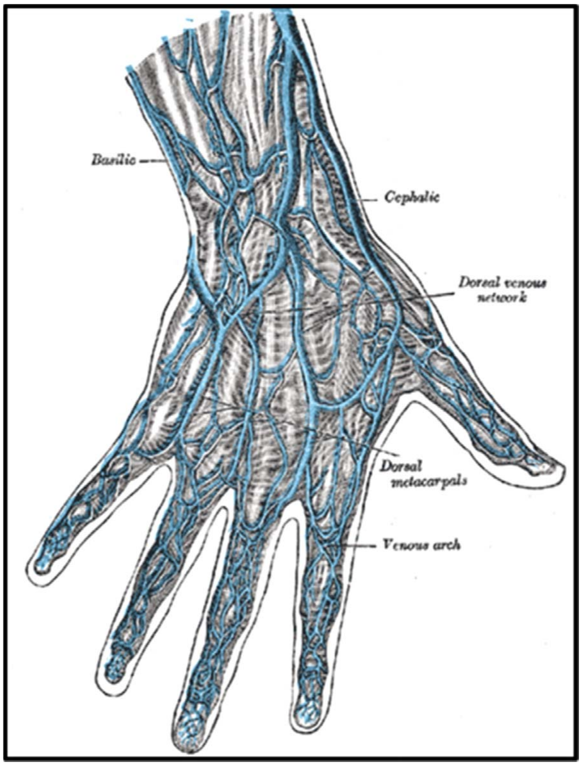

Fig. 1. The Palm Dorsa Vascular pattern of the human hand ([Online]https://en.m.wikipedia.org/wiki/Dorsal_metacarpal_veins#).

sionality reduced) dictionary for computation of the representation residual, itself, have been questioned, especially in the context of application of SRC in a wide spectrum of real – world problems (Zhang et al., 2011; Shi et al., 2011). Moreover, it has been argued by Zhang et al. (2011) that SRC has significantly high computational complexity, because of its utilization of l_1-norm sparse regularization, and hence, an effective alternative classification strategy has been proposed very recently, which has been termed as *Collaborative Representation based Classification (CRC)* (Zhang et al., 2011; Zhu et al., 2012; Chi and Porikli, 2012) that has shown very interesting early promises to provide satisfactory and competitive result in classification applications, using a much lesser computational burden than SRC. In contrast to SRC, CRC has been proposed to utilize a collaborative representation of all training samples to code the query sample, using a weak-sparse l_2-regularization (Zhu et al., 2012).

In real world biometric applications one of the most significant problems, that can greatly degrade the classification results, is the *Small Sample Size (SSS)*, which is nothing but relatively small number of training samples available to the classification strategy. Typically, such problems arise in biometrical applications at airports, in law and order situations, strict surveillance scenarios etc. Under such circumstances, like many other classification methodologies, it is expected that the recognition rate of CRC may degrade substantially too (Zhu et al., 2012). One of the solutions to such kind of a problem, as argued by Zhu et al. (2012), is to convert the whole image into multiple patches, apply CRC on them, and finally combine the classification outputs from all the patches to draw the final conclusion.

However, there is an underlying problem in the patch based CRC (PCRC) strategy, which is, any patch based classification strategy is highly sensitive to the patch size; and achieving the optimality of the patch size is non-trivial (Zhu et al., 2012; Chen et al., 2004; Tan et al., 2005). This hindrance to robust classification can be done away with if *ensemble learning* is performed to combine the information obtained from the PCRC outputs when applied to multi-sized or multi-scaled patches (Zhu et al., 2012). In Zhu et al. (2012), the multi-scale ensemble problem has been solved by casting the problem as a margin distribution optimization problem, where the ensemble margin of a query sample is represented in form of ensemble square loss of the sample and the margin maximization problem has been suitably reformulated as a square loss minimization problem. In this work, we present a new methodology for palm dorsa-vein based human recognition, using thermal imaging, in the challenging small sample size scenario (Joardar, 2014). The human recognition is performed using multi-size patch based CRC. The main highlighting points of this work can be summarized as:

(i) This is the first work where a thermal image based palm-dorsa vein pattern biometric recognition system has been developed for real subjects utilizing CRC.
(ii) The algorithm proposes a new multi-size patch based CRC strategy which solves the ensemble learning based loss minimization problem by proposing an exponential squared loss, instead of the squared loss of the ensemble margin proposed in Zhu et al. (2012). This exponential squared loss makes the learning strategy highly sensitive to the ensemble loss and, therefore, constitutes an *enhanced ensemble learning strategy*.
(iii) To the best of our knowledge and belief, this is also the first work that formulates enhanced ensemble learning strategy as a metaheuristic optimization problem. In this work, this metaheuristic optimization problem has been solved using artificial bee colony (ABC) algorithm (Karaboga, 2005; Karaboga and Basturk, 2008, 2007; Karaboga and Akay, 2009), its variants (Chen et al., 2012; Tsai et al., 2009). The ABC algorithm is a recently proposed swarm intelligence algorithm that simulates the intelligent foraging behavior of a honey bee swarm. The exponential squared loss formulated for ensemble margin maximization in this research work cannot be stated to be convex with utmost definiteness, for all cases. Therefore, utilization of metaheuristic optimization techniques for minimization of the loss function emerges as a viable option.
(iv) The present work also proposes a new variant of ABC algorithm, called the *Modified Interactive Artificial Bee Colony* (*MI-ABC*) *Algorithm*, which could consistently outperform other variants of ABC in solving this exponential squared loss minimization problem.

The rest of the paper is organized as follows. The experimental procedure involved in developing this system comprising data acquisition, image pre-processing, and database creation is described in Section 2. The enhanced multi-size patch based CRC (termed here as EMSPCRC) algorithm is formulated and presented in detail in Section 3. Section 4 describes the basic ABC and its variants and this is followed by the proposal of the new variant of the ABC algorithm, i.e. the MI-ABC algorithm, which is mathematically analyzed and elaborated. The experimental results and inferences obtained are discussed in detail in Section 5. Eventually, the conclusion and the future scope of research is presented in Section 6.

2. Thermal image data acquisition and database creation

As already mentioned and reasoned, we have used the IR imaging technology for acquiring the thermal images of palm dorsa vein pattern. Thermal images of the palm dorsa vein pattern are formed based on the infrared radiation emitted from the dorsum of the human palm (Michael et al., 2011). We have acquired these images from several subjects in our laboratory using KT-384 thermal imager (Manufacturer: Sonel®, Poland), a fully radiometric camera. It has non-cooled microbolometric matrix type detector with 384×288 pixel thermal resolution and thermal sensitivity of less than 0.08 °C (KT-384 thermal imager data sheet).