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Ant colony optimization based fuzzy binary decision tree for bimodal hand knuckle verification system

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ABSTRACT

In the recent trends of touch-less biometric authentication systems, hand knuckles from dorsal part of the hand is gaining popularity as a potential candidate for verification/recognition in variety of security applications. However, most of the available knuckle verification systems offer fixed security achieved for desired level of accuracy which cannot meet the varying levels of security requirements. This paper presents a bimodal knuckle verification system which is designed to meet a wide range of applications varying from civilian to high security regions. We use ant colony optimization (ACO) to choose the optimal fusion parameters corresponding to each level of security. The developed verification system utilizes fuzzy binary decision tree (FBDT) which is aimed at decision making in two classes: *genuine* (accept) and *imposter* (reject) using matching scores computed from the knuckle database. The FBDT is implemented using *fuzzy Gini index* for the selection of the tree nodes. The experiments are carried out on four publicly available HongKong PolyU knuckle databases named as: left index, right index, left middle and right middle with four bimodal systems: left–right index, left–right middle, left index–middle and right index–middle. The experimental results from these four bimodal knuckle databases validate the contributions of the proposed work.

1. Introduction

Hand based biometrics have been the most acknowledged for personal authentication. Not only due to its superior performance which is required for the high security applications, but also for their high distinctiveness, user convenience and acceptance. The hand biometrics can be broadly divided into two categories: the palmer part and the dorsal part. The palmer part of the hand generally spans the areas close to palm. The widely used biometric attributes extracted from this part of the hand are: fingerprints (Jain, Flynn, & Ross, 2007; Maltoni, Maio, Jain, & Prabhakar, 2003; Ratha & Bolle, 2004), palmprint (Huang, Jia, & Zhang, 2008; Jia, Huang, & Zhang, 2008; Kong, Zhang, & Kamel, 2006; Zhang, Kong, You, & Wong, 2003) and finger/palm veins.[1] The dorsal part of the hand occupies the area behind the palmer part and most of the usable biometric modalities from this part are: hand geometry/shape (Jain, Ross, & Pankanti, 1999; Sanchez-Reillo, Sanchez-Avila, & Gonzalez-Marcos, 2000; Yoruk, Bulent, & Sankur, 2006), hand veins (Kumar and Prathyusha, 2008; Wang and Leedham, 2006; Wang, Yau, Suwandy, & Sung, 2008) and finger knuckles (Kumar & Ravikanth, 2009; Kumar & Zhou, 2009; Li, Qiu, Sun, & Wu, 2004; Nanni & Lumini, 2009; Woodard & Flynn, 2005a, 2005b). The palmer region of the hand is supposed to have more informational details than dorsal part and several unimodal/multimodal biometric systems have been attempted using fingerprint and palmprint biometrics. However, people leave their palm/handprint unconsciously wherever they touch and which increases the possibilities of imposter attacks on these security systems. The biometric modalities from the dorsal part of the hand are therefore gaining popularity. Owing to the touch-less acquisition, they have less chance of imposter attacks and being a non-active part of the hand there is less possibility of information degradation, especially compare to the palmer part.

Though, the biometric traits extracted from the dorsal part have shown to be less informative in compare to the high detailed fingerprint or palmprint. Despite promising effort using hand shape biometrics (Yoruk et al., 2006), the geometry of hand is considered as less distinctive (Jain et al., 1999). Beneath the skin, the vein patterns from the dorsal part of the hand possess high textural details. But, its acquisition in outdoor environment is itself a challenge and requires costly infrared thermal sensors with several complex algorithms for pre-processing (Wang & Leedham, 2006). The current popularity of the knuckle biometrics for personal authentication is due to its high textural details, simple acquisition with ordinary digital camera, and high user convenience without use of any pegs or hand docs (Jain et al., 1999). However, since knuckle from one finger has a small surface area, knuckles from more than one finger have been considered for research purposes. Out of the

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[1] http://www.hitachi.com/New/cnews/071022b.pdf.

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five fingers of a hand, knuckles from index and middle fingers have largely been investigated in the literature. The knuckles of these two fingers from left and right hands have also been attempted to make a bimodal/multimodal system. This paper aims at developing a bimodal system by investigating several possible combinations of the four knuckle points from both the hands. The presented approach relies on soft computing pattern classification approach using fuzzy binary decision tree (FBDT) for designing a verification system and evolutionary optimization technique utilizing ant colony optimization (ACO) for optimally select the fusion parameters in the knuckle bimodal system.

1.1. The prior works and motivations

Finger knuckles from the dorsal part of the hand is still in its developing phase and can be considered as new trends in biometric based personal authentication. It is initiated in 2005 when Woodard and Flynn (2005a, 2005b) have first investigated finger back surface for personal authentication. They utilized Minolta 900/910 sensor for acquisition of 3D finger back surface. Their effort validates the uniqueness of finger back surface as a potential biometric trait. However, their work has not fully devoted to knuckle points and they utilized complete finger back surface in authentication. Further, the use of Minolta 900/910 raises the overall costs and preprocessing of 3D finger surface increases the time complexity of the system which limits its usage for online biometric applications.

In 2009, Kumar and Ravikanth (2009) presented a detailed analysis on acquisition and extraction of knuckle points from the dorsal part of the hand. They utilize a low cost and simple-to-use imaging setup using a digital camera (Canon Powershot-A620) for acquisition of hand dorsum. The acquired hand image is then used to compute knuckle points as a region of interest (ROI). The PCA, LDA and ICA features are extracted from knuckle points to show its efficiency on IIT database. In the same year, Kumar and Zhou (2009) presented a Radon transform based features with promising results. In a recent work, Zhang, Zhang, Zhang, and Zhu (2010) proposed a new imaging set up to acquire finger knuckle surface directly instead capturing complete dorsal part of the hand as in Kumar and Ravikanth (2009), Kumar and Zhou (2009). Their imaging set up can significantly reduces the preprocessing size by considering only finger part for knuckle extraction. They proposed a combination of orientation and magnitude as knuckle features and also investigated variety of other textural features like comp code, ordinal code, RLOC and BOCV in comparison. The four knuckle points utilized in their work are: left index, right index, left middle and right middle from the two hands. They also discussed the fusion of these knuckle points using sum and min score level fusion rules.

Despite few very promising efforts, the literature survey shows that knuckle based authentication system is still less investigated for wide range of applications. There have no attempt on investigating a reliable bimodal system by investigating various combinations of hand knuckles which can offer desired level of accuracy. Most of the available knuckle verification systems offer fixed security achieved by selecting a decision threshold from the receiver operating characteristic (ROC) of the system (Jain et al., 2007).

1.2. The proposed work

This paper proposes a pattern classification approach for the knuckle verification system. Considering the knuckle verification as a two class classification problem, we use fuzzy decision tree (FDT) to classify the claimed identity into any of the genuine (accept) or the imposter (reject) classes based on the available training data. The extracted knuckle features of the enrolled samples are matched to compute matching scores of the two classes: when the matching is performed between samples of the same users the scores are labeled as *genuine* class otherwise, *imposter* class. The FDT is trained using these matching scores and the trained-FDT

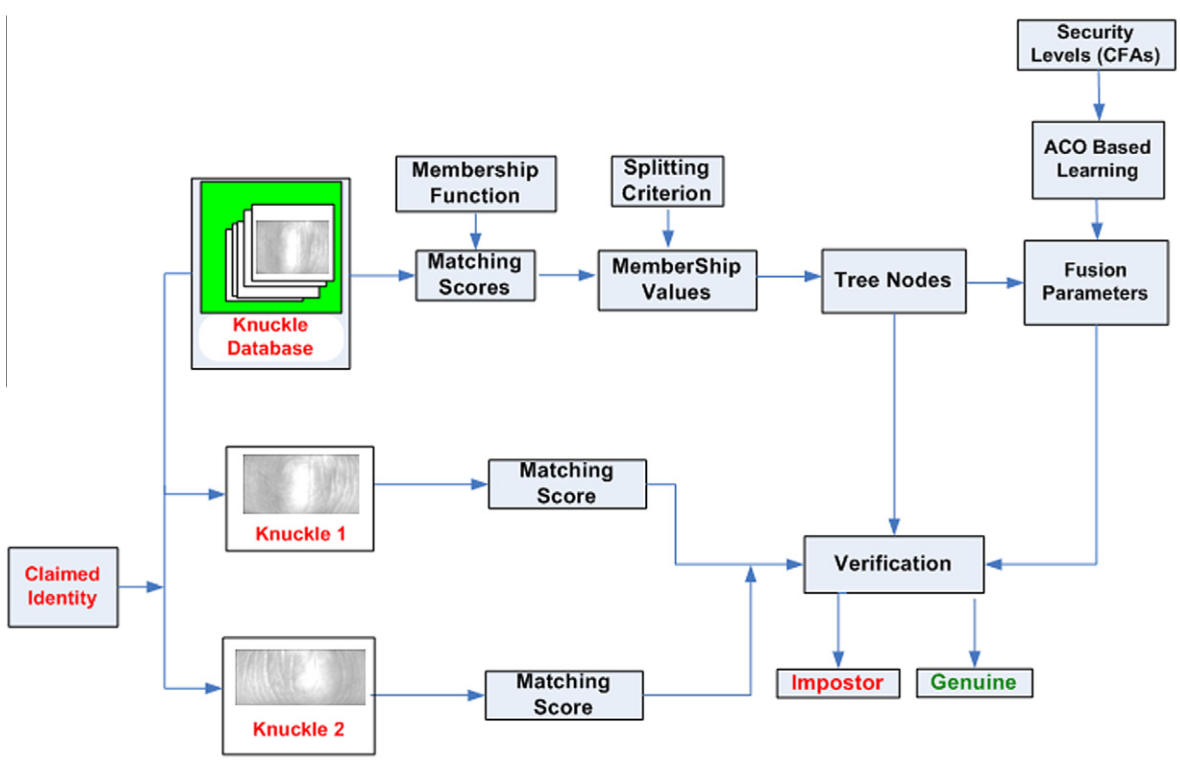

Fig. 1. Block diagram of the proposed verification system.