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Biometric authentication using finger nail plates

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ABSTRACT

This paper attempts to bring a new inventive and non-mainstream biometric development to the fore. A completely automated and unified approach to authenticate individuals using finger nail plate surface images has been proposed. There has not been any attempt in utilizing the texture and the contour information of the nail-plate for human authentication in literature. This has motivated us to explore the nail plate based identification for security applications and applying approaches that ascertain the best possible performance. The complex technique of Interferometry is perhaps the most widely used approach in the literature to carry out analysis on nail-bed which is the inner part of the nail unit. In this paper, we propose a very convenient and efficient method by acquiring low resolution images of nail plate surface which is the outermost part of the nail unit. The contour and texture characteristics of nail plates from three fingers are represented by the appearance and shape based feature descriptors. The paper presents two ways of integrating the nail-plate features from three fingers: (1) score level rules for fusion of matching scores and (2) the classifier based fusion of matching scores by employing decision tree and support vector machines. The experimental results from 180 users and a total of 2700 nail plate images validate the contributions from this paper.

1. Introduction

The increased level of effective security control and transaction fraud in the world of electronic and internet commerce, demands for highly secured identification and personal verification systems. Many unique physiological and/or behavioral characteristics and signaling methods have been employed in the literature to develop a comprehensive biometric based authentication system (Li, 2009). However, there is still no biometric trait able to completely satisfy the requirements of the real deployment in security applications. Inventive biometric developments are making progression to bring non-mainstream biometric technologies to the fore (Biometric Technology Today, 2004; Goudelis, Tefas, & Pitas, 2008; Jain, Ross, & Pankanti, 2004; Nandakumar, 2005). Recently, hand based biometric systems has received considerable attention as they have various unique anatomical features that are highly distinct and informative. This paper investigates the true capabilities and performance that can be achieved from finger nail plates as a distinctive attribute for personal authentication. The nail authentication technology is based on the high individuality of the dermal structure underneath the finger nail plate, known as nailbed. It is a new and challenging characteristic available from hand and is emerging as a promising component of biometric study.

The most popular biometric modalities available from hand are: Palm print (Zhang, Kong, You, & Wong, 2003), fingerprint (Ratha & Bolle, 2004), palm vein (Wang, Yau, Suwandy, & Sung, 2008), finger knuckles (Kumar & Ravikanth, 2009) and hand geometry (Jain, Ross, & Pankanti, 1999; Yoruk, Konukoglu, & Sankur, 2006). Features extracted from the palmer region of the hand are supposed to have more informational details than dorsal part and several unimodal/multimodal biometric systems based on fingerprint and palmprint have been attempted in literature. However, people leave their palm/fingerprint unconsciously wherever they touch an object and thus increasing the possibilities of imposter attacks and impersonation. On the other hand, the biometric modalities from the dorsal part of the hand are more difficult to forge and 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 damage in comparison to the palmer part. Thus, the need of biometric traits that utilizes distinct intrinsic characteristics and has less chances of impostor attack is becoming crucial for civilian applications. In this context, finger nail plate recognition has emerged as a promising candidate for personal identification. The high individuality and utility of the features extracted from finger nail plate surface as proven by the experimental results, deserves attention for its use in civilian and/or forensic applications.

The nail is a skin appendage located at the terminus of the finger, as shown in Fig. 1(a). The cross section of the nail unit consists of tightly knitted keratinized layers that are nail-plate, nail matrix and the nail-bed. The nail bed is the area of pinkish tissue beneath

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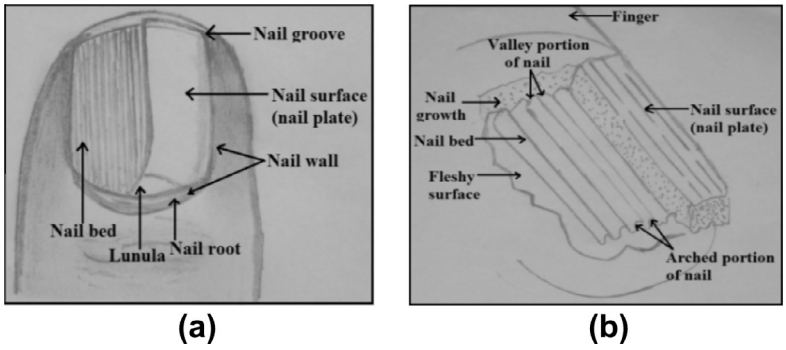

Fig. 1. Finger nail surface in (a), magnification of the nail bed structure in (b).

the nail plate and is enriched with tiny blood vessels. It consists of two types of tissues: the deeper dermis which is anchored firmly to the underlying structure of the finger and the upper epidermis tissue which is closest to the nail plate. The dermis has many ridges and groove like channels and the soft bed epithelium (epidermis) slides into these channels, creating tiny rails (Krstic, 1991; Thomas & Baert, 1965). This tongue-in-groove arrangement of the two layers is referred to as arched and valley portion of the nail in Fig. 1(b) and it forms a structure that is unique, closely parallel and irregularly spaced. The grooved spatial arrangement of the nail bed is observed on the upper (convex) nail plate surface as longitudinal ridges/striations (Topping, Kuperschmidt, & Gormley, 1995). These longitudinal striations are highly unique for every individual and hence serve as a means of personal identification. Thus, the individuality in the uniqueness of nail based biometrics is completely dependent on the intrinsic anatomic characteristics of the nail. *In this paper, we develop a new biometric identifier using the unique characteristics of the finger nail-plate. It is to underline that, the nail-plate has not been utilized as biometric identifier in the past literature and the presented work is the first attempt on making biometric framework using the utility of such features acquired from low resolution nail-plate images* (Chellappa, Tistarelli, & Li, 2009).

1.1. Motivation and related work

The study of nail anatomy reveals that only the nail plate is regenerated as new cells are made, the spacing between the grooves of the nail bed remains proportionally constant over the entire life of the individual (Diaz, Boehm, & Rowe, 1990). Thus unlike face characteristics which changes with the age of an individual, these characteristics of the nail surface can be very useful for identification over the entire lifespan of the individual. The works in Bragulla and Homberger (2009), Nieto, Gómez-Amoza, Delgado-Charro, and Otero-Espinar (2011) illustrates that the presence of different keratin types in the layers of the organ is responsible for the variable physical characteristics of the individuals nail plate surface. The finger nail ridge patterns appearing on the outer nail surface shows a high degree of distinctiveness, even in the case of identical twins (Ralph, Piraccini, & Tosti, 2004) or even between different finger nails of an individual. The nail surface ridge pattern is in some way superior to other biometric traits for identification as the hardened nail structure resists any decomposition or environmental effects, barring the changes caused by nail diseases and disorders (Diaz et al., 1990). Onychomychosis (Taylor, Roberts, & Boyle, 2002), Psoriasis and Beau's lines are some of the diseases that affect the nail plate leading to its deformation in some way. However, the key factor that is cited for the preference of nail plate surface based biometrics is that nail plate utilizes intrinsic characteristics of the nail bed for identification which is a hidden structure and hence crucial identity information is unrevealed. The nail plate is also an important substrate for diagnosis in field of forensic, environmental and sports medicine (MacDonell & Bialousz, 1972). However, forensically finger nails are not likely to be as useful as fingerprints for identification. Nevertheless, in a number of criminal cases broken finger nail plates have proved to be important in associating a suspect with the victim by comparing the nail ridge pattern (Bragulla & Homberger, 2009).

Despite the uniqueness and high stability of nail plate as a biometric trait, the use of nail surface as a means of personal identification has not been extensively investigated in the literature. An initiative in studying the network of narrowly spaced ridges and valleys on the nail bed using a low-powered laser is taken in Nail ID. (2009). The method utilizes a broadband interferometer technique to detect polarized phase changes in back-scattered light introduced through the nail plate and the underneath nail bed layer. By measuring the phase of the maximum amplitude polarized optical signal, nail bed pattern is reconstructed using a pattern recognition algorithm on the interferometric data. But there has been a little development by the company in developing a prototype product and also no potential work has been published so far. The work by Apolinar and Rowe (1980) also examines the ridge patterns on the nail surface by means of polarized light. The nail specimen display sharp bands of interference colors when placed between cross polarizing filters. They showed that the optimum viewing condition are obtained when the nail specimen are oriented such that the direction of nail ridges is 45° from the direction of polarizing filter. Hence, it is a constrained approach and restricts the movement of the finger nails during imaging. The work presented by the authors also requires a specially prepared thin nail specimen which is suitable for examination by transmitted light microscopy. Thus, the technique cannot be employed in civilian applications. Topping et al. (1995) present a system to measure the spacing of the capillary loops separated by valleys through the use of two different wavelengths of highly monochromatic light. The authors suggest significant improvements in the performance of nail recognition using such system, but the method and acquisition system they presented for nail identification involved a lot of computation complexity. The prior research has made an attempt on analyzing the capability of finger nail as a biometric trait, but they lack an experimental analysis on a large public database so as to generate a reliable conclusion on the potential of finger nail as a biometric identifier. *More importantly, till now there is no publically available finger nail database that researchers can utilize for comparison and benchmarking.* In addition, none of the work in Apolinar and Rowe (1980), Nail ID (2009), Topping et al. (1995) utilizes the shape and contour characteristics of the nail plate to systematically compare the suitability of different feature representation techniques.

The summary of research work in past literature suggests that no proposal has been made to present a completely automated