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A further study of low resolution androgenic hair patterns as a soft biometric trait☆

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ABSTRACT

Soft biometric traits such as skin color, tattoos, shoe size, height, and weight have been regularly used for forensic investigation, especially when hard biometric traits, e.g., faces and fingerprints are not available. Recently, a new soft biometric trait, androgenic hair also called body hair, was evaluated. The previous study showed that low resolution androgenic hair patterns have potential for forensic investigation. However, it was believed that they are not a distinctive biometric trait because of the reported accuracy. To explore discriminative information in androgenic hair patterns, in this paper, a new algorithm, which makes use of leg geometry to align lower leg images, large feature sets (about 60,000 features) extracted through multi-directional grid systems to increase discriminative power and robustness, and class-specific partial least squares (PLS) models to utilize the features effectively, is employed. To further enhance the performance of the class-specific PLS models trained on very limited positive samples, one to three images per model in the experiments, and further enhance robustness against viewpoint and pose variations, a scheme is designed to generate more positive samples from a single image. Experimental results on 1493 low resolution leg images with large viewpoint and pose variations from 412 legs demonstrate that low resolution androgenic hair patterns contain rich information and the impression of low discriminative power on androgenic hair is due to the method used in the previous study.

1. Introduction

Soft biometric traits, such as race, gender, height, tattoo, and skin mark, are regularly used by law enforcement agencies all around the world for narrowing down suspect lists and combining with hard biometrics, e.g., faces and fingerprints, to achieve higher matching accuracy and speed [1,38–40]. Some soft biometric traits can be observed from long distance without user cooperation and can be remembered and described by witnesses easily, e.g., race of criminals. In some cases, even single soft biometric trait can provide accurate matching for particular persons, e.g., the angel tattoo on David Beckham's back and the skin mark on the forehead of Mikhail Gorbachev. Soft biometrics is especially critical when hard biometric traits are neither available nor with low quality. Because soft biometrics is not unique, universal, or permanent, development of new soft biometric traits is always demanded for combining other soft or hard biometric traits to improve matching performance and increase population coverage in different operational environments. Gait and comparative descriptions are two examples [2,3]. Recently,[1] androgenic hair also called body hair was evaluated mainly for identifying criminals and victims in riot, terrorist, and sexual offense images, where their faces and tattoos are not always visible because the criminals hide their faces and tattoos to avoid police identification and only a part of the victim body is visible.

With the advance of the digital technology, forensic investigation often deals with digital images, particularly in cases of masked gunmen, riots, sexual offenses, and child sexual abuse images (also known as child pornographic images). These crimes are widespread. In 2011, the England riot caused approximately 2500 shops and businesses looted [21]. In 2011, the Stanley Cup riot in Vancouver [22] was about 100,000 people in the streets. On the other hand, the Statistics Canada reported that there were over 5 million child sexual abuse images on the Internet in 2008 and 15,662 websites hosting those images in 2009 [24].

To arrest criminals in these crimes, effective identification methods are essential. Latent prints, blood samples, DNA, dental records, tattoos, face images, and face sketches are used regularly. However, they cannot

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[1] Androgenic hair, which differs from head hair and the vellus hair, which is much finer and lighter in color, develops on body during and after puberty. The growth of androgenic hair depends on the level of androgens in different persons [35].

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Fig. 1. Riot images collected from the Internet [11,50]. Lower legs are highlighted.

tackle cases with evidence images showing only non-facial skin of criminals without tattoos such as images of masked rioters and child sexual abuse images. Rioters are usually locals with casual dressing style, e.g., T-shirts, short sleeve shirts, and shorts. Their body parts are frequently exposed in front of cameras. Photos of masked rioters showing non-facial skin can be easily found. Fig. 1 shows riot images collected from the Internet. Pedophiles in child sexual abuse images are usually naked and their body parts are always captured in the images. Child sexual abuse images showing the faces or tattoos of pedophiles are rare because they know clearly that police can use these biometric traits to prosecute them. If androgenic hair is an effective biometric trait, it can be used with other soft biometric traits to narrow down suspect lists. Riot images can be captured by reporters, who always use high quality DSLR cameras. Child sexual abuse images are usually close-up images captured by smartphone cameras or consumer digital cameras. These images are not necessarily captured by surveillance cameras, because by 2016 and by 2018, there will be 2.16 and 2.56 billion smartphone users worldwide, respectively [4]. Images captured by surveillance cameras are not within the scope of this paper. It should be highlighted that nowadays, almost everyone has a smartphone and its built-in camera is upgraded every year. For example, Samsung Galaxy S6 has a 16 megapixel camera and Samsung Galaxy K Zoom and ASUS ZenFone Zoom have optical zoom functions. Thus, high quality evidence images can be available for criminal and victim identification.

Though traditional soft biometric traits, including skin color, race, gender, and height, are applicable to these evidence images, their discriminative power is far from enough. Skin marks and blood vessels hidden in color images are recently considered for forensic investigation [31,32,41]. However, they are not suitable for low resolution images because of their sizes. Even for high resolution images, they are not perfect. Body sites exposed in evidence images may have neither enough skin marks nor hidden blood vessel information. High concentrations of fat and melanin weaken visible light passing through the skin and make blood vessel visualization difficult. Recently, skin texture [12] is also suggested for criminal and victim investigation on low resolution images. However, skin can be covered by dense androgenic hair.

Medical studies indicate that new follicles do not form naturally after birth in humans [30]. All androgenic hairs manifest a cycle. When one hair falls out, another new hair will grow at the same follicle [30]. Androgenic hairs have a long life cycle [37]. For example, a complete cycle of androgenic hairs on leg can be up to one year [29]. Fig. 2 shows two images from the same leg. Fig. 2(a) was collected in August 2009, while Fig. 2(b) was collected in October 2008. The color circles show partial corresponding androgenic hair follicles. In this small area, more than 40 corresponding androgenic hair follicles are found. More examples can be found in [23]. These properties found by medical researchers imply that androgenic hairs can be a useful biometric trait [23]. In this paper, androgenic hair is considered as a soft biometric trait because it is not universal same as tattoo, which is also considered as a soft biometric trait. According to a study done on 239 adult white males by Garn [36], 3% of them do not have androgenic hair on their lower legs or lower arms.

Motivated by the medical studies, a method composed of a dynamic grid system for alignment, Gabor orientation histograms as features, and the Chi-square distance as a dissimilarity function was utilized to examine low resolution androgenic hair patterns in lower leg images [23]. In this paper, this method is called the dynamic Gabor orientation histogram (DGOH) method. Their experimental results were encouraging, but they gave an impression that androgenic hair is not very discriminative. It is suspected that this impression is due to DGOH,

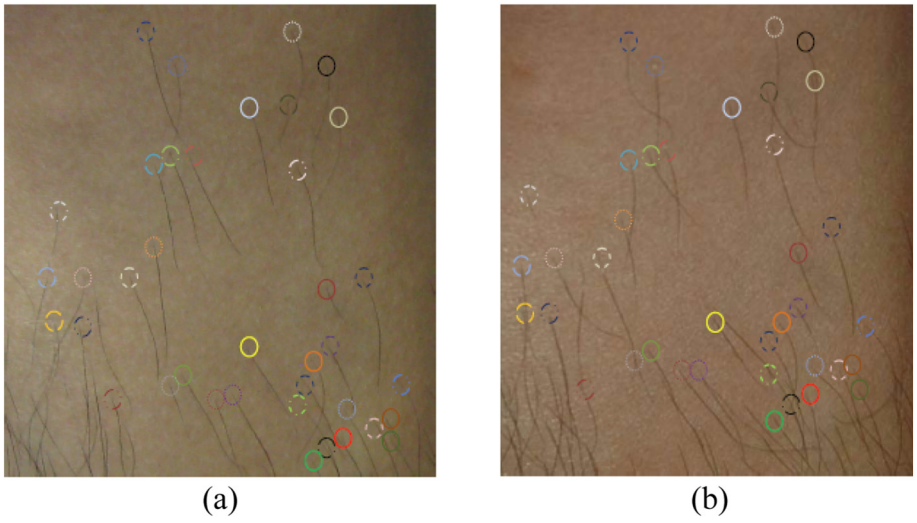

Fig. 2. Two skin images from the same leg [23]. (a) was collected in August 2009 and (b) was collected in October 2008. The color circles indicate the partial corresponding androgenic hair follicles.