Information Sciences 268 (2014) 3–19

Contents lists available at ScienceDirect

Information Sciences

journal homepage: www.elsevier.com/locate/ins

An approach to SWIR hyperspectral hand biometrics

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ARTICLE INFO

Article history:
Available online 22 October 2013

Keywords:
Biometric
Spectrographic
Hyperspectral
Hand
Recognition

ABSTRACT

Hand based biometry includes some of the most useful technologies for person identification. The search for new techniques, which complement the battery of existing methods, is an open topic. This paper examines the utility of hyperspectral imagery for hand recognition. Hyperspectral technology permits the sensing of the subsurface tissue structure, which is significantly different from person to person. The data are collected using a SWIR camera in conjunction with an optical spectrograph. This transforms the camera into a line-scan hyperspectral imaging device.

Three feature extraction methods for hyperspectral hand curve characterization are examined. They are based on the area, slope or curvature at different automatically selected spatial hand positions. We report a set of experiments which explore: best hand zones for extracting local hyperspectral features; robustness against the number of training samples; error detection; and occlusion. Different strategies for combining the spectral features with geometric traits available in the hyperspectral cube are discussed. Our experiments show that local spectral properties of human tissue are effective discriminants for biometric recognition with a performance near to or better than that obtained by other hand traits. Equal Error Rates of 0.05% and an identification rate of 96.71% are obtained from a database of 154 people. These results along with their higher robustness to spoofing attacks make the hyperspectral features a promising alternative for person identification.

1. Introduction

Person identification by hand traits is a widely applied field in biometrics. Several hand traits are used operationally. The most classic is the fingerprint [2], closely followed by the hand-shape, which, because of its simplicity, is one of the most used and studied [7]. The palmprint [18] and palm texture are also frequently employed; vein pattern techniques [31,37] deserve a special mention; and, finally, there is on-going research on other hand traits such as finger knuckles [35] and finger veins [19].

Hand biometrics is most commonly performed on gray scale images acquired at the visible range (400–700 nm) [7]. Some studies consider the complementarity of three different bands in the visible spectrum, namely the red (650 nm), the green (510 nm) and the blue (475 nm), and combine them at feature, score or decision level [34,20]. These bands are easily obtained with a color camera. More recent results extend the band range to include near infrared wavelengths (NIR, 700–1000 nm). For instance, Hao et al. in [15] combine a visible and an NIR band with different fusion techniques so as to reduce the identification error. Zhang et al. in [36] increase the number of combined bands to 4 (red, green, blue and NIR) to obtain an equal error rate of 1.21% with a database of 250 users. Hao et al. in [16] use 6 bands to produce an EER equal to 0.72% from

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0020-0255/$ - see front matter
http://dx.doi.org/10.1016/j.ins.2013.10.011

a database of 330 hands. Finally, Ferrer et al. in [9] include the short wave infrared band (SWIR, 1000–1700 nm) band to obtain an EER equal to 0.15% with 150 users. An additional advantage of the SWIR band is the skin absorption peak at 1470 nm which is used as skin detector for spoofing detection.

These approaches use only a few bands, limited by sensors in the red, green, blue and NIR, but there are many bands in this range that could give a better performance. This is why a liquid tunable filter is used by several researchers. This filter permits the division of the visible and NIR band into tens of bands. Thus we are able to select which and how many bands are the best for hand biometrics. For instance, Guo et al. in [13] select 2 bands out of 69 via $(2D)^2$PCA to obtain an accuracy of 92.8% which is only increased to 93.25 by selecting 3 bands. Again Guo et al. in [14] improve the band selection by using an exhaustive technique based on a clustering algorithm and a classifier based on the complex wavelet structural similarity (CW-SSIM) distance [27]. They obtain an EER equal to 0.078% by selecting the bands at 580 nm, 760 nm and 990 nm. Similar work, but focused on the hand dorsal, is presented by Chen et al. in [3]. They divide the spectrum into 53 bands claiming an EER equal to 2.24% for the best band. They use a database of 211 individuals. These applications use proprietary databases.

So previously reported work uses up to tens of spectral bands to improve the hand biometric performance. It is possible to make further improvements by exploiting the hundreds of bands available in hyperspectral technology. This technology is used in many disciplines, especially in remote sensing [10] for material identification [17,12] where unmixing is the main problem [25]. In most of these applications, the spectrum range is from 400 nm to 2500 nm. This is the case for the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) hyperspectral sensor [38]. Now that hyperspectral cameras are more accessible, computing methods developed initially for remote sensing problems are being introduced to biomedical applications. For instance, hyperspectral spectrometry is being applied to skin detection for search and rescue applications. Nunez et al. in [21,22] study 81 bands from 800 nm to 1600 nm and propose a normalized difference skin index (NDSI) for detection which they obtain by combining the reflectance of the 1100 nm and 1400 nm bands. The bands selected by the NDSI coincide with the results of spectroscopic biomedical studies of human skin reflectance [1].

The hyperspectral curve of the skin is the subject of numerous studies such as those of Anderson [1] and Nunez [21]. The spectral reflectance of the skin depends on the composition of the subject's tissue. The epidermal and dermal layers constitute a scattering medium that contains various combinations of water, blood, melanosomes, bilirubin, betacarotene, etc. which provide different absorption coefficients. Small changes in the distribution of these layers and pigments induce changes in the skin's spectral reflectance, which is difficult to modify, and generates a unique response for each person. Considering the wide person to person spectral variability for different tissues types, hyperspectral technology is able to improve automated systems for human identification.

The technique is already used for facial recognition, as in Di et al. [6], Pan et al. [23,24] and more recently by Shen et al. in [29]. Pan et al. [23] analyse the hyperspectral facial skin response in the 700 nm to 1000 nm band. They use 31 bands from small, manually selected, facial skin and hair areas. Their more recent work [24] extends the previous study by using and comparing results from both constant illumination and uncontrolled outdoor illumination. A different approach is proposed by Di et al. in [6] where they apply feature band selection based on PCA projection. The work of Shen et al. [29] performs a

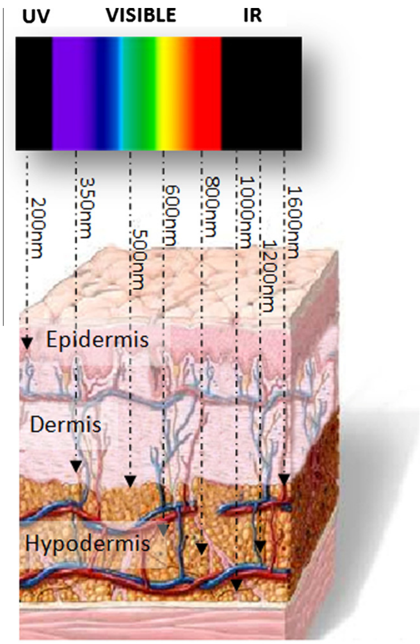

Fig. 1. Light penetration into human skin, according to wavelength (arrow tips).