Near-infrared images of skin

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Abstract

The near-infrared region is much more rarely used in imaging applications than the visible wavelength area. This is partly due to applications which often require evaluation for human vision point of view. Near-infrared can still offer useful information which may not be available at visible wavelengths. Many cameras are also sensitive to near-infrared region. Due to all this, it has been used in applications like face detection. In this study, the skin spectra of different complexions are acquired from three media: real faces, photos and prints. The photos and prints are reproductions of RGB images taken just before spectral imaging of faces. The skin is studied and analyzed from these spectral images. The goal is to examine if the media source can be recognized for database search and if different part of the face can be separated.

Introduction

Near-infrared (NIR) region can be very interesting for face-based applications for several reasons: it does not need a special light source like infra-red (IR), it can be achieved with relatively cheaper instruments than IR (see e.g. [1]) and it offers additional information to RGB. In fact, even a standard silicon based cameras are sensitive to this NIR region [2]. However, filters are included in these cameras to avoid NIR responses.

Unlike in the visual wavelengths (VIS), spectral responses are relatively slightly studied in NIR. Partly this is because NIR region does not contribute for visual perceptions made by human visual system. Many spectral devices have been so far quite expensive and difficult to use. In addition, the handling and applying of NIR spectral data to vision system may be more difficult than VIS data to RGB or gray scale systems.

NIR images are typically taken by a camera with one or more sensors for this range [3, 4]. This can be also achieved by a commercial camera (see e.g. [1]). This data can be used for face detection and it has been shown to be able to help in separating skin from 17 other materials. Hyperspectral NIR images (31 channels, 700-1000 nm) have been shown to be useful tool for face recognition [5].

In other studies like in [6], the spectra of skin are measured by a point measurement device. We, however, took spectral NIR images of facial skin between 780-1000 nm range with 5 nm steps. These images provide more details about wavelength and spatial characteristics of skin than point or band measurements.

Unlike the other studies, we took the facial skin from different targets: real faces, photos and prints. The data is collected from persons of different skin complexions. Our previous study has shown that three components like sRGB cannot separate the skin from different media sources [7]. The goal of this paper is to study skin at NIR region for different media and, if possible, to use it to separate different medias. Possible applications are identification sensors (real or fake face) and databases (recognition of media type).

Measurements

The faces were acquired with two different types of imaging: spectral and RGB. Both imaging was done in a short time span to ensure the relationship between data in them. The RGB images were taken with a customer level digital camera and they were further used for reproduction of facial images. The reproduction forms were photos and prints. Of course, many methods exist for these two reproduction type but we just selected method for each type. This paper does not aim to study all possibilities, just a realistic indication of spectral behavior of a typical material.

The RGB images were taken just before spectral acquisition with Nikon D70S digital camera to ensure a relationship between RGB and spectral images. The illumination for both acquisitions was the same. The relationship is not point-by-point type but rather with average values. The size of the digital image is 3008x2000 pixels. Settings for image acquisition are given by the camera automatically.

HP Color LaserJet 4600N printer was used to make the prints for the RGB images from the digital camera. The prints were made for two different head size as shown in Fig. 1. The photos from RGB images were produced in Kodak one-hour photo shop and like the prints, with two different head size as shown in Fig. 1. These reproductions were also subjected to spectral imaging.

Spectral images of faces were taken with an Imspector V10 (E) camera. The spectral range of camera is from 400 nm to 1000 nm by 5 nm steps. The light source was D65 (daylight 6500 K) from Macbeth SpectraLight III booth. The system for real face acquisition is shown in Fig. 2. It contains the spectral camera, the light source Macbeth SpectraLight III and moving sledges. The sledges can be used to move the camera in xy-direction.

A white reference (used before taking images) was used to cancel out the illumination spectra and to get the reflectance. Since the head is not flat and persons have different head shapes, there is some uncertainty in the level of the reflectance. The distance and geometry are not the only factor affecting to reflectance; many other factors like skin oil also affects and they vary between persons.

During the imaging session, the person was advised to stay as still as possible. This proved to be difficult for some persons. Especially difficult was being without blinking so some rows contain spatial distortions. The measurement time for a person took 15 minutes with the spectral range of 400 nm to 1000 nm with 5 nm steps. The spatial size of the real face images is 800x806 pixels in 12 bit accuracy. An RGB representation of spectral images is shown in Fig. 1.

The color reproductions (photos and prints) were also imaged by the spectral camera under the daylight D65 of SpectraLight III with the measurement system of Fig. 2. The spectral range was again 400 nm to 1000 nm with 5 nm steps and 12 bit accuracy. The spatial size of spectral images for prints was 800x449 or 800x838 depending on the number of persons in the image. For photos, the spatial sizes were either 800x891 or 800x1336 pixels again depending on the number of persons in the image.

The database consists of 13 persons with different complexions. Together there are three different forms for the same face: spectral images from real human face, photos of the face and printed images of the face. The database contains one digital RGB image and five spectral images (real face, photos with two different head sizes and prints with two different head sizes) of each face.

Figure 1. RGB representations of spectral images for (a) prints with bigger head size, (b) prints with smaller head size, (c) photos with bigger head size, (d) photos with smaller head size, and (e) a real face.

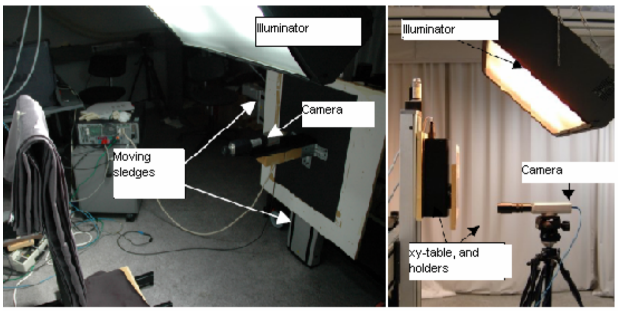

Figure 2. Spectral imaging systems for acquiring images of real faces (on the left), and for photos and prints (on the right).

Results

The data for most skin databases are usually acquired from the visible wavelengths 380-780 nm either in spectral, RGB or gray scale format. However, we study here the spectral images in the wavelength range from 780 nm to 1000 nm by 5 nm steps. Since we use spectral images it is possible to study the spatial characteristics of faces in addition to the spectral properties. This chapter concentrates mainly on three different sources in which skin spectra is obtained: real skin of facial areas, prints and photos.

The real skin spectra are analyzed in more detail than the spectra from the other sources. First, we study the spectral variation in a small area at different facial positions. Similar comparison was done also for photos and prints, like in the real skin case. However, no comparisons between different facial positions are made. Finally, we compare the skin spectra from different media.

Spectra of real facial skin

Spectral channel images of faces of different complexions are shown in Fig. 3 from three wavelengths 800 nm, 900 nm, and 1000 nm. The complexions do not seem to be so different NIR than in visible wavelengths. The main difference is again in intensity level. The shape of the head affects to the image just like in RGB. Note also the noise at wavelength 1000 nm. This might be caused by the device characteristics or low light level or both.

From these images, we selected areas at three different facial positions: left and right cheek, and forehead. We tried to avoid highlighted region but in any case the intensity level is uncertain. The spectra of selected areas were subjected to calculating the average and standard deviation spectra. These two operations were done for both original and normalized spectra. The average skin spectra from different positions for the original data are shown in Fig. 4. As can be observed, the spectra of left and right cheeks are somewhat similar in their levels but the spectra of foreheads are much higher. This may have been caused by different head geometry and skin structure. The shape of spectra at different positions is in any case very similar. One should also note that the difference in spectra of different complexions is not as large as it is in the visible wavelengths.

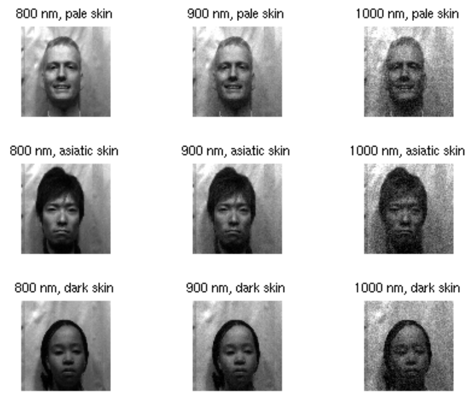

Figure 3. NIR channel images of 800 nm, 900 nm, and 1000 nm for different skin complexions. Upper row: pale skin complexion. Middle row: Asiatic or yellowish skin complexion. Lower row: dark skin complexion.

Spectra of skin from ***photos***

The photos were also subjected to spectral imaging. The photos were made with two different head size so we try to figure out if the size of reproduction affects on the results.

From these spectral images we selected skin areas. Again we tried to avoid highlights. The mean spectra were calculated from the selected areas. The results for the original data can be seen in Fig. 5. As can be seen from the figure, the different head size in photos does not have much effect. The skin spectra from different complexions seem to overlap quite a lot.

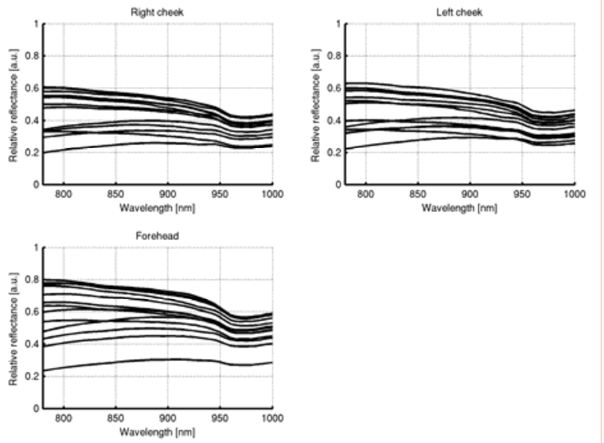

Figure 4. Real skin spectra from facial area at NIR region. The average spectra is calculated from selected areas and shown at different facial positions. Upper left: right cheek. Upper right: left cheek. Lower row: forehead.

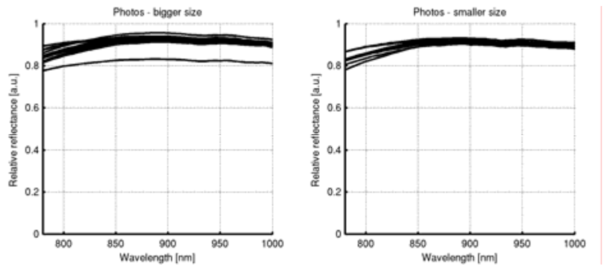

Figure 5. NIR spectra for the facial areas extracted from the photos. Left: bigger head size. Right: smaller head size. A reasonable head size variation does not seem to have an effect on results.

Spectra of skin from **prints**

Like the photos, also the prints were subjected to spectral imaging. The prints were made with two different head size. The purpose was again to try to figure out if the size of reproduction affects on the results.

We extracted the skin areas from these spectral images and tried to avoid highlight like in the earlier cases. The extracted areas were subjected to the mean spectra calculations. The results for original data are displayed in Fig. 6. As in the case of photos, the different head size in photos does not have much effect. However, the spectra have more variation in level than in spectra from photos. This might be due to properties of ink, printer or paper.

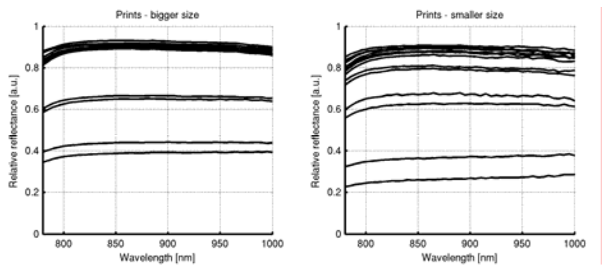

Figure 6. NIR spectra for the facial areas extracted from the prints. Left: bigger head size. Right: smaller head size. A reasonable head size variation does not seem to have an effect on results.

PCA of selected samples

Principal Component Analysis (PCA) was done for selected samples. From each media source, 75.000 random spectra from skin were selected and the PCA components were calculated. Also, the corresponding eigenimages were generated. The results are shown in Fig. 7 and 8. As can be seen in Fig. 7., the PCA vectors 3-4 are very similar. The notch at the end is probably due to presence of noise. One can see from Fig. 8 that the first component is the most important one. However, also the second component holds information in case of real faces and prints, and there are also differences in eigenimages between different media sources. The second eigenimage from photos seems to contain a lot of noise.

Results obtained indicate that spectral shapes are very similar at NIR and can be presented with very few components. These are expected results based on similarity shown earlier. The results can be useful for filter design and compression applications.

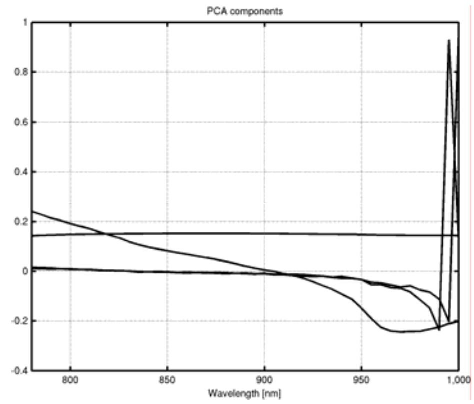

Figure 7. The first four PCA components of a skin data which includes 75.000 skin spectra from each media, totally 225.000 spectra.

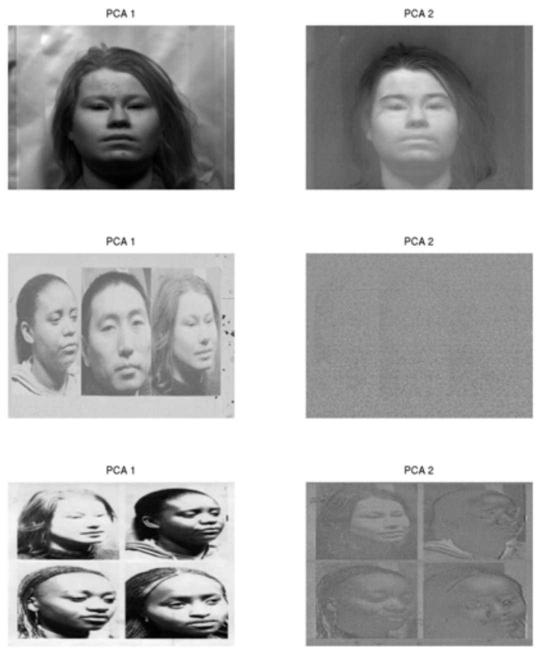

Figure 8. The first two eigenimages generated with PCA components shown in Fig. 7. The images in the first row are generated with spectral image of real face, the second row with spectral image of photos and the third row with spectral image of prints.

Comparison of NIR skin spectra from **different sources**

The NIR spectra of skin vary greatly depending on its source. The spectra from prints have more variation in level than from the other two media. On the other hand, the photos produce very overlapping spectra with high level. The shape of spectra from the three media differs and this indicates that properly selected infrared bands can be used to separate the source of skin.

Fig.9. shows result images for ratio between 900 nm and 980 nm for real faces. Fig. 10 displays the results for paper and photos. These images clearly indicate that the ratio can be used to separate real faces from "fakes" of paper material. The average 980 nm/900 nm ratio was also calculated, which were 0.81 and 0.98 for skin data of real face and skin data of other media sources, respectively.

Since the CCD cameras have sensitivities to the NIR area of 780-1000 nm and even ordinary lamps have output for this area, it would be possible to make a relatively cheap camera with few NIR bands for face detection.

Fig. 9. The images shown on the left are 900 nm channel images. On the right the ratio images 980 nm/900 nm are shown. The spectral imaging was done on real faces.

Conclusions

We have studied spectral image data of skin from three different media (real faces, photos and prints) at NIR area 780 nm – 1000 nm.

The NIR spectra of skin vary greatly depending on its source. The spectra from prints have more variation in level than from the other two media. The photos produce very overlapping spectra with high level. The shape of spectra from the three media differs and this indicates that properly selected infrared bands can be used to separate the source of skin. The PCA results show that shapes of skin spectra are very similar at NIR. Since the CCD cameras have sensitivities to the NIR and even ordinary lamps have output in it, a relatively cheap camera with few NIR bands could be used for face detection.

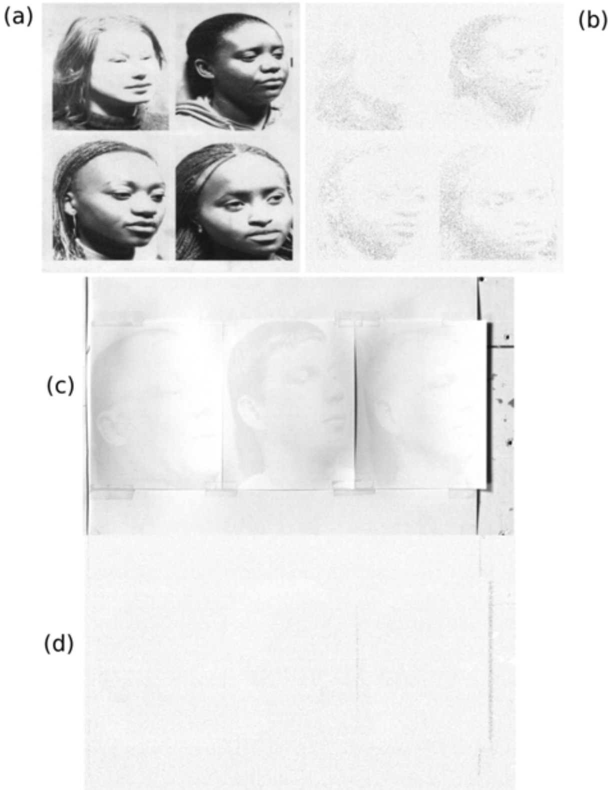

Fig. 10. The images (a) and (c) are 900 nm channel images, (b) and (d) are the ratio images 980 nm/900 nm. Images (a) and (b) are the results from printed papers, (c) and (d) are the results from photos.

References

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