Registration of Finger Vein Image Using Skin Surface Information for Authentication

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ABSTRACT

The finger vein image acquired with an acquisition system should be properly aligned to proceed with comparing algorithm. However it is not easy to find control the points since the images are naturally blurred with an inherent scattering property. To overcome this problem, we propose a novel finger vein registration method utilizing skin surface information (i.e. wrinkles and outlines). We assumed that finger crooking was insignificant. Images were sampled with intended translation and rotation. Each time, two images were acquired successively by switching the light source; one with infrared light and the other with white light. Degree of rotation and translation of sampled image were calculated using outline features in the white light image and then the infrared image was transformed according to the calculated data. To validate our method, correlation values were computed between identical subjects and different subjects. High correlation values were shown between identical subjects whereas low values were shown between different subjects.

Keywords: Image registration, finger vein, authentication, finger, biometric

1. INTRODUCTION

Authentication based on finger vein pattern is one of the most promising technologies in the field of biometrics. Since veins are under the skin surface, it is not easy to forge their patterns, contrary to fingerprints. Finger vasculature can be viewed with a near infrared (NIR) light source and CCD sensor which is sensitive to NIR rays because hemoglobin in blood absorbs more NIR light than other tissue[1].

The finger vein images acquired with an acquisition system are tilted and translated relative to the enrolled data, thus it should be properly aligned using image registration techniques to proceed with comparing algorithm. Point mapping is one representative image registration method for the alignment, and control points are used to match pictures taken at different times. Typical control points used in biometrics are corners, line intersections, points of locally maximum curvature and so forth [2, 3].

However, finger vein images do not easily show control points since the images are naturally blurred with inherent scattering property. Moreover, it is awkward to define proper control points due to the remarkable differences between different finger vein patterns. To overcome these problems, we propose a novel finger vein registration method utilizing skin surface information (i.e. wrinkles and outline). We assumed that only rotational and translational transformations are present between acquired and enrolled data. Local geometric transformations originating from the finger crooking could be easily remediable by the hardware or ignorable.

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8 images were acquired from 2 subjects with intended translation and rotation. Two images were acquired successively at each sampling, switching the light source; one with infrared light and the other with white light. Outlines and wrinkles at the knuckles were shown in the white light source image and finger vein patterns were shown in the infrared images. Degree of rotation and translation of sampled data were calculated using outline and surface features and then the infrared image was transformed according to the calculated data. Correlation values between images from the different subjects were computed as well as those from same subjects. Our algorithm showed reasonable results in a small range (i.e. small translation and small rotation). High correlation values were found between identical subjects whereas low values were found between different subjects. However, with relatively large transformations correlation values between identical subjects dropped significantly although their results were not mentioned in this paper. We assumed that this was largely affected by lens distortion[4] and non-uniform illumination.

2. METHODOLOGY

2.1 Imaging system

An image acquisition system consisting of a light source and a detector was used to capture two images successively; an infrared image and a white light image. The infrared image was taken by illuminating a finger with an infrared light source while the white light source was turned off. Rays of an array of five 890nm infrared LEDs were transmitted through the finger and detected on the infrared sensitive camera (Fig.1). IR pass filter was used to stop dim visible lights. The white light image was taken immediately afterwards, switching two light sources. Rays of white light were reflected off the finger skin and surface information such as outlines and wrinkles at the knuckles were viewed. Some miscellaneous considerations (i.e. light diffuser on the top of the LED array to make uniform illumination and a carbon paper to reduce background noise) were made to improve image quality (Fig.2).

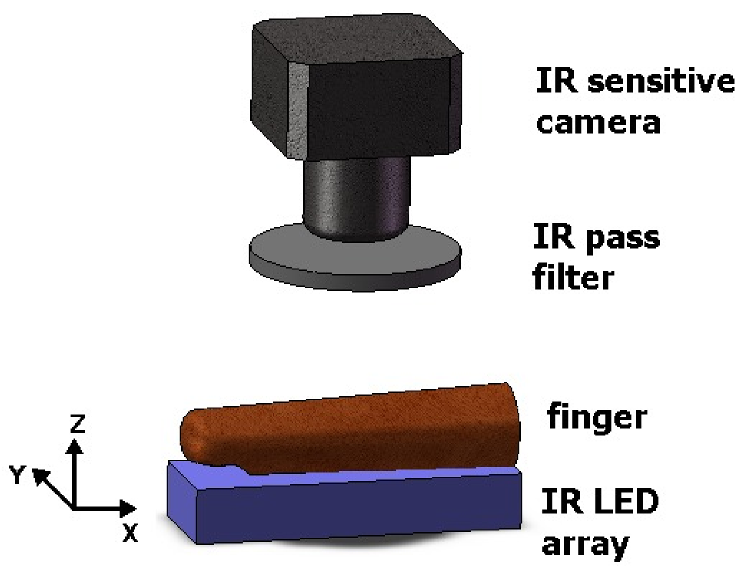

Fig. 1. Schematic of imaging system. Infrared lights from LED array were transmitted through a finger and detected on the IR sensitive camera.

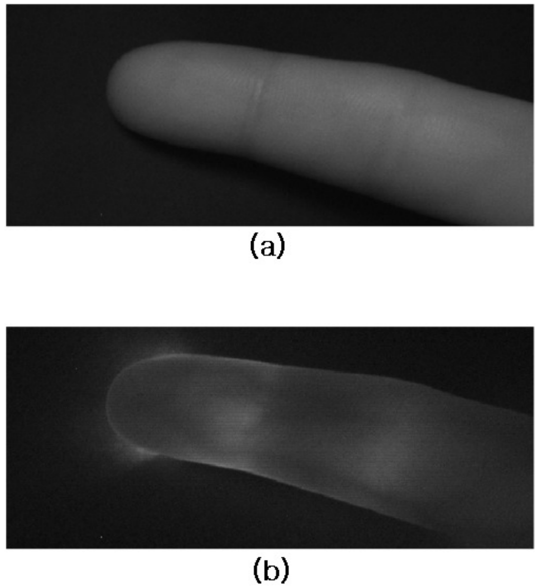

Fig. 2. Two images were taken with a small time interval. Upper image is captured using white light source and lower image using infrared light source.

2.2 Block diagram of image registration process

Acquired finger vein images should be transformed to be matched with the enrolled data. Common geometric differences between acquired and enrolled data are rotation and horizontal and vertical translation. Degrees of each difference were specified by the image template since it defines the correct position of enrolled data. Degree of rotation θ , horizontal translation dX and vertical translation dY were computed comparing image with template. Finger vein image was then transformed based on the θ , dX and dY for comparing process.

Skin surface image, instead of vein image, was utilized during alignment since no general features that enable consistent registration were found in the finger vasculature. On the contrary, outlines and knuckle features on the finger surface were common and distinct to every person. Fig.3. shows the overall registration process.

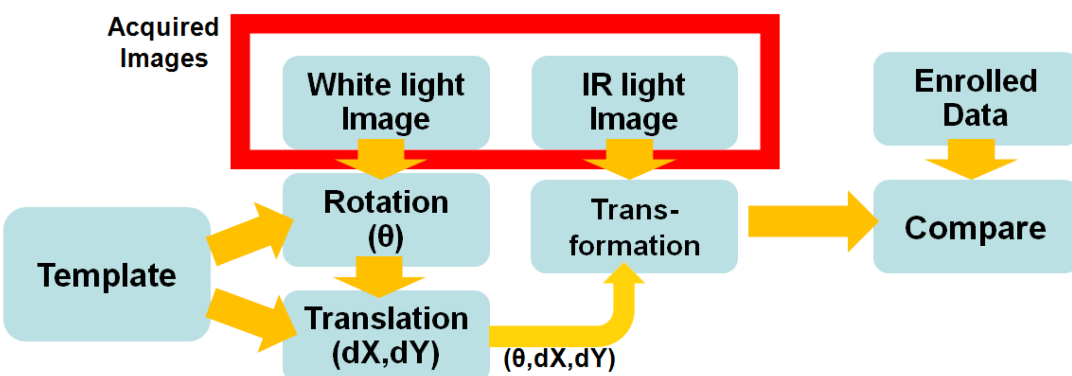

Fig. 3. Block diagram of algorithm. Two images were taken at once. Degrees of differences to the enrolled data were computed comparing surface image with template. Finger vein image was transformed using the calculated data for further comparison process.

2.3 Degree of rotation

A binary image mask was derived from skin surface image to eliminate the background. Pixels under the threshold level were converted to zero (black) and the others to one (white). The mask was placed over the original image leaving only the region of the finger. The rest of the finger was suppressed to black.

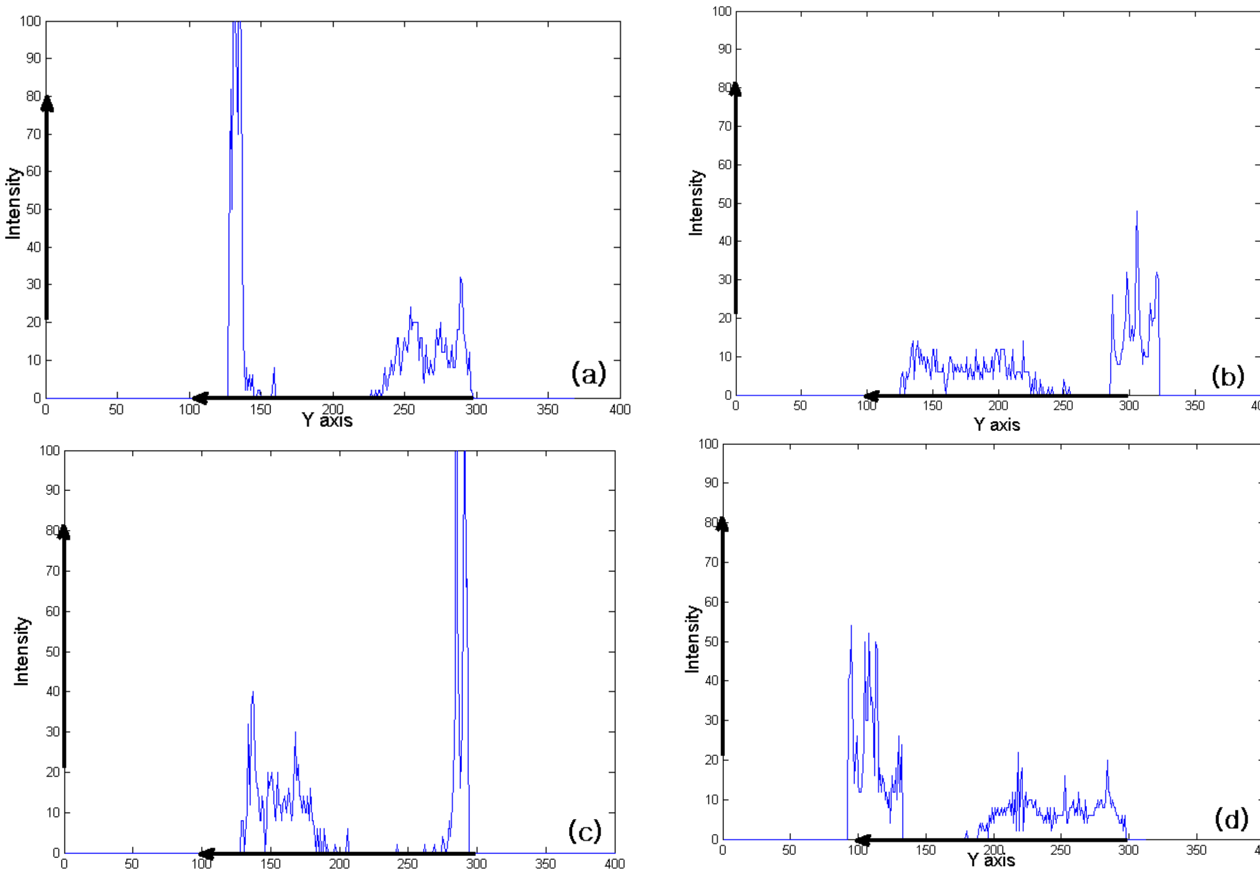

Fig. 4. Projected outline (a) of original data, (b) with 5 degrees, (c) 10 degrees, and (d) 5 degrees rotation clockwise. Each plot has two typical mountain-shaped curves but dispersion varies as image rotates. At 10 degrees rotation, lower mountain-shaped curve had minimum spatial dispersion value resulting in smallest degree of rotation.

The degree of the acquired image's rotation is determined based on the outline of the finger which was derived using the Sobel method. The outline is then rotated back and forth in a range of 60 degrees and projected onto the Y axis, stepping 1degree each time. The projected data at each projection showed two mountain-shaped curves along the axis mostly due to the two horizontal finger outlines but varied in shape (Fig.4). We defined degree of rotation as spatial dispersion of the lower mountain-shaped curve. The degree of rotation is plotted as the image is rotated and the image was fixed to the direction of minimum value (Fig.5).

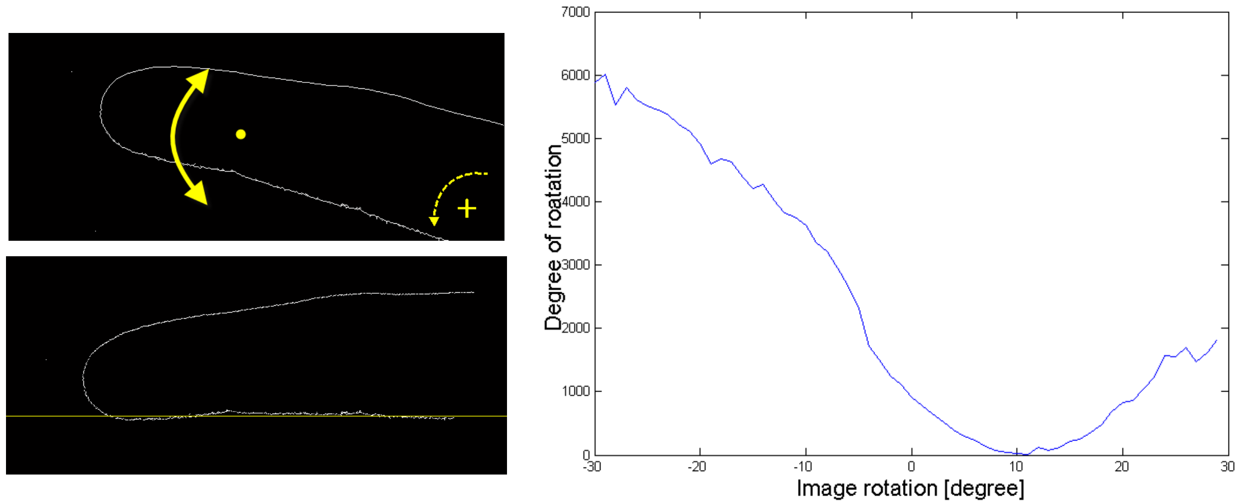

Fig. 5. Degree of rotation as image rotates about its center, and correction of direction of the minimum value.

2.4 Degree of translation

The degree of horizontal transformation was computed by wrinkles at the knuckles. Since wrinkles at this site are almost vertical and clear to find, they can serve as a horizontal criterion during registration. Adaptive histogram equalization was done on the skin surface image in order to increase contrast locally. The image was converted to black and white according to the threshold level. Small black dots were eliminated by image closing method.

The degree of vertical transformation was computed using the byproduct in the rotation compensation process. The mean position of the lower mountain-shaped curve at smallest degree of rotation served as a vertical criterion (Fig. 5). A control point located at the intersection of the first wrinkle and the bottom outline was decided (Fig.6).

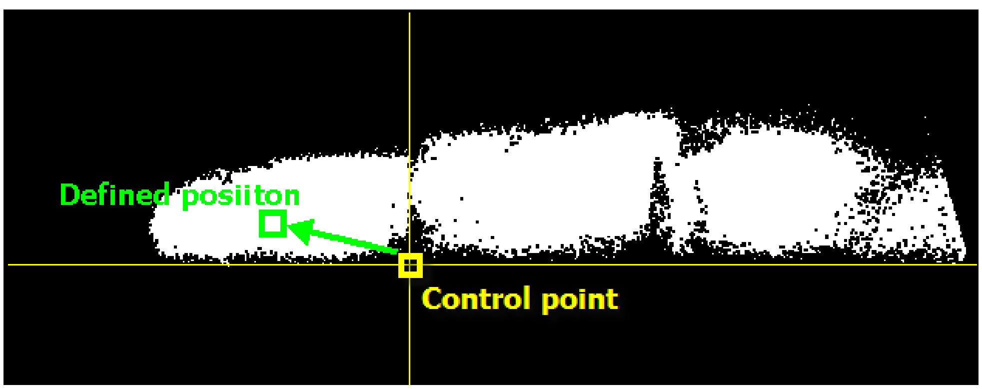

Fig. 6. Translational compensation. Control point located at the intersection of first wrinkle and the bottom outline was determined. Image was translated as the control point is moved to the defined template position.

The finger vein image was registered according to the equation below. Degrees of rotation and translation are denoted as dX, dY and θ respectively.

$$\begin{bmatrix} X' \\ Y' \\ 1 \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ dX & dY & 0 \end{bmatrix} \begin{bmatrix} X \\ Y \\ 1 \end{bmatrix} \tag{1}$$

Finger veins were traced for the evaluation step (Fig.7). Contrast of the registered vein image was enhanced by applying adaptive histogram equalization and then repeated line tracking method was performed to track vein sites[5].

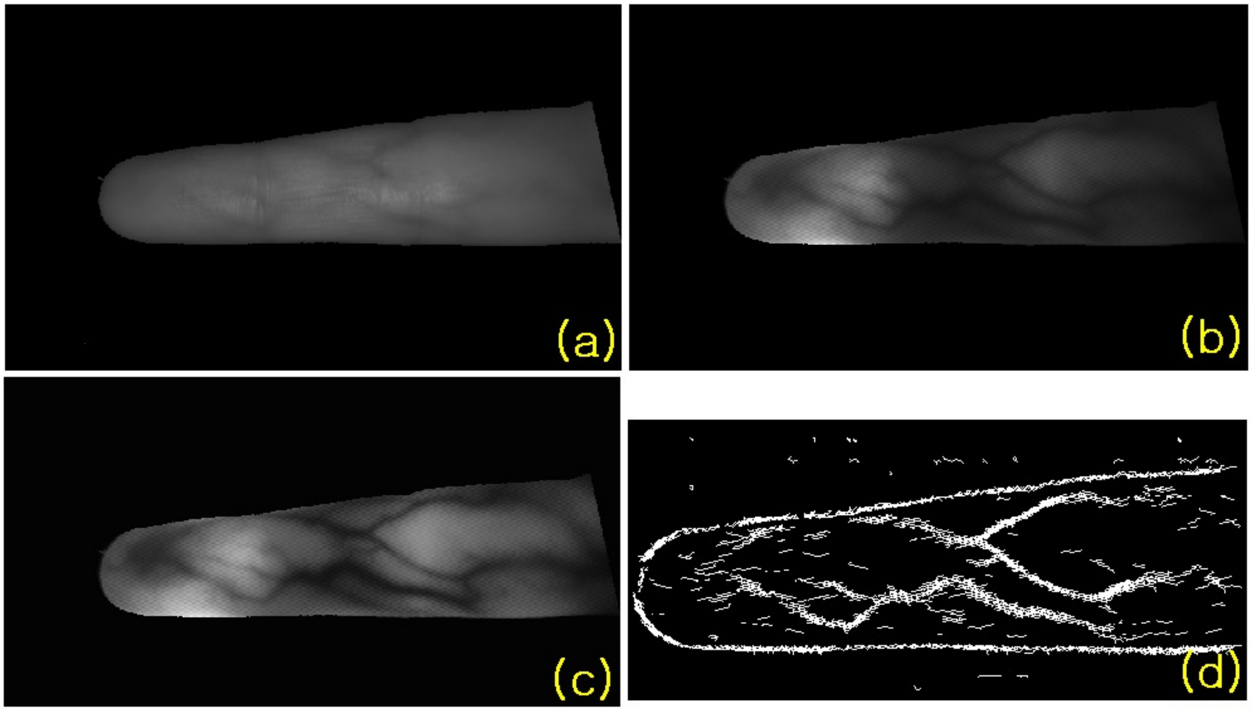

Fig. 7. Registered finger skin surface and vein images ((a) and (b)). After applying adaptive histogram equalization (c), finger veins were traced using repeated line tracking method(d).

3. RESULTS

3.1 Evaluation method

Our proposed image registration method was evaluated by making 6 comparisons based on the 8 captured images. Data were collected with intended rotation and translation to check validity of our algorithm. Each comparison was numbered as below (Fig.8). The first two comparisons were between two images from identical person but taken at different times and the rest of them were between different people. We expected high similarities on the same person and low ones on the different people.

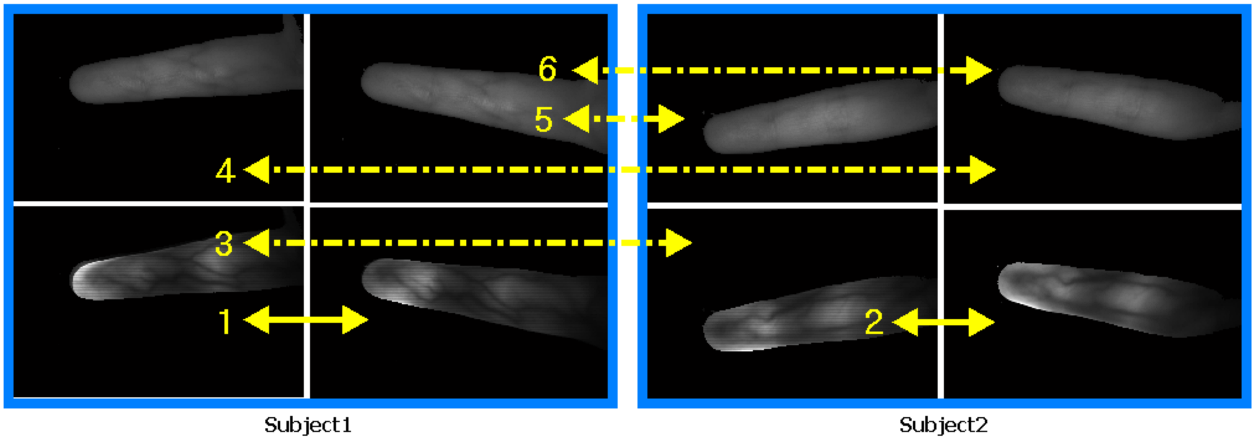

Fig. 8. Six comparisons to validate proposed image registration method were conducted. First two comparisons were between two images from same subjects but taken at the different time (solid lines) and rests of them were between different subjects (dashed lines). At each comparison, 4 images were involved as both skin surface image (1st row) and finger vein image (2nd row) are required.

3.2 Registration evaluation based on the series comparison

Each traced line in the vein image was dilated to decrease the sensitivity of comparison. Without dilation process, since the width of each line is only one pixel, very small differences between two images would result in low correlation even though there is a great similarity. At each comparison, one image was assumed to be an enrolled data and another one to be sampled data. By applying 'logical and operation' on both vein images, regions only common to both survived as white. Islands after operation were assumed to be pseudo veins thus removed applying image open and close methods in series.

Fig.9 shows the comparison process between same subjects (comparison 1 and 2 in Fig.8). Correlation values were computed as a ratio of number of white pixels in the traced images to the number of white pixels in the 'logically and operated image'.

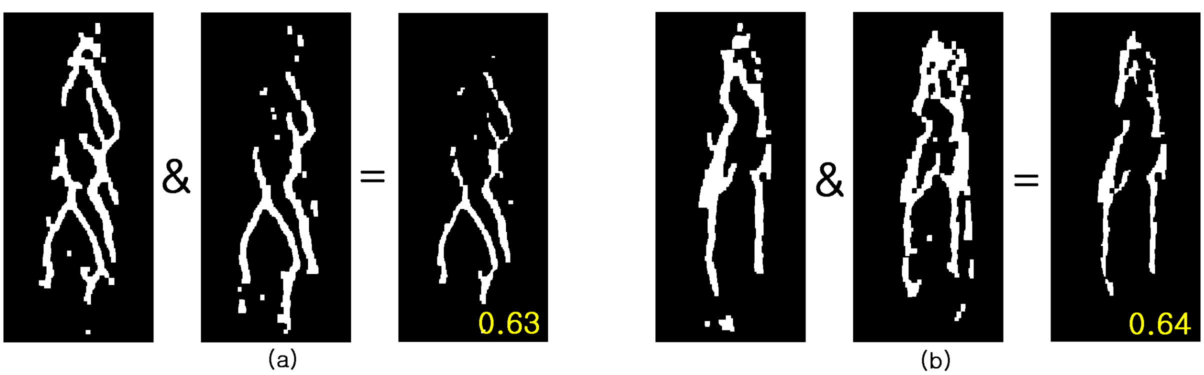

Fig. 9. Comparison process between same subjects. (a) Comparison between two images from subject 1 (b) from subject 2. Correlation value was calculated after logical and operation.

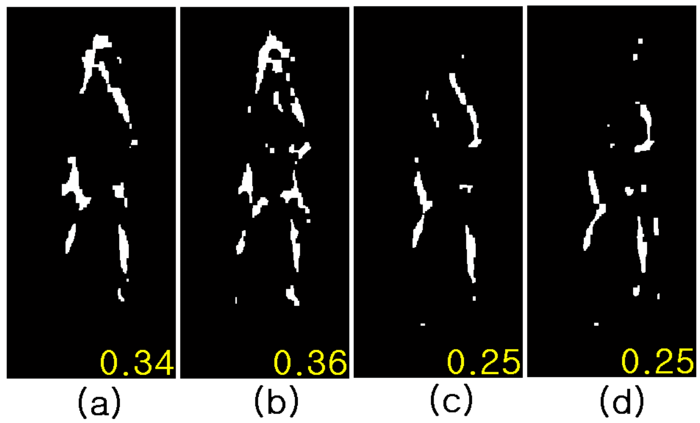

Fig. 10. Comparison results between dissimilar subjects denoted as dashed lines in fig.8. (a) Results of comparison 3, (b) comparison 4, (c) comparison 5 and (d) comparison 6 and corresponding similarity value. Only the fragments of veins were visible instead of intact lines.

4. CONCLUSIONS

A new method that corrects rotation and translation between sampled and enrolled finger images in the finger vein-based authentication system was proposed. A skin surface image was utilized instead of a finger vein image to increase the registration efficiency. Rotational transformation was compensated by using finger outline. The outline image was rotated back and forth to find the most horizontal direction with the dispersion degree of its Y-axis projected pattern. The translational transformation was compensated by determining the control point. The X coordinate of this point was decided as the first knuckle position and the wrinkle at this site served as a criterion. The Y coordinate was decided as the second middle point of the projected outline after rotational transformation was corrected. The control point was then moved to the predetermined position and the whole image underwent the same effect.

To validate our image registration method, six comparisons were conducted resulting in correlation values. ‘Logical and operation’ was applied to the two the vein-traced images and patterns only common to both images survived as white pixels.

Our algorithm showed a reasonable result within a small rotation and translation. Comparisons between identical subjects resulted in about twice as high similarity values to that of different subjects. Since cross points of both side’s patterns were also found as common, certain correlation values were recorded even when two different subjects were compared.

However, although it was not mentioned above, as degree of transformation increases between enrolled and acquired data, correlation values between identical subjects started to drop significantly. Images that were assumed to be almost identical resulted in low correlation value. Two major reasons had been discussed. The first one was lens distortion. Barrel distortion was observed when a plotting paper was viewed with a camera. As magnification was varied with distance from center of the image, registration could not be satisfactory. The second one was non-uniform illumination. Since infrared light sources were made of a series of LEDs, their intensity was discrete. Change of illumination patterns as the position of the finger changes greatly affected traced finger vein patterns. Patterns under high intensity ray regions were clear but those of under low intensity regions were dim.

Further study should be done to validate the quality of our method compared to the existing ones. Local geometric deformation effects based on lens distortion and non-uniform illumination will be corrected by software and hardware. We are expecting a great contribution to the finger vein based authentication field since our algorithm can decrease the number of image registration process using the global features common to every subjects.

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