Method for Correcting Palm Vein Pattern Image Rotation by Middle Finger Orientation Checking

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Abstract: This paper presents a method in correcting palm vein pattern image rotation for palm images which had suffered rotational variation during its image acquisition process. The method suggests the use of middle finger orientation checking, in performing rotation correction processing. The processing is tested over 1,200 palm images and implemented in Python environment. Based on images produced after the rotation correction processing, it is observed that the method had successfully corrects the hand image rotation. The rotation correction processing can be employed either as a checking mechanism for rotational variation, or to automatically correct the angle of rotation of palm images after its image acquisition process.

Key words: Image rotational variation, orientation correction processing, palm vein image.

1. Introduction

Contact-free imaging device usually suffers with rotational variation of images captured real-time [1]. For hand-based biometrics, specifically for palm vein pattern image capturing device, the images acquired are not robust against the rotational variation [2]. Hand image rotational variation is due to the inconsistencies of hand in maintaining a fix position during the acquisition process. Sometimes, the hand is by nature rotated to a certain angle subconsciously. Hand image that is aligned to the image axis is preferable to ensure standardization on the image acquired. This image standardization is important for accurate region-of-interest (ROI) extraction in palm vein pattern recognition purpose. Hence, to correct the orientation of hand images that suffer rotational variation, a method for correcting the image rotation is presented in this paper. This method can be added in the system design so that the correction processing is done automatically after the image acquisition process.

Figs. 1 and 2 show samples of palm image from the Chinese Academy of Sciences' Institute of Automation (CASIA) database [3]. The palm images shown are those acquired under the illumination of near infrared (NIR) light with peak wavelength of 850 nm. Palm images in Fig. 1 shows samples of images that are in the right orientation. The palm areas in Fig. 1 are observed to be in line to the image axis. Comparing images in Fig. 1 with those in Fig. 2, it can be seen that images in Fig. 2 suffer rotational variation during the image capturing process. This is because the palm areas are not in line to the image axis. Palm images shown in Fig. 2 are those that need rotation correction processing.

To perform the rotation correction processing, specific behaviors of hand orientation in the acquired palm images need to be clarified so that the information can be utilized in correcting the image rotation. This clarification is described in the next section. Section 3 presents the steps needed in performing the rotation correction. The implementation of the steps in algorithm development is explained in Section 4. Result, observation and performance of the rotation correction processing are given in Section 5. The last section in this paper summarizes major contribution and potential application areas of the proposed rotation correction method.

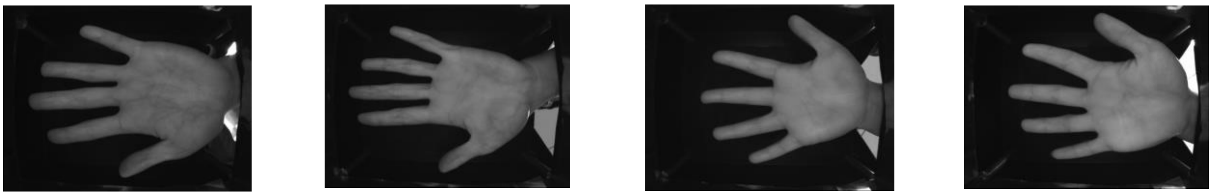

Fig. 1. Sample of palm images that are aligned to the image axis [3].

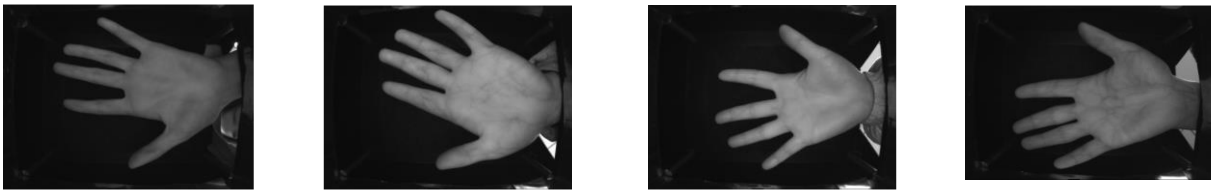

Fig. 2. Sample of palm images that are not aligned to the image axis [3].

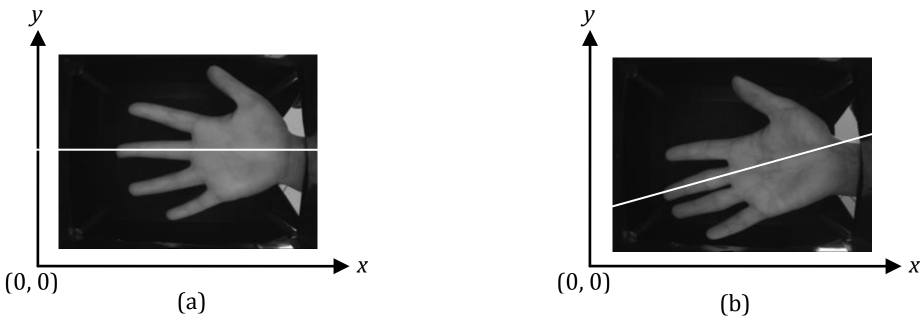

Fig. 3. Palm images mapped on Cartesian plane with straight white line drawn in parallel to the middle finger orientation. (a) Palm is in good orientation because the drawn line is in parallel to the *x*-axis. (b) Palm is not in good orientation because the drawn line is not in parallel to the *x*-axis.

2. Palm Vein Pattern Images

Samples of palm images used in this paper are obtained from the mentioned CASIA database [3]. The images are captured in controlled surrounding, but the hand is not guided during the acquisition process. The database presents a good collection of palm vein pattern images acquired using contract-free device. These images possess interesting observations that can be employed for rotation correction purpose, which are:

- A palm is in good orientation if the middle finger is in parallel to the *x*-axis when the palm image is mapped on the Cartesian plane. This observation is further clarified by Fig. 3. In the figure, 2 samples of palm images with different orientation are mapped on a Cartesian plane. In both sample images, a straight white line is drawn in parallel to the middle finger orientation to check whether it is in parallel to the *x*-axis or not. It is noted from Fig. 3 that only if the middle finger is in parallel to the *x*-axis that the palm image is in good orientation.
- If a palm is in good orientation on the Cartesian plane, the tip of middle finger has the smallest *x*-value

compared to the tip of other fingers. This observation is further illustrated in Fig. 4. In the figure, a palm silhouette is mapped on a Cartesian plane to compare the location of each fingertip. If the location of each fingertip is projected on the *x*-axis, it can be seen that the tip of middle finger has the smallest *x*-value if the palm is in good orientation.

Based on the two observations, palm images need to be rotated to the correct orientation if the middle finger is not aligned to the x-axis on Cartesian plane. The correction is done by rotating the palm image so that the middle finger is aligned to the x-axis after the rotation. As such, an angle of rotation needs to be determined to rotate the image. Processes involved in correcting the image rotation will be presented in the next section.

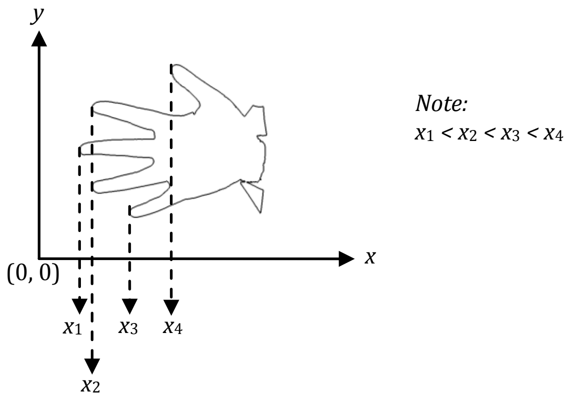

Fig. 4. Palm image mapped on Cartesian plane with projected value in the *x*-axis.

3. Rotation Correction Steps

The image rotation correction consists of four processes which are presented in Fig. 5. These processes are demonstrated by an illustration in Fig. 6 where the input image is obtained from the mentioned CASIA database [3]. Sample of the input image is shown in Fig. 6(a) and its corrected image after the processing is given in Fig. 6(e).

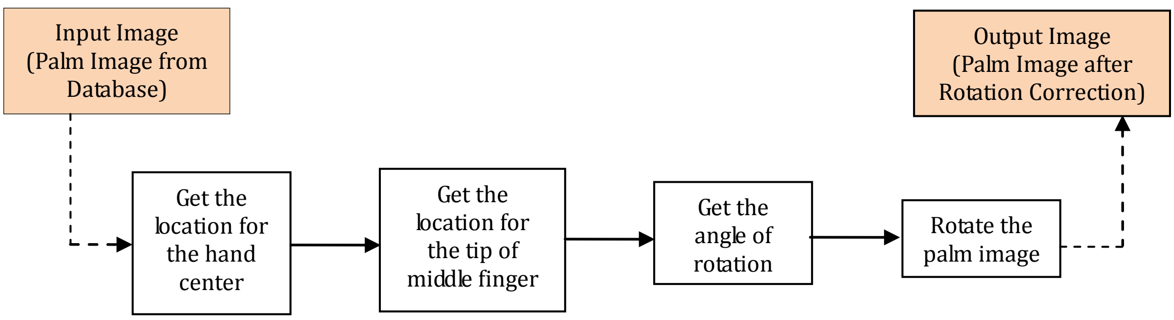

Fig. 5. Block diagram of processes involved in correcting the image rotation.

Referring to Fig. 5, the rotation correction processes start with the determination of location for hand center from the input image. The location of hand center is indicated by a red star in Fig. 6(b), obtained by treating the hand area as a big rectangular shape. The middle point of the wrapping rectangular shape is regarded as the hand center. This location acts as the base point in order to determine the angle of rotation. Next, the location of the tip for the middle finger is extracted. The tip of middle finger is marked with a red star in Fig. 6(c). By connecting this point to the base point found earlier, a line that estimates the middle finger orientation is obtained. The line is illustrated in Fig. 6(d) by the label *M*-line. A third location is then calculated, to get the angle of rotation. The third location is the *y*-axis intersection point when a line parallel to *x*-axis is drawn crossing the hand center obtained earlier. In Fig. 6(d), the third location is indicated by a blue star. Another line is drawn connecting the third location to the hand center, which is marked by the label *O*-line in Fig. 6(d). The angle of rotation is determined by measuring the angle of separation between the two lines (*M*-line and *O*-line). Using the angle of rotation obtained, the palm image is rotated counter-clockwise as illustrated by a flexed arrow in Fig. 6(d).

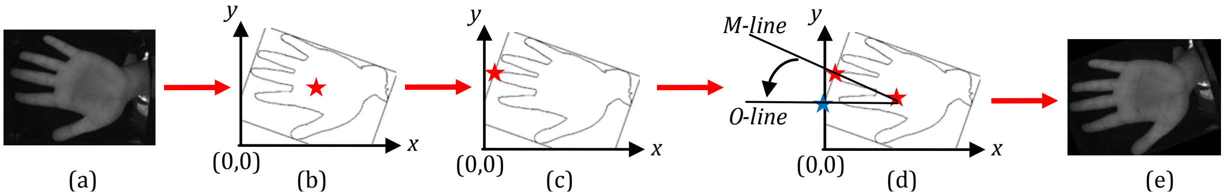

Fig. 6. Illustration of processes involved in correcting the image rotation. (a) Input image, (b) Location of hand center marked in red star, (c) Location of tip of middle finger marked in red star, (d) Two lines connecting the three points to get the angle of rotation, and (e) Output image after the rotation correction processing.

4. Algorithm Implementation

The rotation correction steps are implemented in Python 2.7.8 environment with the help of OpenCV module as image processing tool [4]. Outcomes after the algorithm implementation are given in Fig. 7. To get the location of hand center, input image from the database is first binarized using Otsu thresholding method [5] to extract the hand area from the image. Resulted image after the binarization process is a black-and-white image where the white region indicates the hand area whilst the black region is its background. The black-and-white image is shown in Fig. 7(a). A rectangular shape is then wrapped around the detected hand area using the function minAreaRect() from OpenCV module, to determine the hand center. The hand center extracted is the center point of the rectangular shape represented by location (*x*_center, *y*_center) in Fig. 7(d). The binarized hand area wrapped by the rectangular shape is given in Fig. 7(b).

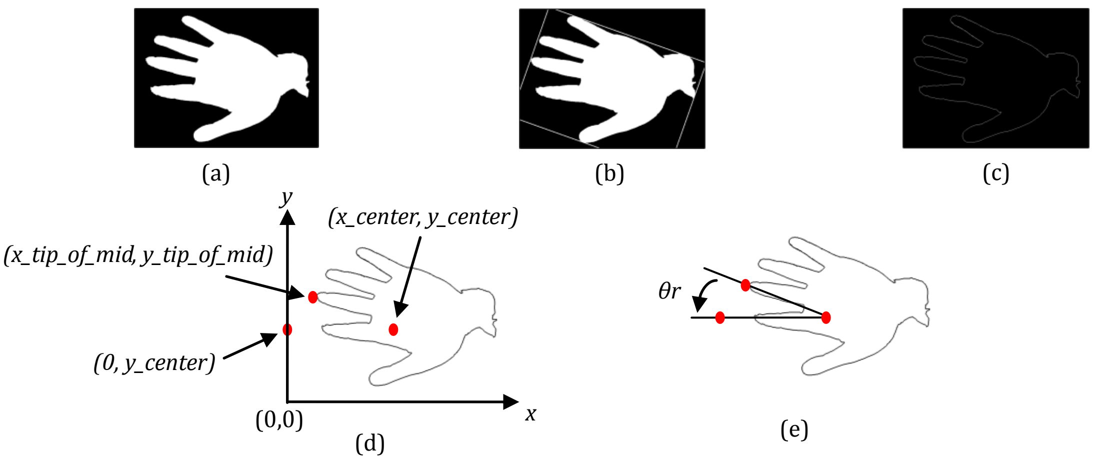

Fig. 7. Outcomes of the algorithm implementation. (a) Palm image after binarization, (b) Binarized palm area wrapped by a rectangular shape, (c) Hand boundaries detected by Laplacian filtering, (d) Locations of three points in the palm image marked by red circles, and (e) Angle of rotation mapped on the palm image based on the three points location.

The tip of middle finger is located by extracting the binarized hand boundary using OpenCV Laplacian filtering function, Laplacian(). Output image after the Laplacian filtering is shown in Fig. 7(c). The tip of middle finger location is the hand boundary point with the minimum *x*-value. With respect to the Cartesian plane, the tip of middle finger point is represented by location (*x*_tip_of_mid, *y*_tip_of_mid).

The third location is a *y*-axis intersection point, given by location (0, *y*_center). The three points location are as illustrated in Fig. 7(d). The angle of rotation is determined from these three points (*x*_tip_of_mid, *y*_tip_of_mid), (*x*_center, *y*_center), and (0, *y*_center) using the function math.atan2() from Python Numpy *math* module. The angle is labeled in Fig. 7(e) as θr. Palm image is then rotated counter-clockwise using OpenCV warpAffine() function according to the value of θr.

5. Results and Discussion

The rotation correction processing is tested over palm images obtained from the CASIA database [3] that are acquired using the illumination of NIR light with peak wavelength of 850 nm. Such palm images contain palm vein information that can be used for biometric recognition purpose [6]. The database consists of 100 subjects for each right hand and left hand palms. Each subject has 6 versions of palm images, which makes the total images used for the testing to be 1,200 palm images (= 100 subjects × 2 hand-sides × 6 image versions each). Summary of the palm image database is given in Table 1.

Table 1. Number of Images Used for Algorithm Testing

Palm Vein Database	Image Versions					
	Version 1	Version 2	Version 3	Version 4	Version 5	Version 6
Right Hand	100	100	100	100	100	100
Left Hand	100	100	100	100	100	100

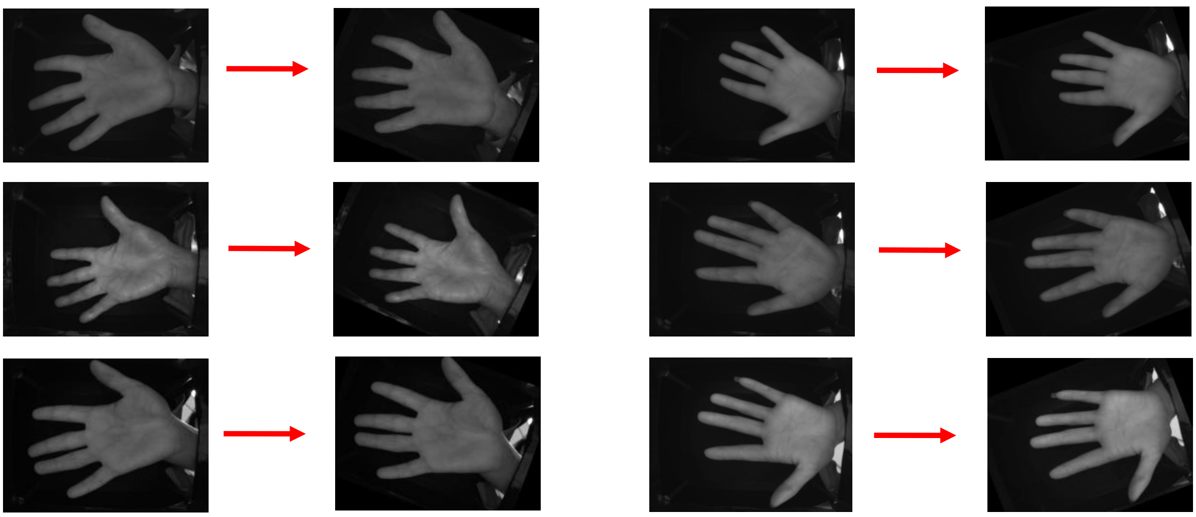

Fig. 8. Samples of successfully corrected palm vein images before and after the rotation correction processing.

Some of the result after the rotation correction processing is given in Fig. 8. The direction of arrows in Fig. 8 show the palm image transformation, before to after the rotation correction processing. Based on the images, it can be seen that the rotation correction processing had successfully corrected the orientation of palm in the images. Still, there are some images that are incorrectly rotated by the algorithm. The incorrectly rotated images are due to the hand orientation itself where the hand is slightly slanted during the acquisition process, resulted to incorrectly identified point as the tip of middle finger. For a slanted hand, the minimum *x*-value point extracted from the hand boundary location does not necessarily point to the tip of middle finger location. Rather, the location extracted may belong to either the tip of index finger or the tip of ring finger. Samples of slanted palm images for such cases are given in Fig. 9. In Fig. 9, the minimum *x*-value projected on the Cartesian plane belongs to the tip of index finger.

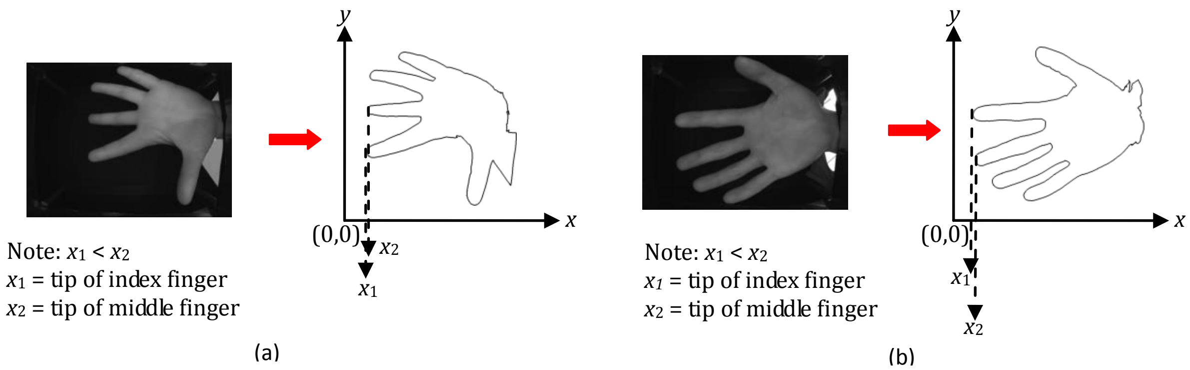

Fig. 9. Hand orientation that are slightly slanted during its image acquisition process. Note that the smallest *x*-value in the hand boundary does not belong to the tip of middle finger.

The rate of errors produced, such that the image is not correctly rotated after the rotation correction processing is summarized in Table 2. Based on the table, it seems that left hand images have higher rate of errors compared to right hand images. However, the highest rate of errors recorded is 0.15 %, which is still significantly low. This suggests that the rotation correction processing method has promising ability to successfully correct palm vein pattern image rotation.

Table 2. Rate of Errors in Rotation Correction Processing

Palm Vein Database	Image Versions					
	Version 1	Version 2	Version 3	Version 4	Version 5	Version 6
Right Hand	0.02 %	0.06 %	0.06 %	0.05 %	0.06 %	0.07 %
Left Hand	0.11 %	0.10 %	0.14 %	0.15 %	0.13 %	0.10 %

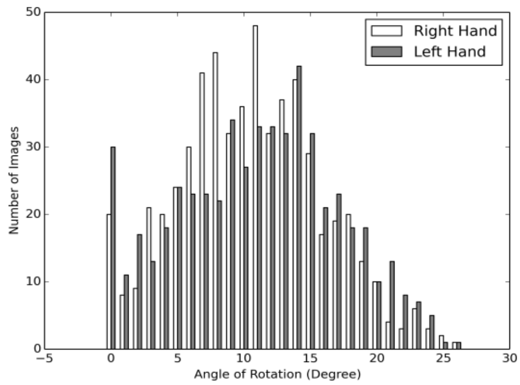

Fig. 10. Number of images for each angle of rotation.

The angle of rotation obtained from the rotation correction processing is as compiled in Fig. 10. The angle compiled in Fig. 10 combines all images used in the testing and only included the correctly identified angle of rotation. Images with 0 degree angle of rotation suggest that the hand acquired is in the correct orientation. Still, based on the empirical study, images with angle of rotation between 0 to 5 degree do not need to be rotated because the images produced after the rotation does not show significant differences in the hand orientation. The maximum angle of rotation recorded is 26 degree, which suggests that it is the largest angle a hand can be diverted from its correct orientation in general.

6. Conclusion

The result of the rotation correction processing shows that the hand orientation had been successfully corrected. Besides correcting the hand orientation, the rotation correction processing can be used as a checking mechanism in determining the angle by which the hand image had been diverted from its correct orientation. It can also be used to check if the low performance of a palm vein biometric recognition is mainly due to the hand orientation during the image acquisition process. For a fast and high capability acquisition system, the rotation correction processing can give a real-time automatic feedback for users to attempt another image acquisition process with adjusted hand orientation.

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