Hand Surface as Biometric Identifier

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Abstract. Recognition of persons based on biometric features is the most discussed question. This paper investigates a new approach how to recognize people using 3D hand geometry. Currently, the only systems available in the market are HandKey and HandPunch in different variations which use hand geometry as a feature for recognition. These systems use only two-dimensional contour of the hand, which limits the final number of users on hundreds. Therefore, we have decided to construct device based on three-dimensional hand recognition. This system uses the whole hand surface to gather the biometric properties. Projector is used as a source of structured light and CCD camera capture the image. Paper is focused on the hand reconstruction and feature extraction.

Keywords: Recognition of persons, hand geometry, surface reconstruction, features extraction.

1 Introduction

The hand recognition system uses the unique human hand geometry for the person verification. The most common technologies are based on the fingerprints of humans and their uniqueness in the population. However, one of the most widely used technologies for human recognition is the hand geometry. The physical dimensions of human hand geometry contain information that is capable of authenticating the identity of an individual.

The current solutions of the devices in the market are based on the hand contour recognition only. An example of such device is Handkey II [1], which uses only 16 measures to verify the person. The disadvantage of this system is its low rate of biometric entropy. The idea is to use the whole hand surface to define unique measures.

Often, users are required to place their hand on flat surface fitted with pegs to minimize variations in the hand position. In general, the use of pegs introduces three problems. First, pegs almost definitely deform the shape of the hand. Second, pegs may cause problems with hand reconstruction, because pegs will cover lighted finger in particular segments. Third, even though the pegs are fixed, the fingers may be placed differently at different instants. Therefore in our case we are using only pad without guiding pegs. The whole hand has to be placed on a flat surface and fingers have to be splayed correctly.

The contribution of this paper can be summarized as follows. The paper begins with the detailed description of our method, especially image acquisition and image processing. The results of 3D hand reconstruction experiments are presented. Last part includes feature extraction method. In the last section some conclusion is stated and further development is outlined.

2 Image processing

Our method is based on the part of the patent [2] we got in 2010. The whole hand surface is used for the verification/identification of the user. The process starts with image acquisition using the CCD camera and the line projector. The certain sequence of images is captured including the image with the projected lines. The image processing follows and it includes the line extraction and its indexing, which has to be done precisely to achieve proper surface reconstruction. After image processing the surface points are calculated. From their position and relationship the features for templates are extracted. At the end, the template of the captured image is compared with template stored in the database to verify the user. The above mentioned phases are described in detail in following subsections.

2.1 Image Acquisition

Two main approaches are used in practice for 3D surface reconstruction: stereovision and structured light based reconstruction. Structured light is more convenient for hand reconstruction. The requirements of the capturing scene are as follows. Object is captured from relatively small distance. External source of light can be used and the accuracy of the reconstructed hand model should be as precise as possible.

2.1.1 Structured Light

Our requirements for reconstruction are high accuracy and especially short capturing time. We would like to reconstruct complete hand model using only one or a few scene images. Therefore the light pattern should consist of several lines. The obtained information is in this case identical with progressive line scanning; however, a question with precise line indexing occurs. It is impossible to distinguish where the line continues in places of surface discontinuity. That is why there must be some additional information, which helps us to determine precise index of the line within the image. This information can be provided using multiple colors, widths or patterns within projected lines. Projector is used as a source of structured light.

2.1.2 Light Color

The combination of multiple colors can help with the problem of line indexing. If we project the strips of different colors in the appropriate order, we can reduce the probability of wrong determination of the line index based on color of nearest lines (de Bruijn sequences [3]). Therefore, we have decided to use combination of green and blue lines.

2.2 Stripes extracting

This section describes how the strips are extracted and indexed. Scene is captured by high resolution color camera. Projected pattern consists of 25 green and 25 blue lines. Image processing algorithm works with 4 images:

- Image of scene without hand fully illuminated by white light.
- Image of the hand fully illuminated by white light.
- Image of the hand without external illumination.
- Image of the hand illuminated by structured light pattern.

The image processing algorithm described in pseudo code:

1. Compute hand mask M.
   - Subtract fully illuminated images of hand and background:
   - Obtain mask by consequent Thresholding.
2. Extract color strips.
   - Subtract images of the hand without illumination and with structured light illumination.
   - Convert subtracted image to *HSV* color model, then extract pixels with intensity in specific range from H(Hue) channel and use tresholding T
3. Index color strips.

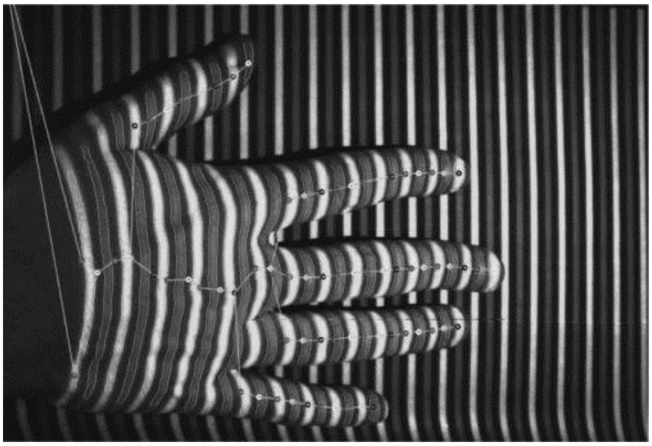

Fig. 1. Indexing of lines.

One strip can be divided to several blobs in the processed image, therefore all blobs are organized to graph structure, which helps with determination of proper strip blobs. Each node of the graph represents one blob. Nodes are grouped to layers according to strip they belong to. Graph is created by processing image with extracted green and blue strips from left to right. Strip index is then easily computed by graph structure evaluation (See Fig. 1).

3 3D Hand Reconstruction

After proper line indexing the surface of the hand can be calculated from the knowledge of the camera and the line projector position. The positions can be directly measured or they can be pre-calculated as a part of the system calibration.

The surface reconstruction process starts with the lines generating leaded from the vanishing point. For each line the interception points with base strips and hand strips are computed. Then the virtual ray is created started from the camera lead to the certain hand strip point. The ray base point, projector position and the centre point of the projector in the image (centre of the trapezoid) form a plane. The points on the hand surface are then calculated as the intersection between the camera ray and the given plane. The resulting hand surface is shown in Fig. 2.

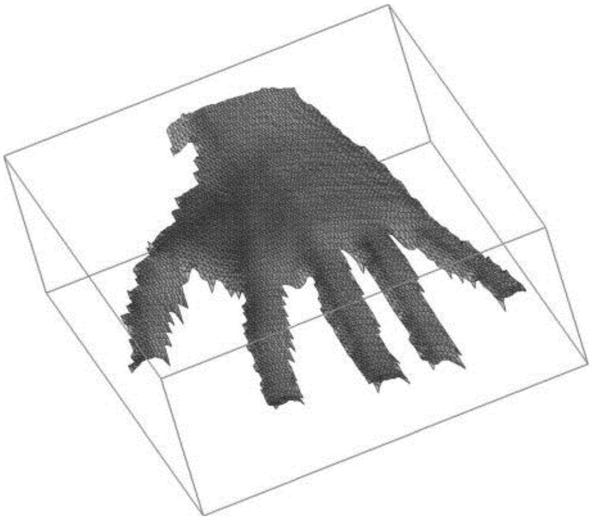

Fig. 2. The example of hand surface reconstruction.

The advantage of the method is that the resolution of the calculated points can be done arbitrarily in the direction perpendicular to the projected lines.

4 **Feature** extraction

There are several approaches how to extract features from the 3D model. For feature extraction and comparison, there are widely used finger width, height and length measurements in particular segments. These measurements are used for 2D hand geometry, but do not exploit all of possible biometric entropy from the hand. Therefore there are used others methods for feature extraction which are based on hand surface. Methods based on surface can get better matching score than methods based only on 2D feature extraction, because we can combine 2D and 3D hand geometry features [4].

Some of techniques for personal verification, based on 3D hand geometry features, have been proposed in the literature [4], [5], [6]. All of these techniques are focused only on feature extraction from fingers without a thumb. The thumb is excluded since its measurements are mostly unreliable. Mean curvature, unit normal vector, shape index and 3D mesh model are mostly used as a feature for extraction.

In our case, we use the whole hand surface to define unique measures. It increase rate of biometric entropy, because we can combine back of the hand and finger surface. Feature extraction method based on 3D mesh model is described in following subsections.

4.1 Feature extraction based on 3D mesh model

This method can find an inspiration in face recognition based on 3D mesh model [7], where mesh model precisely reflects the geometric features of the hand. Mesh model can be easily extracted from the hand surface reconstruction and used for the following comparison. Our mesh model consists of the collection of vertices and facets. The verification and recognition is realized by comparing the global distance between two mesh models, which can avoid the influence of the local noise.

To realize the matching, it is important to find a distance measure which can quantify the difference between two 3D meshes. Matching progress includes two phases: regulating the models to the same position and calculating the difference between two models.

Each of the separate fingers has a rotation left/right. To realize rotation, it is important to get a direction of the finger. We can use hand mask and get width of the finger in particular segments (top, middle, bottom). Than we can get direction of the finger, because we can calculate midpoint of each width measurement and create imaginary line through these points. Last step is to rotate this mesh model until the imaginary line will be parallel with *y-axis.*

Now, we can calculate the distance measure *diffbetween* two models with the sum of all distances along *z-axis* from the nodes of one model to the facets of another model. This situation is illustrated in Fig. 3. Calculation of the distance measure is described as follows:

$$diff = \sum_{i=1}^{n} d_z(u_i), \qquad (1)$$

where n is the number of the mesh nodes and $d_z(u)$ is the distance along *z-axis* of the node u_i.

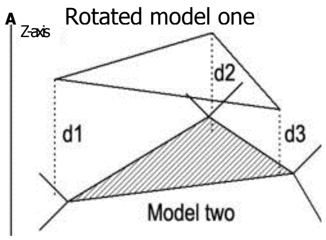

Fig. 3. Distance measure of two models.

The smaller value means higher similarity of both models. Match scores generated for four fingers and back of the hand are then averaged to obtain the final matching score of two models.

5 Conclusion

This paper has presented a new approach of the human recognition using 3D hand geometry. The proposed system uses projector and CCD camera for image acquisition. This system has one great advantage; it is not needed to know explicit information about projector and camera position. This position is automatically calculated using the triangulation method.

We have collected the database of the users that count over 150 volunteers with both hands captured 5 times and thus more than 750 hand images are available. As a next step we will focus on the testing of features extraction.

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