PASSTHROUGH SCANNER FOR RECONSTRUCTION OF HUMAN HAND SURFACE

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Abstract: In this article, a novel approach for 3D scanning of human hand surface is presented. Instead of using a static scene, the user is required to pass his hand through the scene under laser illumination in order to obtain the 3D model of the hand.

Keywords: surface reconstruction, passthrough scanner, 3D scanner, 3D hand, hand biometrics, hand geometry

1 INTRODUCTION

Nowadays a lot of 3D acquisition devices can be found on the market. However, only few of them are suitable for use in biometric systems. The problem is usually the price. The very precise acquistion devices are usually very expensive. Because of that, considering industrial biometric systems, cheaper sensors have to be used in order to keep the final price as low as possible. Unfortunately, those cheaper sensors do not have to be always precise enough for the task of biometric identification. This still leaves an open space for future development in the field of the 3D acquistion devices. For 3D hand biometric systems, one solution might be to require user to move the hand in front of the sensor in order to be captured and identified.

2 PASSTHROUGH 3D HAND SURFACE RECONSTRUCTION

Instead of using static scene and complex structured light pattern, only one laser creating single straight line illuminates the scene. This approach is identical to using laser scanner. To reconstruct the model of the whole hand surface, it is assumed that the user will move his hand through the scene. From each single image of the captured sequence, one profile line of the hand surface is reconstructed. At the end, all the profile lines are registered and put together to create the final hand model.

2.1 ACQUISITION DEVICE

A simple device was created for the acquisition of the image sequence. It consists of 10 mW laser with the wavelength of 532 nm. It is a point laser mounted with an optical lens which creates single straight line. For easier image preprocessing phase and in order to allow usage of the device during night, it is also equipped with 3 green LEDs that are used during the capture. Lasers and LEDs are driven by TI MSP430 controller that is connected via USB connection to a computer. Communication between the controller and computer is done using virtual serial port. For the image capture, Microsoft Lifecam HD 3000 webcam is used.

2.2 SURFACE RECONSTRUCTION

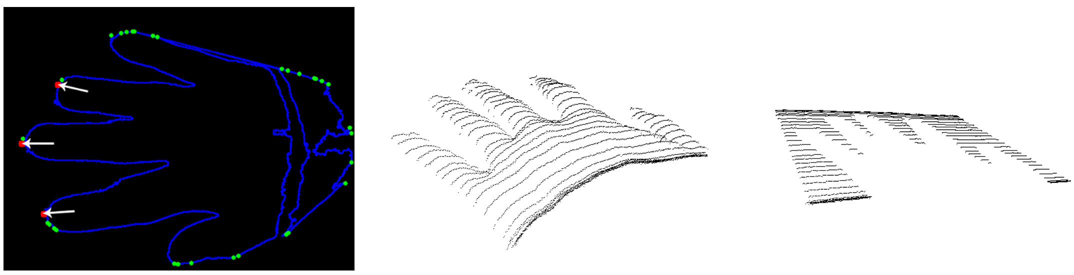
The reconstruction process consists of few steps. First of all, the images from the captured sequence have to be aligned so that the laser lines on the images form the hand surface. Subsequently, 3D information is obtained using triangulation. The 3D surface is processed in order to remove the background and denoise the final data at the end.

Image alignment begins with detection of the fingertips. In each image, contours are detected. Few biggest contours are selected and merged together into one, which is assumed to be the hand contour. The hand contour is then approximated by convex hull [1]. Convex hull points are analyzed using their x- and y-coordinates in order to find the fingertips of index, middle and ring finger as shown in fig. 1(a).

As the images are aligned, 3D information is obtained using already mentioned **triangulation** [2] method. In order to be able to perform triangulation, acquistion device has to be calibrated first. This is done using chessboard pattern and OpenCV [4] library. During the reconstruction, alignment information are used in order to put the 3D profile lines together to form a hand surface model.

After the scene surface 3D data is obtained, **postprocessing** begins. First of all, scene background is removed from the model. This is done easily using RANSAC [3] plane fitting (see fig. 1(b), 1(c)). Background removal in the postprocessing phase is much more robust than background removal during image processing phase, because it is not influenced by light conditions, etc. Next postprocessing step is denoising, which is achieved using statistical distribution of the distances between a point and its neighbours. Points that do not satisfy certain distance criterion are marked as outliers and removed from the model. Last postprocessing step is downsampling of the acquired point cloud using uniform grid.

In order to implement all the methods mentioned above, OpenCV library was used for image processing and PCL [3] library for 3D model post processing.



(a) (b) (c)

Figure 1: (a) Red dots marks detected fingertips; (b) Hand segmented from the reconstructed scene; (c) Background segmented from the reconstructed scene.

3 RESULTS

Evaluation of the proposed acquisition system was done having multiple models reconstructed using this system.

In order to compare the models, they were first aligned using Iterative Closes Point algorithm [3]. After the alignment, the distance between the models is computed using the following equation

$$distance = \frac{\sum_{i=1}^{n}(model_1[i] - nearestNeighbor(model_1[i], model_2))^2}{n}, \quad (1)$$

where $model_1$ and $model_2$ are the models, function $nearestNeighbor(model_1[i], model_2)$ is searching the nearest neighbor of the i-th point on the first model in the second model and n is the number of points in the first model.

If comparison of the same models is done, distance should be ideally 0. In practice, that is never true, but if the distance is small enough, it can be assumed that the models are the same.

Different scenarios were considered during the evaluation. Acquisition scenarios are divided into few groups, namely fast passthrough (approx. 18 images), normal passthrough (approx. 30 images), slow passthrough (approx. 70 images), wrong position of the hand, acquisition of a different hand. The results of the comparison are shown in table 1.

Table 1: Comparison of the model distances. Reference model is the one obtained by first normal acquistiion. The distance is in relative units.

Acquisition	slow	normal	fast	wrong position	different hand
1	0.0985	0.0000	0.2615	2.3058	0.5969
2	0.0693	0.0910	0.4057	1.5818	0.5810
3	0.0597	0.0848	0.5603	4.95873	0.8473

4 CONCLUSION

One of the possibile solutions to the problem of having affordable 3D acquisition device that is precise enough was proposed in this article. It allows to use very cheap components, however the scene is not static during the acquistion. The user is required to move his hand in front of the scanner. By combining reconstruction from multiple images, model that is precise enough can be obtained using those cheap components. The possible future improvements are mainly better alignment of the profile lines, which would result in better precision of the reconstruction and also performing the reconstruction using camera with higher FPS.

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