RECONSTRUCTION OF HUMAN HAND SURFACE FOR THE PURPOSE OF BIOMETRIC RECOGNITION OF PEOPLE

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Abstract: New approach to the 3D reconstruction of human hand surface is presented. Lasers combined with diffraction gratings are used to generate structured light pattern. Obtaining reference images during the device calibration, it is possible to perform a surface reconstruction having single image captured for each laser later on.

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

1 INTRODUCTION

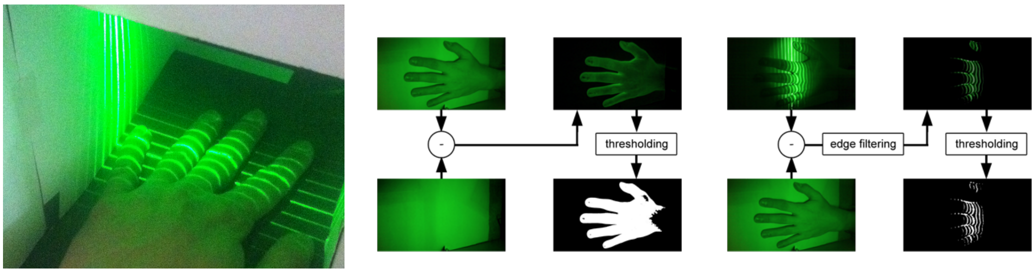
Biometrics developed quickly during the last decade and it has taken its place in the field of security systems. Yet there are still biometric features that were not explored deeply and may posses sufficient amount of information. Those features might become important in the future especially in cases, where others cannot be used because of some limitations that come from the environment the device is to be used at. Secondly, new biometric features could be used in the verification process, speaking about 3D hand geometry for example, it could be combined with fingerprint or finger vein technologies resulting in much stronger security system.

2 3D HAND SURFACE RECONSTRUCTION

3D hand geometry mentioned above is one of the features that were not explored deeply so far. Nevertheless it has quite big potential and it definitely worths experimenting with. Nowadays, only 2D hand geometry identification systems, such as Handkey [4], exists in the industry. In the following subsections, one of the possible approaches to the 3D hand surface reconstruction for the purpose of biometric recognition of people is proposed.

2.1 DEVICE DESIGN

Device itself consists of fours 10 mW lasers with the wavelength of 532nm, each laser has an optics mounted that creates a single line pattern, this single line is diffracted into multiple equally spaced parallel lines. For these 4 lasers, it is sufficient to have 2 diffraction gratins of size 50×50mm, one for each couple of lasers. These diffraction gratings are placed in a certain distance from the backplane to create the pattern with the desired line spacing. To help the image processing and to allow the device to be used also during the night, device also contains 3 green LEDs that enlights the scene in a particular moments during the capture. Lasers and LEDs are controlled via TI MSP430 controller powered by USB connection to a computer. Communication between the controller and computer is done via virtual serial port. To capture the scene, device contains two Microsoft Lifecam HD 3000 webcams, one observing the scene from the left, second from the right, both placed at a certain angle with the backplane. Laser stripe projection example is in Fig. 1(a).



(a) (b) (c)

Figure 1: (a) Example of the laser stripe projection; (b) Hand detection processing pipeline; (c) Stripe detection processing pipeline.

2.2 Image processing

Before the device can be used, it has to be calibrated. To calibrate the cameras, simple method from OpenCV library is used [3]. The calibration of the lasers is done using diffraction theory, considering the diffraction equation [2]. The description of the calibration process is not part of this article, for further details, please refer to [1]. During calibration process, so called reference images, that are used later during image processing, are captured.

Thanks to the device design and the capture process, it is sufficient for the hand detection to use a simple scheme from Fig. 1(b). In both input images, the scene is illuminated by the previously mentioned LEDs. The input image without hand present in the scene is one of the reference images. As the last step, morphological operations are used to create the final hand mask.

Stripe detection is actually done 4 times, once for each laser, because a separate image is generated for all of them. It uses the scheme simillar to the one presented in Fig. 1(b) with slight modifications. First modification is that the vertical edges are detected by convolving the image with the Robinson edge detection kernel [1]. After that, considering only the G (green) channel, adaptive thresholding is applied in order to filter the stripes. At the end, median blur is applied to remove some noisy pixels or small regions from the resulting image.

Algorithm 1 Indexing of the stripes in the image

```
for all columns in the image do
  for all points in the current column do
    if point belongs to a stripe then
      FloodFill() {Match whole stripe area}
      if surface too small then
        Skip it {Probably not a stripe}
      end if{Otherwise it is probably a stripe}
      for all rows in the stripe area do
        Find stripe area edge point
      end for
      Make stripe from the found edge points
      Add stripe to the tree {Indices are assigned according to the hierarchy}
    end if
  end for
end for
```

Stripe indexing is done using the Algorithm 1. Error correction process is run on the output of stripe indexing algorithm to eliminate some errors. The detailed description of these algorithms is in [1].

Surface reconstruction is done using the well known triangulation principle, for further reading please refer to [1].

3 RESULTS

In order to perform an evaluation of the proposed approach, simple objects of known proportions were captured and deviations from the real values were computed for each of them. This way, it could be easily computed how precise the reconstruction process is. As the metric, the RMSE was chosen. Table 1 shows some testing results for boxes of different proportions. Reconstruction results from the different lasers differs, this is due to the constructed device geometry, which is not very precise, and has to be further improved. Since the device is to be used as a biometric system, tests against intraclass variability were done also. The result was that the method is quite stable as stated in [1].

Table 1: Surface reconstruction *RMSE*(Root Mean Squared Error) values

	Box 13.5mm		Box 25.5mm	
Model	NRMSE	RMSE	NRMSE	RMSE
Laser 0	0.1671	1.2816	0.2190	1.4558
Laser 1	0.1144	0.6912	0.1993	0.7977
Laser 2	0.1525	0.3743	0.1764	0.4317
Merged	0.1155	0.9114	0.1576	1.0474

4 CONCLUSION

New approach to the hand surface 3D reconstruction was presented. The goal was to keep the price low, thus cheap diffraction gratings and lasers in combinations with ordinary webcams were used. Future work is to combine the results from all 4 lasers into the one complete hand model. Also, the calibration and stripe indexing approaches have to be revised. The results are promising, but still, a lot of additional work has to be done to make the solution far better and usable in the field.

ACKNOWLEDGEMENT

This research has been realized under the support of the following grants: *“Security-Oriented Research in Information Technology“ - MSM0021630528 (CZ), ”Advanced secured, reliable and adaptive IT“ FIT-S-11-1 (CZ) and ”The IT4Innovations Centre of Excellence“ - IT4I-CZ 1.05/1.1.00/02.0070 (CZ).*

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