Photogrammetric System for Frontal Face Image Acquisition

Vladimir A. Knyaz
State Research Institute of Aviation System (GosNIIAS)
Moscow, Russia
knyaz@gosniias.ru

Abstract

An often reason for face recognition system failure is image changing because of head rotation. The way for improving face recognition is some kind of image transformation, for example, to some given head position. Unfortunately image transformation itself (without using information about spatial geometry of a face) in most cases does not provide adequate synthetic photograph and results in low reliability of recognition.

The accurate way to obtain a proper image of a rotated face is to use 3D model of the face for image transformation. Then the resulting synthetic photograph can be obtained correctly for any required image orientation.

This paper presents the approach for correct face image transformation for recognizing purposes, the 3D face model capturing system, the results and discussion of the results of the system applying.

Keywords: *3D reconstruction, close-range photogrammetry, image transformation, calibration.*

1. INTRODUCTION

Last years the number of applications working with images of a human face is noticeably increased. Face processing and face recognition systems are widely used in such areas of computer vision as recognition, medical imaging, video communications etc. The important problem in face recognition is to match images of the same face obtained from different points of view and in different capturing conditions.

The most number of approaches uses only image information for person identification [1]. Some preliminary image transformation is usually performed before processing. The common initial stage for face recognition is image normalization. Usually it includes the following steps:

- Standard positioning of the face center;
- Image rotation for face vertical orientation
- Image scaling to standard size
- Detection of the central face region in an image

Firstly face area is detected in the image. The traditional method for face localizaton is template matching. Then the eye (iris) centers are detected for using the distance between eyes as some normalization factor.

In the next step the initial image is transformed by rotation, scaling and cropping of the central face part. Usually background and hair are removed to keep for analyzing the most invariant part of a face. The most important invariant features are located around eyes, eyebrows, and nose. The nose shape varies a lot as a consequence of head rotation and lighting conditions. The mouth is the most variant part of the face.

The general approaches for face recognition a based subdivided to geometric analysis, elastic matching and neuron nets [2].

Geometric approach uses some geometric features based on a set of typical points. Geometric features could be generated as segments, perimeters and areas of some figures formed by these points. However these geometric features significantly vary if face is rotated.

In contrast to geometric approach which evaluates only point-based features elastic transformation approach supposes changing image geometry and image texture for comparing two photographs. Given the variability of a face, even under controlled conditions it is useless to compare directly original images. The correlation between original and transformed face images is rather low in most cases of warping. A practical way to maneuver in the warping parameter space is to check the quality criterion with the previously achieved level of similarity after every warping. But in this case the image transformation process becomes some kind of art rather then determined procedure.

Neuron nets use a lot of different images of the same person for studying process and so they are more robust to image changing because face rotation. Nevertheless the problem of image mismatching due to insufficient or inadequate database set exists for neuron nets also.

The accurate method for face image transformation to given capturing condition is to used adequate 3D model of the face for generating synthetic photograph. In this case any pixel in generated image is determined using reliable information about 3D model and image orientation in a given coordinate system. Below the method for accurate image transformation based on face 3D model along with system for face 3D reconstruction is presented.

2. SYSTEM OUTLINE

The developed system is aimed at automated face 3D model creating and face image transformation to given condition.

The main requirements for developed system are:

- Short processing time
- Possibility of working in bright light condition
- Convenience for captured person
- Producing 3D model for most important part of a face
- High accuracy of produced 3D model
- Color texturing of the 3D model

To meet the described requirements the following system configuration is chosen:

- Three black and white CCD cameras for 3D reconstruction
- Color high resolution CCD camera for color texturing of face 3D model
- PC controlled structured light projector for automated correspondence problem solution
- Video signal distributor from four cameras
- Frame grabber for image acquisition
- PC as central processing unit

The view of photogrammetric face 3D reconstruction system is shown in Figure. 1.

Figure 1: The exterior view of photogrammetric 3D reconstruction system.

The developed system supports a variety of methods of automated correspondence problem solution based on various structured light pattern. Human face could not be reconstructed from two images because of its complex shape. So two image stereo pairs (left-middle and middle-right) are used for whole 3D face model generation. Parts merging is provided by system calibration and exterior orientation based on special test field.

The system is developed for two modes of operating. In stepped mode firstly the color image is captured for texture in normal lighting condition, secondly, in low illumination monochrome images from three black-and-white cameras are acquired for 3D reconstruction.

In synchronized mode the color image is captured simultaneously with monochrome images in bright illumination, but monochrome images are captured in infra red part of the light spectrum.

4. 3D RECONSTRUCTION TECHNIQUE

4.1. Calibration

Calibration is an important preliminary stage of system operation providing given accuracy of the produced 3D model. The developed calibration procedure [3] allows determining system orientation in given coordinate system. Image interior orientation (principal point x_p, y_p, scales in x and y directions m_x, m_y, and affinity factor a, the radial symmetric distortion and decentering distortion) and image exterior orientation (X_i, Y_i, Z_i – location and $\alpha_i, \omega_i, \kappa_i$ and angle position in given coordinate system) are determined as a result of calibration.

For automation and high accuracy of calibration special coded targets are used for test field reference point marking. Coded targets provide automated identification of corresponding reference points in the images and sub-pixel coordinate determination.

The images of test field with reference point marked by coded targets are shown in the Figure. 2.

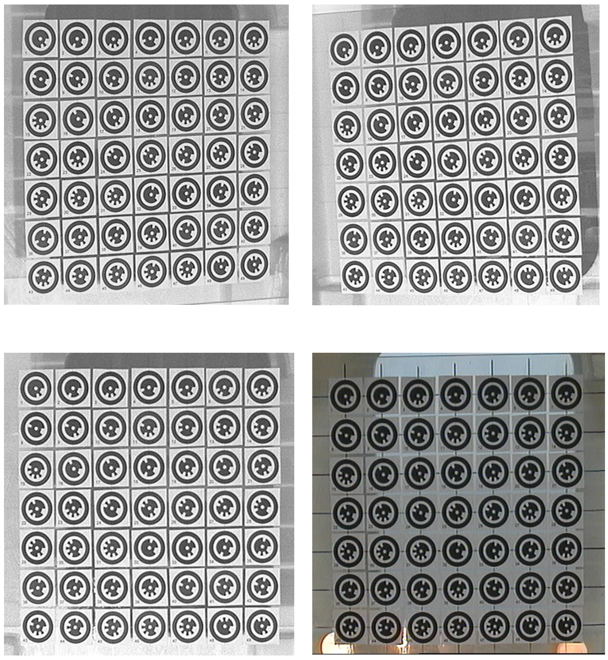

Figure 2: The images of the test field

A set of 12 test field images for each camera is acquired for calibration. Then the images are processed for automated image coordinates of reference points determining. Then camera model parameters and camera exterior orientation are determined by least mean squares solution.

The accuracy results of interior orientation (IO) and exterior orientation (EO) parameters for considered system are presented in Table 1.

#	σ_x, mm	σ_y, mm	σ, mm
IO	0.035785	0.04724	0.05926
EO	0.042160	0.058806	0.07235

Table 1: Accuracy results of calibration

Table 1 shows that the calibration provides high accuracy of 3D measurement by the developed system.

4.2. 3D face model generation

For 3D model reconstruction three monochrome images are used. TO determine 3D coordinates of a point of a face by photogrammetric method used in the system it is necessary to find the image of a given point of the face in two or more photographs with different orientation. Another word it is necessary to solve correspondence problem. To solve correspondence problem in automated mode the structured light is used. It provides special light pattern on a face allowing to apply various matching techniques for corresponding points in the images.

The solution for correspondence problem is developed for various types of structured light: stochastic pattern, coded light, phase shift [4, 5]. The samples of photographs and resulting 3D models are presented in Figure 3.

Figure 3: Face 3Dmodels produced by the system

Produced face 3D models has the real scale and high accuracy due to calibration procedure. It provides the possibility of their applying for given biometric parameters determination. Also face 3D models can be used for generation new images of the face with given face orientation.

The system provides 3D reconstructing of the most considerable part of the face including eyes, eyebrows, nose, moth, necks. For expanding 3D model to cheekbones and years regions additional cameras are needed.

4.3. Frontal photo generation

The system supports the function of automated generation of frontal image of the captured person. The frontal image is defined as the image which satisfies the next condition (Figure 4):

- C1. The line connecting pupils of the eyes (points A and B) is horizontal in the image
- The plane containing pupils of the eyes and mouth corner (points A, B, C) is parallel to the plane of image.

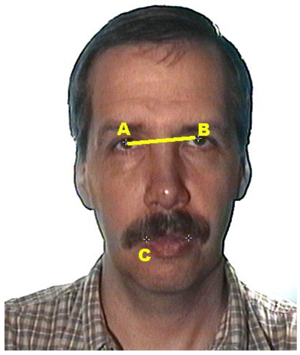

Figure 4: Frontal image definition

Points A, B and C are detected in the color photograph and then are found in the face 3D model basing on the image and the 3D model orientation known from calibration. Then transition matrix is calculated which rotates face 3D model to satisfy the conditions C1 and C2.

The Figure 5 presents the results of frontal photo generation based on face 3D model. In Figure 5a the original photos are shown and Figure 5b presents the frontal photographs created from original photos and face 3D model.

a

b

Figure 5: Results of frontal photograph generation

Figure 5 shows that the glance direction is changed on generated frontal photograph accordingly with 3D model rotation.

4.4. Software

The original software developed for face 3D reconstruction and frontal face generation supports the following basic function:

- Image acquisition from four cameras
- Automated system calibration
- Face 3D model reconstruction
- Automated face detection in the image and eyes and mouth detection
- Frontal photograph generation using 3D coordinates of eyes and mouth determined from face 3D model
- Possibility of manual correction reference points for regeneration of the frontal photograph
- Visualization of reconstructed 3D model

Software interface is shown in Figure 6.

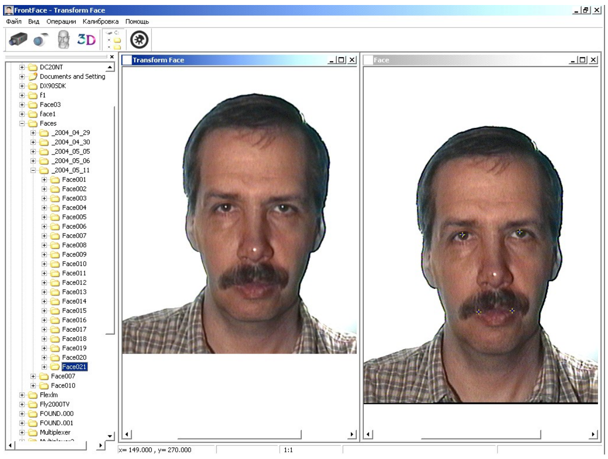

Figure 6: Software interface in frontal photo generation mode

The time needed for 3D model reconstruction and frontal photo generation is about 3 sec for P4-1.6/256 personal computer The accuracy of spatial coordinate determination is at the level of 0.3 mm, the point density is about 3000 points per 3D model.

5. CONCLUSION

The system for automated face 3D model generation and frontal photograph making is presented. A face 3D model is produced by photogrammetric processing of three monochrome images in structured light for automated correspondence problem solution. 3D face model is textured using image from color camera. The system supports working in bright light condition.

Produced face 3D model has a real scale and high precision and can be used for accurate measurement of biometric parameters of the person.

The system outputs the frontal photo of a person based on eye pupils and moth detection. Also the system can produce the image of a captured person from given point of view and given face orientation.

The developed system can be applied for fast and imperceptible obtaining a person face 3D model for various purposes beginning with video communication and finishing with access control.

6. REFERENCES

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About the author

Vladimir A. Knyaz, Head of dept. State Research Institute for Aviation System (GosNIIAS)

7, Victorenko str., Moscow, Russia
Telephone: 7-095-1573127, Fax: 7-095-1573900
E-mail: **knyaz@gosniias.ru**