A New Three-Dimensional Facial Landmarks in Recognition

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Abstract. In recent years, the number of biometric solutions based on 3D face images has increased rapidly. Such solutions provide a much more accurate alternative to those using flat images; however, they are much more complex. In this paper, we present subsequent results of our research on a new representation of characteristic points for the 3D face. As a comparative method the standard PCA is applied.

Keywords: biometric, 3D face, mesh, depth map.

1 Introduction

A biometric system is a pattern recognition system that determines the authenticity of an individual using physical or behavioral features. The physical features include unique anatomical features such as fingerprint, DNA, etc. Behavioral features are related to the behavior of a person e.g. signature[3][4]. Biometric systems are divided into two groups. The first group is constituted by systems that require some user interaction, e.g. systems based on fingerprints. A biometric capture device must scan a fingerprint, hence the user intervention is required. The second group consists of systems based on the feature that is always and easily available such as faces.

Research on automatic face recognition has been carried out for more than half a century; however, a big step in this field has been the development of the eigenface algorithm[12,26]. Currently, mainstream focuses on the use of three-dimensional model of the face.

2 A New Three-Dimensional Facial Landmarks

Since our previous work [17], we deal with the new approach to determine three-dimensional facial landmarks. In the first stage of the proposed method, the input set is organized in the form of a depth-map. Then, we have to examine the

L. Rutkowski et al. (Eds.): ICAISC 2014, Part II, LNAI 8468, pp. 179–186, 2014.

possibility of extracting face landmarks (new, with no relation to anthropometric points) on the basis of extremes. We assume that each row and each column is represented in function forms. Besides, each function can be classified as one of the four types of values:

local minimum of a function at a specified window size,
local maximum of a function at a specified window size,
global minimum of a function,
global maximum of a function.

Therefore, our method consists of two stages (Algorithm 1). The first stage extracts characteristic points from columns, and the second one does the same with rows. In each step, only points of the selected range are analyzed.

Algorithm 1. First state of landmark extraction

```
for x = 1 → COLUMNS do
  for y = 1 → WINDOWS_SIZE do
    find_Local_Minimum
    find_Local_Maximum
    if is_Global_Minimum_in_Range then
      save_Global_Minimum
    end if
    if is_Global_Maximum_in_Range then
      save_Global_Maximum
    end if
  end for
end for
for x = 1 → ROWS do
  for y = 1 → WINDOW_SIZE do
    find_Local_Minimum
    find_Local_Maximum
    if is_Global_Minimum_in_Range then
      save_Global_Minimum
    end if
    if is_Global_Maximum_in_Range then
      save_Global_Maximum
    end if
  end for
end for
```

In our algorithm, the height of each point is the smallest distance from the straight line matching the function at the window borders (fig. 1).

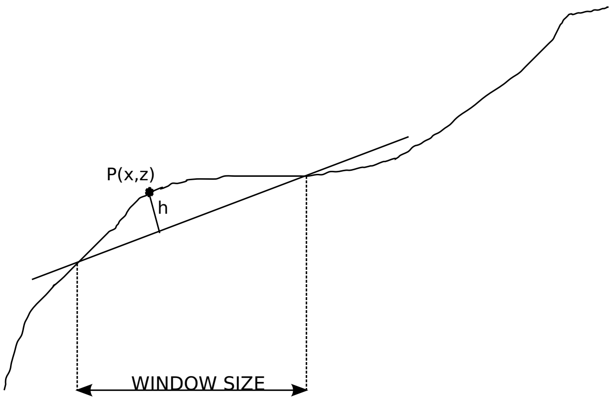

Fig. 1. Determination of the height of the point

3 Early Tests in Recognition

For the experiment, we firstly obtained characteristic points with the previously described method. For each person face, the training set consisted of dozens of face shots. The extracted characteristic points were subsequently analyzed by the principal component (PCA) method to form the data base. During the testing phase, we made use of the image that was not present in the learning phase. A series of tests comparing different types of characteristic points with each other were performed.

3.1 3D Face Database

The comparative study was carried out on a set of biometric three-dimensional images *NDOff-2007*[7]. The collection of 6940 3D images (and corresponding 2D images) were gathered for 387 human faces. The advantage of this collection is that, for a single person, there are several variants of face orientation.

3.2 Results

In the study, we used thousand 3D images taken for sixty people. Individual features can be categorized as follows:

all, all local and global landmarks from columns and rows,
col-l, local landmarks from columns,
col-g, global landmarks from columns,
glob, global landmarks from columns and rows,
row-l, local landmarks from rows,
row-g, global landmarks from rows.

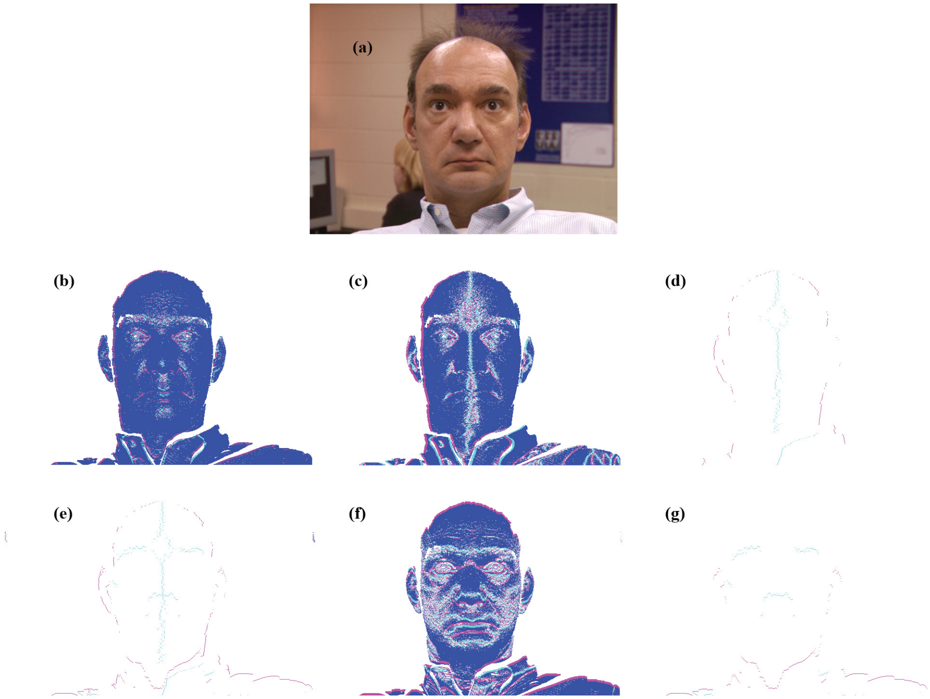

Fig. 2. Landmarks visualization.(a) original reference photo, (b) all landmarks, (c) col-l landmarks,(d) col-g landmarks, (e) glob landmarks, (f) row-l landmarks, (g) row-g landmarks.

Table 1. Results. Indexes of recognized faces. Correct are indexes: 1–38(C - correct, I - incorrect).

	all	col-l	col-g	glob	row-l	row-g
all	**36(C)**	**6(C)**	529(I)	529(I)	**6(C)**	529(I)
col-l	**36(C)**	**36(C)**	434(I)	434(I)	**6(C)**	434(I)
col-g	287(I)	287(I)	246(I)	246(I)	404(I)	246(I)
glob	238(I)	497(I)	370(I)	578(I)	238(I)	578(I)
row-l	**36(C)**	**36(C)**	626(I)	626(I)	**27(C)**	626(I)
row-g	235(I)	235(I)	452(I)	**11(C)**	235(I)	**11(C)**

Table 1 presents results of recognition process. In first column, there are listed landmarks databases used to recognize pattern image, which are based on landmarks from first row. Figure 2 presents visualization of new landmarks.

Figures 3 –6 presents results of comparisons of different class of landmarks with other landmarks. This experiment was aimed to define which points are the best to store in the database and which are the best for comparison purposes. For the calculation of the false acceptance rate (FAR), the false rejection rate (FRR) was assumed to be zero.

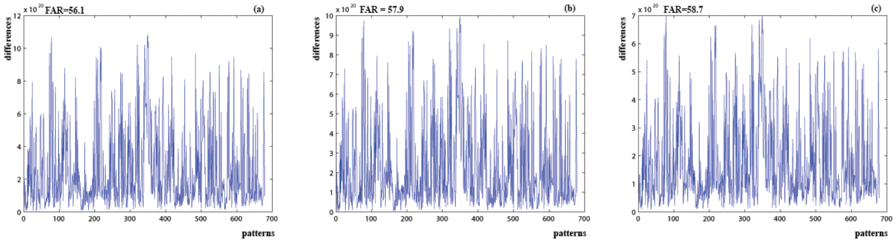

Fig. 3. Positive resutls for all landmarks. (a) - all to all comparison (b) - all to col-l comparison (c) - all to row-l comparison.

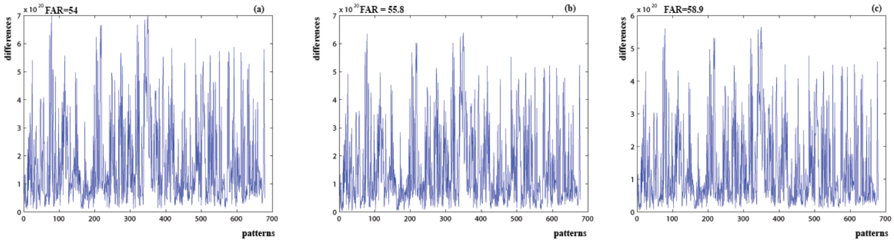

Fig. 4. Positive results for col lanmarks. (a) - col-l to all comparison (b) - col-l to col-l comparison (c) - col-l to row-l comparison.

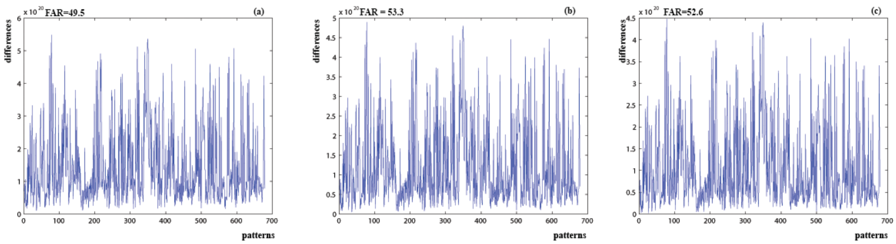

Fig. 5. Positive results for row landmakrs. (a) - row-l to all comparison (b) - row-l to col-l comparison (c) - row-l to row-l comparison.

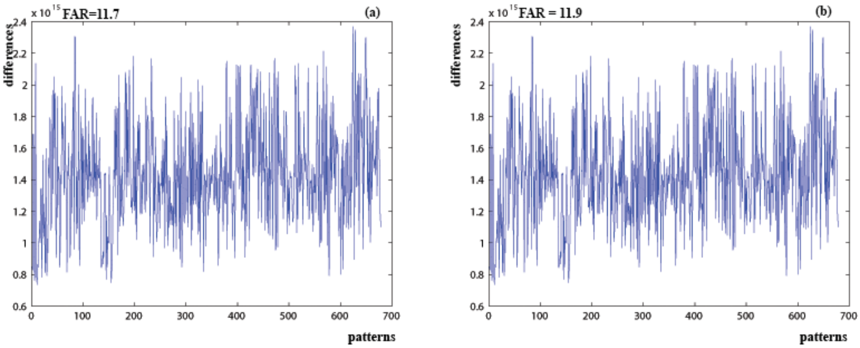

Fig. 6. Positive results for row-g landmarks. (a) - row-g to glob comparison (b) - row-g to row-g comparison.

4 Conclusion

In this contribution, the preliminary results of extraction of landmarks based on the new representation of 3D face was presented. In the comparison tests, the best result of 11% FAR was obtained, which can be regarded as a very promising for future works. Row-g landmarks are the most effective landmarks in our 3D face representation. Moreover, the row-g landmarks database is small comparing to databases created from other landmarks, since it is the most appropriate for recognition.

In the future work, we want to focus on the further development of the representation of the face, in particular, on the methods for model interpretation, e.g. on fuzzy methods [5,9,15,16,18,24] or neuro-fuzzy methods [10,21,22,25] as well as combinations with methods of image understanding [2] and processing [1]. Some work on non-parametric methods [6,8,11,13,14,19,20,23] can be done as well.

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