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Implementation of perceptual aspects in a face recognition algorithm

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Abstract. Automatic face recognition is a biometric technique particularly appreciated in security applications. In fact face recognition presents the opportunity to operate at a low invasive level without the collaboration of the subjects under tests, with face images gathered either from surveillance systems or from specific cameras located in strategic points. The automatic recognition algorithms perform a measurement, on the face images, of a set of specific characteristics of the subject and provide a recognition decision based on the measurement results. Unfortunately several quantities may influence the measurement of the face geometry such as its orientation, the lighting conditions, the expression and so on, affecting the recognition rate. On the other hand human recognition of face is a very robust process far less influenced by the surrounding conditions. For this reason it may be interesting to insert perceptual aspects in an automatic facial-based recognition algorithm to improve its robustness. This paper presents a first study in this direction investigating the correlation between the results of a perception experiment and the facial geometry, estimated by means of the position of a set of repere points.

1. Introduction

Biometric techniques are more and more diffused in security applications. Among them face recognition is particularly appreciated since it does not require subject collaboration and the recognition process can take place unbeknown to the subject [1].

Applications regards both authentication and recognition. The former is just a confirmation of a declared identity of a subject, typical applications regards access control where, after and identity declaration, the subject undergo a biometric verification of the identity. In this case the task is a one to one verification. Recognition is a rather more complex task, since there is no a priori knowledge of the expected identity. In fact the goal is to verify if a subject is or not classified in a reference data base, so in this case is a one to many task. Of course in identification task, subject collaboration is generally required and several biometrics techniques find their application, such as voice recognition, retina imaging and so on, while in recognition problems the subject under test is often just moving in the field of view of a camera at the station or at the desk counter, so no collaboration is possible and low

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invasivity is required. Such cases are the peculiar application of face recognition, so in the following we will refer to recognition problems, where there will be a test image of the subject's face and a reference data base of face images of a set of known subjects.

Face images in the reference data base are captured under controlled conditions, i.e. good illumination, controlled distance and orientation to the camera, and with the subject collaboration, i.e. frontal face images with neutral expression. Face image captured in the field suffers for several unfavorable conditions due to: the imaging device (i.e. poor quality cameras, low resolution, noise), the surrounding environment (i.e. illumination, shadows, camera to subject distance), subject collaboration (i.e. face to camera orientation, non-neutral expression, camouflage).

These are just some examples of the possible quantities influencing the face image captured in the field, so generally the situation is rather complex since the task requires the comparison of a reference face with a test captured under non-controllable conditions.

This is the major cause of failure for automatic recognition algorithms, as well known in literature [2, 6]. In order to evaluate the recognition robustness ad hoc face images data bases are available and contests are performed to identify the most performing algorithm.

On the other hand human face recognition is really robust, since humans are able to recognize a subject even when just a little portion of face is available or under poor illumination [8-10].

In such a scenario two possible strategies to improve automatic face recognition performances emerge. One considers the possibility to improve the face measurement process at the base of the recognition decision, the other focuses on human perception of similarities among faces, to find out the robust perception mechanisms that could be implemented to improve the automatic face recognition algorithms.

This paper deals with this opportunity and, on the base of a measurement of perceptual similarity of modified faces, focuses on their consequences on a recognition method based on specific facial landmark points.

In particular the goal of this work, although to be considered as a feasibility study, is to identify which geometric entities (distances between features, areas of face regions, angles, ratios between distances...) are more relevant in human perception of similarity/dissimilarity in order to assign to these entities a higher importance in automatic recognition techniques. Since human capability to identify people relying on the facial image is very high, it is expected that trying to mimic some aspects of this recognition process might improve the reliability of automatic recognition systems.

The paper will briefly introduce the basics of the perceptual similarity measurement, some details regarding the algorithm used to measure the facial geometric characteristics, then it will present some experimental results with a set of artificially modified faces and it will consider the relationship between the position of reference points and their effect on perceived similarity identifying the most significant reference points. Final results will be discussed with a look to future possible applications.

2. Perceptual similarity

The direct measurement of perceptual quantities is a rather new field with a set of possible applications that is getting wider, consider for example social science, customer satisfaction, quality perception. After a long period of indifference due to the conviction that such kind of quantities could not be treated at the same scientific level than the traditional physical quantities, the theory has consolidated new, and well established approaches, new experimental approaches have been developed and their general consideration increased obtaining the recognition of the scientific community [3].

In this specific application the interest is the perceived similarity among a set of faces and the measurement has been designed to obtain reliable robust results with a metrological validity.

The measurement procedure consists of two independent tests one focused on an interval scale the other on a ratio scale. The complete detail of the approach is presented in [4, 5], here we will briefly provide some details that we consider important in this specific context.

2.1. Creating the set of faces

The set of faces to be evaluated is the central point in the design of the perceptual similarity tests. Here a set of slightly different faces of some subjects is needed and the face should undergo a controllable face modification process, in order to be able to control the modification for each subject. The controlled modification of a face image is rather complex in two dimensions, while it is possible on a three dimensional model of the head. So three dimensional head models were realized starting from the real face images of four subjects, then they underwent a controlled modification process, by acting on specific face characteristics such as mouth to chin distance or forehead height. Five modification for each model were introduced, and from them we obtained a set of 6 frontal images, as presented in figure 1.

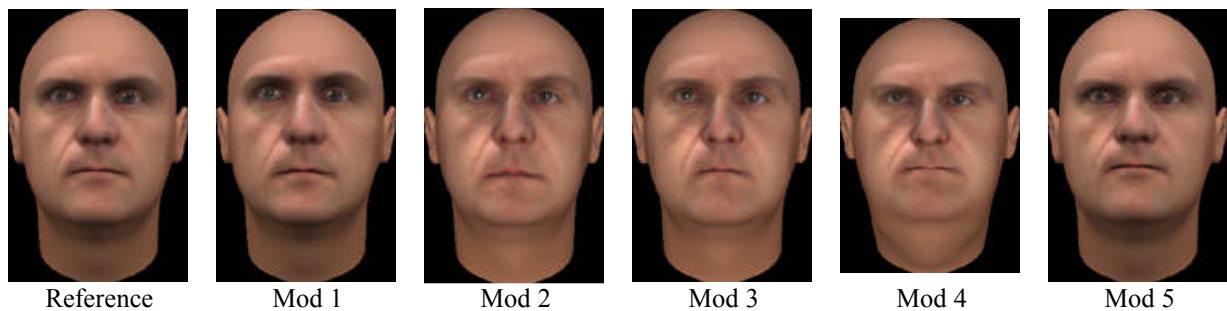


Figure 1. Reference model and related face modifications

2.2. Perception tests results

The set of faces including 6 images for 4 different subjects was proposed to a jury of 12 users, to evaluate the perceived similarity among the modifications of each subject. Results from the two test methods were compared to obtain a validated measure as presented in figure 2. For two face modifications (nr 3 and 5) the validation procedure was not successful (incoherent results from the two tests) and they were excluded from further evaluation. So we concluded that modification type 4 deeply affected perceived similarity while both number 1 and 2 had a slight reduction effect. Correlation coefficient between the results of the two tests, for these 3 face modification, is above 0.95, confirming the validation procedure.

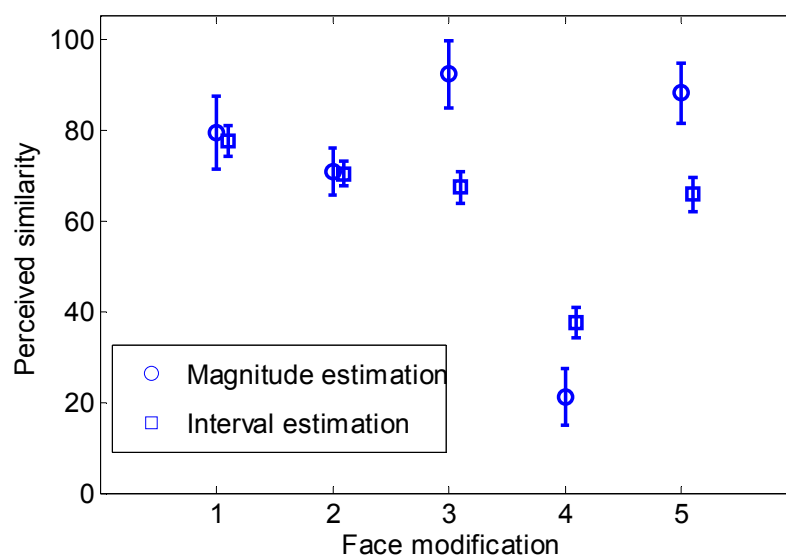


Figure 2. Perceived similarity estimated with “Magnitude estimation” and “Interval estimation.”

3. Repere points identification

Several face recognition algorithms are based on the measurement of biometric features and subject identification is undertaken by evaluating geometric discrepancies between facial masks [14]. The purpose of this work is to analyze facial geometric information and to compare them with the results of perception tests with the goal to identify which facial characteristics are more influents/relevant for the perception of similarity/dissimilarity in human recognition. The final goal is to introduce a weighting of the facial geometric details in recognition algorithm [11] in order to try to emulate the human recognition mechanism in machine-based recognition.

Repere points marked on facial images are used to describe face biometrics. In particular, according to [12, 13], 58 points has been used to represent facial geometry.

These ‘reper’ points, also known as landmarks, are detected on face images through features extraction algorithms, which permit to select most relevant biometric information. In literature it is possible to find many different codes that permit to automatically extract position of relevant landmarks [15]. One of the most popular algorithm is the Active Appearance Model (AAM) [17], a model based code [16], which permits to create a deformable model that allows to detect features from any image of the same type of those used to create the deformable model. The AAM technique uses a statistical approach based on the processing of a training set of images where biometric features are manually outlined to build the model that will be used to automatically detect the features in the following pictures. A principal component analysis of the training images collection generates a set of parameters which represents geometry and texture variation. The resultant model is a compact representation of the training images variability. Once the model is created, it is iteratively matched as well as possible to the new analyzing image and sought features are detected.

The use of the AAM imply three steps:

- 1)The model creation: the 58 points could be manually labeled on various facial images and this information is analyzed with a statistical approach and the AAM model is created.
- 2)The fitting of the model to a new image permit to automatically detect the 58 set of landmark.
- 3)The extraction of coordinates of the points of interest from the matched model.

A training set consisting of 20 face images from 6 different subjects was used in this work to create the model for the AAM technique. Then the model was applied to the same set of 24 faces that was previously evaluated by perception tests (these images are different from the ones used in the AAM training). In this way a quantitative and user-independent estimation of the features position is obtained; this geometric information can be used as a comparison with the results of perception tests with the goal to identify which geometric characteristics of the face are relevant for the perception of similarity/dissimilarity in human beings.

4. Perceptual similarity and face geometry: results and discussion

In this section the relationship between the modifications of the repera points positions in the test faces, and their perceived similarity is analysed. The perceptual results shown in section 2 will be used here as a reference, while the facial geometric information analysed with the technique discussed in section 3 will be considered in order to detect which geometric details modification correspond to the most relevant perceptual variation.

4.1. Quantification of facial features geometric modifications

As explained in section 3, a set of 58 repera points is used to represent the facial geometry, as represented in figure 3.

Analysis of the modifications effect on facial geometry has been based on the observation of 11 geometric indexes, listed in Table 1. In Figure 3 the geometric entities described in Table 1 and their related Center of Gravity (CoG) are shown.

Table 1. List of the biometric indexes.

Index #	Biometric quantity	Reference in figure 3
1	Eyes distance	A
2	Nose-mouth distance	B
3	Mouth heigth	C
4	Mouth width	D
5	Eyes-mouth distance	E
6	Eyes area (sum of the 2 eyes)	
7	Mouth area	
8	Eyebrows-Face CoG distance	F
9	Average jaw width	G
10	Jaw height	H
11	Mouth-chin vertical distance	I

All the indexes listed in table 1 were calculated for each of the 4 persons considered in the perception test and for each of the 6 images belonging to every person (reference image plus 5 modifications).

The difference between the index evaluated on the reference image and the same index evaluated on each modification is then computed, obtaining the index discrepancies. Finally the mean and standard deviation of the discrepancies on the four persons is computed for each modification. The mean discrepancies will be used in the following of the work as indexes of the effect of face modifications on the geometric changes of the facial biometrics.

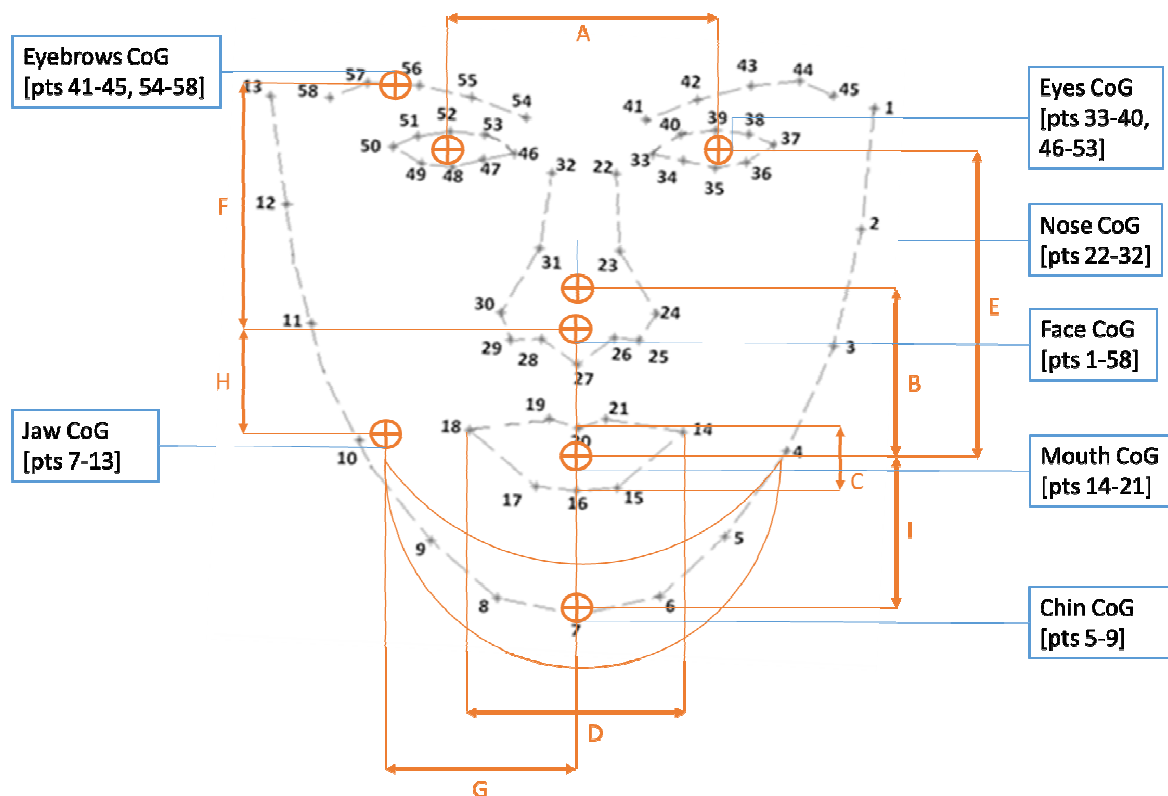


Figure 3. The 58 facial landmarks used in the analysis and the references to the 11 indexes described in table 1.

The obtained geometric indexes show a variability among the four faces with a standard deviation of the means ranging between 0.15 and 2.5 pixel with a conversion factor of 0.8 mm/pixel.

A first analysis can be carried out on the variation of the biometric indexes. Among all the 11 calculated biometric quantities (listed in table 1), the most interesting results, observed for the 4th modification in terms of appreciable mean discrepancy, can be found in the analysis of indexes number 9, 10 and 11 (average jaw width, jaw height and mouth-chin distance respectively). In fact, biometrics indexes 9, 10 and 11 are highly influenced by 4th modification in all 4 individuals while they are not influenced in an appreciable way by other modifications.

Results of this analysis are shown in figure 4, for the three parameters 9, 10 and 11 respectively.

In particular, observing the variation of index no.9, the 4th modification induces an evident widening of the jaw producing an average enhancement of 8.4% of the distance between reciprocal jaw landmarks (i.e. pairs of points 1-13, 2-12, 3-11 ... of Figure 3) whereas, observing the mean variation induced by other modifications, it is possible to state that index 9 is affected only by the 4th modification. Very similar results can be found analyzing the index no. 11, which represents the mouth-chin vertical distance: the 4th modification strongly impacts on it, with a change of 8.2% of this parameter, while the effect of the other face modifications is negligible. The 4th modification also affects jaw height variations (index no. 10), although with a less evident effect.

We can assess that the 4th modification produces a significant geometric alteration only of the lower part of the face and correspondingly produces a relevant reduction in the perceived similarity results (see Figure 2). This demonstrates that the geometric changes of the lower part of the face play a role in the perceptual similarity and therefore should be carefully considered in automatic face-based recognition systems.

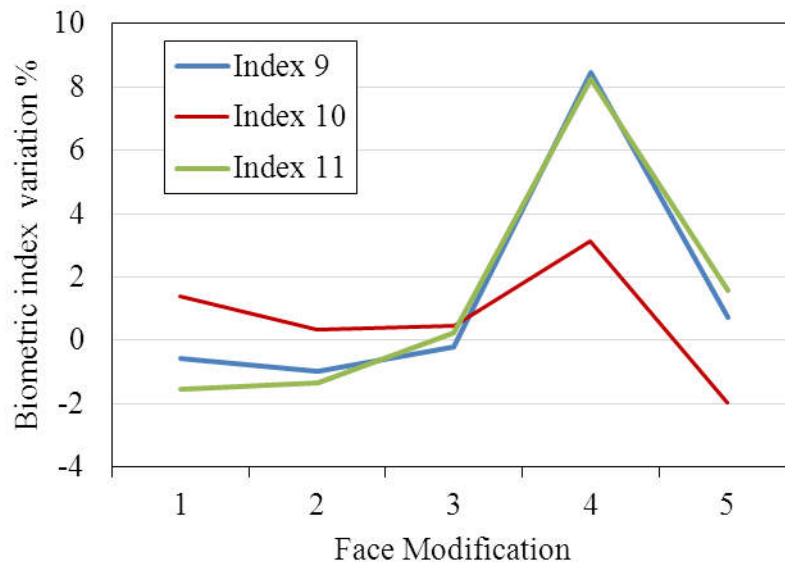


Figure 4. Mean values for % variation of biometric indexes 9-10-11

4.2. Comments

A preliminary analysis of the results shows that not all the considered biometric variations have the same effect on perception. In particular a high effect of face widening on the human perception was found.

However, these results are based on a limited number of facial modifications performed on few individuals; it seems therefore reasonable to expect better and more detailed information by studying a larger individual sample and a wider set of face modifications. The goal of this work was mainly to develop a feasibility study on the possibility to insert perceptual aspects in an automatic facial-based recognition algorithm to improve its robustness and the obtained results, although preliminary, are encouraging.

The outcomes of this work will be useful to further develop feature-based automatic algorithms for facial identification (see for example [12]). In this type of algorithms the recognition decision is based on the relative position of a set of facial feature points and in the evaluation of the similarity among faces, the most stable feature points are considered with a larger weight than the others. Since human capability to identify people relying on the facial image is very high, introducing a sort of perception weight in the recognition process it is expected to increase the recognition performance and robustness against negative influence factors such as expression variations.

5. Concluding remarks

Human recognition of face is a very robust process, for this reason in this work the possibility to insert perceptual aspects in an automatic facial-based recognition algorithm was studied, with the goal to improve the robustness of the automatic facial recognition techniques. The correlation between the results of a perception experiment and the facial geometry modifications was analysed and discussed, showing the presence of correlation between modification of some facial biometrics and human perceived dissimilarity. An extended analysis based on a larger statistical sample would permit to

increase the results goodness and to identify the effect of a larger number of biometric modifications on the human recognition.

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