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Statistical Analysis of the Characteristic Features of Standard Image for Racial and Ethnic Identity of a Person

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ABSTRACT

The paper provides statistical analysis of the characteristic features used to determine racial and ethnic identity of a person basing on the images. Standard characteristic features of the persons of each ethnic group have been set accordingly. Characteristic features of random image have been compared with the characteristic features of standard image to determine belonging of a person to this or that racial and ethnic group. Comparing the characteristic features of the random image with the characteristic features of the standard image of each ethnic group, it is important to define the reliability of the interdependence between them. Note that, characteristic features of standard image were determined basing on the characteristic features of a real human face belonging to each ethnic group. The dependence was defined among the characteristic features of racial and ethnic standards set up according to the images with the characteristic features of a human face. A Fischer criterion was used to determine the dependence.

Keywords: Fisher criterion, race, ethnicity, person, correlation

1 Introduction

Recently, modern information and communication technologies have developed rapidly. Emerging information society includes a number of important issues that have not been fully resolved and studied. One of these pressing issues is the racial and ethnic identification of a person basing on the images. Currently, specialists in various fields of science are dealing with this issue. The problems existing in this area have been partially solved by very few specialists using different methods.

Upon recognizing a person, a facial image (photo portrait) is of particular theoretical and practical value [1]. There is currently a significant number of articles devoted to recognize people based on portrait photographs]. However, there are much less works on the recognition of people based on their affiliation to an ethnic group is much less [2].

A new method is proposed to create a real three-dimensional portrait photograph based on the two-dimensional portrait for synthesis of two dimensional portrait photographs arbitrarily made in some works using special models prepared in accordance with gender and ethnicity [3].

Ethnicity is considered as a very important demographic characteristic for the humanity. Automatic ethnic classification based on human face is important in different fields. Some articles have research both two- and three-dimensional characteristics of the human face, MM-LBP multi-modal method (multi- scale multi-ratio) has been proposed for ethnic classification. LBP (Local Binary

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Pattern) histograms were compiled from multi-scale multi-ratio quadrangular parts based on texture and range images [4].

Visual information such as gender, age, ethnicity and facial expression play an important role in face-to-face communication. Some articles have proposed a new approach for ethnic classification of the human face based on the portrait photograph. Gabor Wavelets Transformation identifying the main facial expressions and eye reticular membrane samples were combined in this approach. Support vector apparatus was used for ethnic classification. Using the system based on this approach, 94% ethnic evaluation was achieved in different lighting conditions [5].

Unlike existing models depending only on two-dimensional portrait photographs in some articles, a new method was proposed for solution of issues related to combination of local texture and form characteristics obtained using three-dimensional models of the face. Proposed method used Oriented Gradient Maps in order to demonstrate local geometric variations, as well as all texture variations of the face [6].

Specialists in Ethnography conduct research to solve existing problems in the field of humanities; and the experts in technical sciences study "Pattern recognition".

2 Problem statement

In the previous study, the author of the paper have developed an algorithm for the standard characteristic features to determine racial and ethnic identification basing on the images of people who have the same historical and ethnic features. Taking into account three generations of tribal and ethnic groups of the people with the same race and ethnicity, a database was formed based on their images. The standard image, i.e. the basic matrix of its characteristic features was formed by calculating selected geometric points of the face and characteristic features of the images in the database. Then, the characteristic features of the random image were compared with the characteristic features of the standard image of each racial and ethnic group, and belonging to any racial of ethnic group of the random image was defined [7-11].

It was decided to use 30 identification points during the preliminary tests.

Note that the characteristic features of the standard image were drawn up, based on characteristic features of the images of people of mongoloid, negroid and European race. And the standard characteristic features were compiled according to defined real features of the people belonging to racial and ethnic groups.

The task of determination of affiliation of the reference image to one of the *l* ethnical groups comes down to finding Euclidean distance among the matrix of $P^l(p_{ik}^l, i=1,9, k(i,j)=1,190)$ of *l* ethnical groups and the matrix of $P^*(p_{ik}^*, i=1,9, k(i,j)=1,190)$ of characteristic parameters of the reference image as following:

$$D_l = \sqrt{\sum_{i=1}^{9}\sum_{k=1}^{190}(p_{ik}^l - p_{ik}^*)^2}\ , l=1,2,\ldots \tag{1}$$

Further, the value of $D_{l*} = min(D_l, l=1,2,..)$ determines the number of the ethnical groups with which the reference image is affiliated [12].

3 Solution algorithm

Dependence was compared with the characteristic racial and ethnic standards drawn up on the basis of the real characteristic features of the human face. Fischer criterion was used for this purpose. Fisher criterion (F) shows a reliable correlation. It is quite valid between more than two depended numeral variables. The correlation describes statistical relationship between two or more random variables. The change in one or more variables leads to a systematic change in the others. The correlation between the two variables is mathematically expressed in coefficients. The coefficients are negative or positive depending on the nature of the interaction. If the correlation is negative the increase in the value of one variable affects the decrease in the values of others, and vice versa. The values of the correlation coefficient vary between -1 and +1. If the value of the coefficient is close to 1 the relation is likely to be strong between the two variables. If the coefficient is close to 0 it is the weakest relation.

The correlation relation is calculated by the following formula:

$$\eta = \sqrt{\frac{\sigma^2}{\sigma_*^2}} \tag{2}$$

For instance, racial and ethnic groups are $l\,(l = 1,2,\ldots)$. The database developed for each group includes male or female photos at the n_l number. Then, the matrix of characteristic features of the standard image $P^l(p_{ik}^l, i = 1,9, k(i,j) = 1,190)$ are defined for the l_i - th group as follows (tab.1):

$$p_{ik}^l = \sum_{j=1}^{n_l} w_{ik}^{jl} / n_l \tag{3}$$

As a numerator of the radical a dispersion calculated for the real values of a human face is denoted by σ^2, and as a denominator empirical values, i.e. a dispersion of the characteristic features calculated according to the images of the human face are denoted by σ_*^2 and they are calculated by the following formula:

$$\sigma^2 = \frac{\sum_{i=1}^{9}\sum_{k=1}^{190}(\,p_{ik}^l - \overline{p}_{ik}\,)^2}{n}, l = 1,2,\ldots \tag{4}$$

$$\sigma_*^2 = \frac{\sum_{i=1}^{9}\sum_{k=1}^{190}(\,p_{ik}^{l*} - \overline{p}_{ik}^{*}\,)^2}{n}, l = 1,2,\ldots \tag{5}$$

i=1,9; k=1,190;

Here, ethnic group *l* indicates number of features *k*.

p_{ik}^l, p_{ik}^{l*} - is the value of the i-th theoretical (calculated) and empirical (actual) row;

$\overline{p}_{ik}$, $\overline{p}_{ik}^{*}$ - is the average value of theoretical (calculated) and empirical (actual) row.

n is the number of the members.

In conducted studies the form of relations is preferred, where the value of the correlation relationship is closer to 1.

Fisher criterion (F) indicates reliable correlation (it describes statistical relationship between two or more random variables). Fisher criterion is quite valid between more than two depended numeral variables.

The values of Fisher criterion are calculated by the following formula:

$$F = \frac{\frac{\sum_{i=1}^{9}\sum_{k=1}^{190}(p_{ik}^{l} - \overline{p}_{ik})^2}{n-1}}{\frac{\sum_{i=1}^{9}\sum_{k=1}^{190}(p_{ik}^{l*} - \overline{p}_{ik}^{*})^2}{n-m-2}}, \quad (6)$$

$$F = \frac{\sigma^2}{\sigma_*^2}, \quad (7)$$

m is the number features taken into account in the model (independent variables).

The mean-square relative error of actual variables found from the calculation is calculated by the formula:

$$m' = 100.\sqrt{\frac{\sum_{i=1}^{9}\sum_{k=1}^{190}(\frac{p_{ik}^{l} - \overline{p}_{ik})^2}{p_{ik}^{l}}}{n}}, \quad (8)$$

The mean-error approximation ($\overline{\varepsilon}$) calculated by the formula:

$$\overline{\varepsilon} = \frac{1}{n}\sum_{i=1}^{9}\sum_{k=1}^{190}(\frac{p_{ik}^{l} - \overline{p}_{ik})^2}{p_{ik}^{l}} .100 \quad (9)$$

Both indicators characterize the degree of accuracy of reflecting the real number by these models.

The size of correlation relations, Fischer criterion, the mean-square error and mean error approximation are reduced.

The approximation or approaching is a research method, in which one object is replaced by another, in other words, is closer to the primary variable, but is relatively simple.

4 Identification system

"Racial-ethnic" biometric identification system (REBIS) was established for the recognition of a person's racial or ethnic origin.

Numerous experiments were carried out through IEBIS. The database includes images of different sizes of the people belonging to different races at *n* number. An algorithm was developed in order to add automatically the values of characteristic features to the database, which are used for the racial and ethnic identification of a person on the basis of images, and in order to search and identify the human face on the basis of his image in the database. The front page of REBIS is shown in Figure 1.

Experimental tests were carried out by using the images of FERET database.

Value of dispersion and the standard error for race groups is shown in Table 1 and diagram in Figure 2.

The distances calculated automatically in accordance with the characteristic points, which are determined on the basis of the image of each human face, are included and saved into the database. This data is included into the database once and can be modified.

For the successful racial and ethnic recognition of a person on the basis of face images a number of issues need to be solved:

1. Choosing the anthropometric points of human face on the basis of template;
2. Calculating the geometric features according to the characteristic points of the random face images given for the recognition, and adding them into the database automatically;
3. The recognition process should not depend on the image scale;
4. Realizing the recognition of human face and informing the user about it.

The main difference of REBIS from the others is its high speed processing by means of developed algorithm, efficient use of images stored in the database and its prompt recognition. The main advantage of the proposed algorithm is the resistance of the results to the change in the person's appearance depending on his aging. The experiences were carried out on more than 150 people of European, negroid and mongoloid race, and 96 - 98% recognition accuracy has been achieved by means of developed algorithm. Identification process carried out through REBIS is more rapid, saving time.

Entering the REBIS an image of a person of any racial group is given, in the output of the proposed system the racial and ethnic identification of the given person is determined.

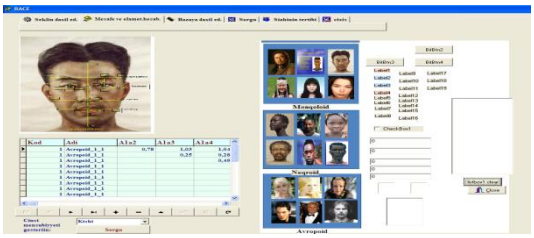

Figure 1: The front page of REBIS

Table 1. Value of dispersion and the standard error

	European	Mongoloid	Neqroid	Any person
Dispersion	0,35	0,44	0,47	0,37
The standard error	0,36	0,45	0,49	0,38

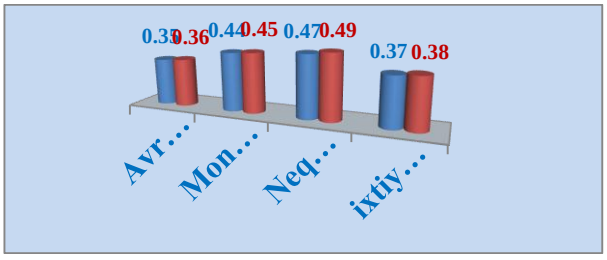

Figure 2: Diagram of Value of dispersion and the standard error for race

5 Results

The paper informs about the application of Fisher criterion to define the dependence of the features, which are used for racial and ethnic identification of a person on the basis of images. Note that, characteristic features of standard image were determined basing on the characteristic features of a real human face belonging to each ethnic group. The dependence was defined among the characteristic features of racial and ethnic standards set up according to the images with the characteristic features of a human face. The recognition tests gave promising results.

The dependence forms meeting the following requirements are preferred:

- The highest coefficient of multiple correlations;
- Higher Fischer criterion;
- Mean-square error is smaller.

Theoretical studies and practical results of recognition by national - racial affiliation based on the portrait photographs can be used in the interests of the many professions that require adequate recognition of people (customs, border control, security, etc.). Upon determining the identity based on identification systems, the basis of which contain several millions of portraits – will significantly narrow the search area while reducing the time of recognition.

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