A Simple Method for Generating Facial Barcodes

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ABSTRACT

In this paper we propose a simple method for generating standard type linear barcodes from facial images. The method uses the difference in gradients of image brightness. It involves averaging the gradients into a limited number of intervals, quantization of the results into the range of decimal numbers from 0 to 9, and table conversion into the final barcode. The proposed solution is computationally low-cost and does not require the use of any specialized image processing software, which makes it possible to generate facial barcodes in mobile systems. Results of tests conducted on the Face94 database and a database of composite faces at different ages show that the proposed method is a new solution for use in real-world practice. It ensures the stability of the generated barcodes against changes of scale, pose and mirroring of facial images, as well as changes of facial expressions and shadows on faces from local lighting.

Keywords

facial images, brightness gradients, barcodes, real time system.

1. INTRODUCTION

Barcoding technologies for various goods, payment bills and financial documents, advertisements and services have widely and irrevocably entered our everyday lives. The first application of standard barcodes for person identification was suggested in the patent [Pat99] in 1999. There it was assumed that the identification of the person is performed at the moment of her/his electronic payments, that is, in real time, and the unique barcode, which is printed on her/his hand, is read by means of a special device. However, the practice of person identification using barcodes was not developed further, although biometric standards were accepted to represent people by means of anthropometrics, and biometric identification methods already exceed the abilities of people. Nevertheless, a barcode printed on the human body is already advertised today as a fashionable tattoo [Bar00]. In barcodes [Bar00] placed on the human body, there is no information about any biometric characteristics of the person. But we can say for sure that when the barcode on a person's body can represent the person in a way similar to biometric features, it will be widely used not only as a "fashionable tattoo", but also applied in person identification. However, it is almost impossible to imagine the process of person identification by barcodes when they are hidden under clothes or on inaccessible body parts. The ideal solution could be barcode generation in real time and directly from a person's face or voice. In this case person identification can be performed at a distance, imperceptibly for the person, without demanding any action from the person or any barcode printed on the person's body.

Assuming that such a solution exists in principle, the resulting method may be used to encode faces or voices of people [Mat12, For12] in the form of barcodes. These barcodes can be used in many different areas such as biometric systems, access control (AC) systems, video surveillance systems, content-based video retrieval systems, etc. Of the two approaches based on voices or faces of people [Mat12, For12], we will develop the latter one based on new solutions presented in [For12]. However, there are some problems in generating facial barcodes.

One of the unsolved problems of today's practice in facial biometrics is the variability of real-world facial images (illumination and pose variations, facial expressions, etc.). Solving this problem would simplify person identification and improve the performance and reliability of corresponding recognition systems, since barcode readers and decoders have been effectively used in various practical applications for a long time. That is why there has been continuing interest in the problem of stable facial barcode generation, starting from the moment of the appearance of first computer systems recognizing people by their faces.

In this paper we propose an approach to presenting facial images in the form of linear EAN-8, EAN-13 or UPS barcodes [UPS14].

2. BRIEF OVERVIEW OF EXISTING APPROACHES

Ten years after the publication of the patent [Pat99], authors of [Dan09] noted that facial identity is largely conveyed by horizontal image structure, such as eyebrows, eyes and lips lines. They showed that this information can be successfully represented in the form of a set of binary strips or a so called “biological barcode”. Furthermore, they explored some invariant features of people’s facial "biological barcodes". An example of face representation in the form of a "biological barcode" described in [Dak09] is shown in Fig. 1: a) the original facial image; b) horizontal information contained in the facial image; c) the «biological barcode" of the human face; d) the resulting linear barcode [Fac09].

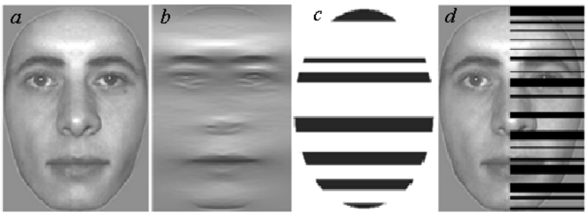

Figure 1. Representation of a human face in the form of a “biological barcode”

However, as noted in [UPS14] and further publications by these authors, they do not define the algorithm for generating such barcodes, but note that the representation of a facial image with only thick straight black and white stripes will never be an exact model of a person’s face. This model, while remaining a precise "biological barcode" of a face, is a very rough approximation of the specific person's face, which, for example, can be seen in Fig. 1 a) and c). The inaccuracy of this approximation is due to the morphology of a person’s face: the boundaries of the hair/forehead, the lines of eyebrows, eyes, nostrils and lips are difficult to define, and even more difficult to describe by thick strait strips. Representing a person's face requires a structure of thinner and multiple lines, and a corresponding barcode would appear as shown in Fig. 1 d).

Five years later, the most serious practical research on the problem of the representation of faces in the form of barcodes was published [Que13]. The authors of this paper proposed an algorithm for barcode generation based on searching for specific (key) points on a face, describing local features with descriptors, and creating a two-dimensional color barcode HCC2D. The HCC2D barcode combines the advantages of two-dimensional codes HCCB (High Capacity Color Barcode) and QR (Quick Response), but differs from them in high capacity (data density). However, the algorithm for generating HCC2D barcodes, proposed in [Que13], is unlikely to be implemented in the near future in mobile systems on tablets and smartphones. This conclusion about HCC2D barcodes is based on its use of SIFT (Scale Invariant Feature Transform) and SURF (Speeded Up Robust Features) procedures.

The concept of a "biological code" uses the algorithm for comparing two facial images presented in [Hit13]. The idea of the algorithm is explained in Fig. 2. Here we at first calculate brightness gradients between two specularly located bands which synchronously slide along a facial image from top to bottom, as shown in Fig. 2 a). Then we calculate the differences between the current and mean values of the gradients, and these differences are encoded. In this case, the values of the differences equal and below zero are coded as "0", and above zero as "1", i.e. we generate a binary code representing a facial image that is similar to a "biological code" [Dak09]. These results are shown in Fig. 2: b) shows the current values of the gradients and their mean value; c) shows “biological barcodes” for each source image.

The disadvantage of the approach [Hit13] is its inability to generate the same binary code for facial images of the same person in cases when facial images are slightly different. These differences could be insignificant (but visible to the eye) variations in illumination, scale and pose of facial images, facial expressions, etc. This disadvantage makes it impossible to use the method in case of variation in these image parameters, so it cannot be applied in systems requiring high accuracy of conversion of facial images into appropriate codes.

Assessing the situation as a whole, it is possible to note that presentation of facial images in the form of such binary codes as described above can only be useful for the classification task of finding the generalized class of "facial images of people" among other classes of images which do not include faces, as emphasized by the authors of [Dak09]. That is why in this paper we propose an approach to representing human faces in the form of standard linear barcodes, developing the ideas of [Hit13].

3. AN ALGORITHM FOR BARCODE GENERATION

The generalized structure of the system for facial barcode generation consists of four main blocks: 1 –

image preprocessor; 2 – feature extractor; 3 – feature coder; 4 – barcode generator.

Let us consider the use of facial barcodes in AC systems. In this case a person facing the camera is cooperative and tries to fulfill the conditions to ensure the stability of shooting. These conditions are necessary for generating a stable barcode, especially in mobile systems. However, in real-life scenarios it is difficult to meet these conditions, therefore it is necessary to allow for some changes in facial images. Often in the AC systems based on the ideas of bimodal systems the input data are not only faces, but also voices [Mat12]. In this case, the human facial expression changes when pronouncing some passwords, a given phrase or a given conversation. Some examples of such changes are shown in Fig. 3, where all images are from the database Face94 [Fac94].

Based on the above, two major problems can be solved in block 1 (preprocessing of the original image). The first is the analysis of the parameters of the source image: the size, color and the deviation from the horizontal line of the eyes. The second one is rotation of the image plane depending on the results of the analysis, the adjustment of image size and correction of its brightness. Solutions to these two tasks can be found in [Hit13]. Feature extraction is implemented in block 2 using the difference in gradients of image brightness.

At step 3 we perform the most important task, namely the coding of features, in order to represent them as the required number of decimal digits. This problem is solved by averaging the difference in gradients of brightness on a limited number of intervals, and the quantization of the result in the range of decimal numbers from 0 to 9.

The task of step 4 in this case becomes trivial – table conversion of the results of step 3. Barcode generation also includes checksum computation for the decimal code created at step 3, and the conversion of this code into a binary matrix representing the source facial image in the graphic form of a barcode of a standard type.

The proposed approach makes it possible to generate linear barcodes from facial images in the EAN-8 format and can be used to generate linear barcodes in EAN-13 and UPS formats [UPS14].

4. GENERATING FACIAL BARCODES

The initial extraction of features from the original image is based on calculating the difference of brightness gradients in two specularly located windows with the height $H \geq 1$ pixels and the width equal to the width of the original image. The windows synchronously move (slide) along the facial image with a step $S \geq 1$. They slide only in the vertical direction from top to bottom and at each step t we calculate the distance $d(t)$ between the sub-images in the sliding windows. These distances are the required differences in gradients.

The sliding of the windows starts at the "hair/forehead" boundary, and ends at the lower boundary of the nose. Thus the difference in gradients converted into distances emphasizes the drops in brightness on the boundary of the hair/forehead, the line of eyebrows, the line of eyes and the lines of the nose/lips, that is, on the lines of the "biological code" of the facial image. The calculated values of distances represent the integral characteristics of the least changeable part of the face in case of noticeable changes of facial image parameters.

The idea of the method of gradient difference calculation and encoding using a sliding window is illustrated in Fig. 4, where *a*) shows the image with the initial position of the two rectangular windows (H - window height); *b*) shows the same image with the final position of the two rectangular windows; *c*) shows the diagram representing the distance values $d(t)$ between the corresponding areas of images "covered by the windows" depending on the number of steps t = 1, 2... T.

Let the original image have the size of $M \times N$ pixels. Let us transform the image to an EAN-8 barcode. In the initial position, the two windows U and D, consisting of H rows each, are arranged specularly relative to the current values t on the axis Y. In total we have $T = LA$ sliding steps, where L is the code length and A is the smoothing module.

For generating a barcode in the EAN-8 format, the parameter L = 7. The parameter $A \geq 8$, in general, is chosen from the condition of boundary termination:

$$T = LA \leq (M - H). \tag{1}$$

The value of T should be approximately on the lower border of the nose area (or, in some cases, between the nose and lips), which will exclude from consideration the lower part of the face and thus eliminate the influence of emotions on the stability of barcode generation.

On the other hand, if the value of

$$T > (M - H), \tag{2}$$

then it will be necessary to increase the size of the input image, in order to meet the condition (1). Increasing the size is performed in block 1, at the stage of image size correction, as described above.

Each subsequent (current for t = 1, 2, 3, ..., T) position of the axis between the windows $U(t)$, $D(t)$ is selected from the condition:

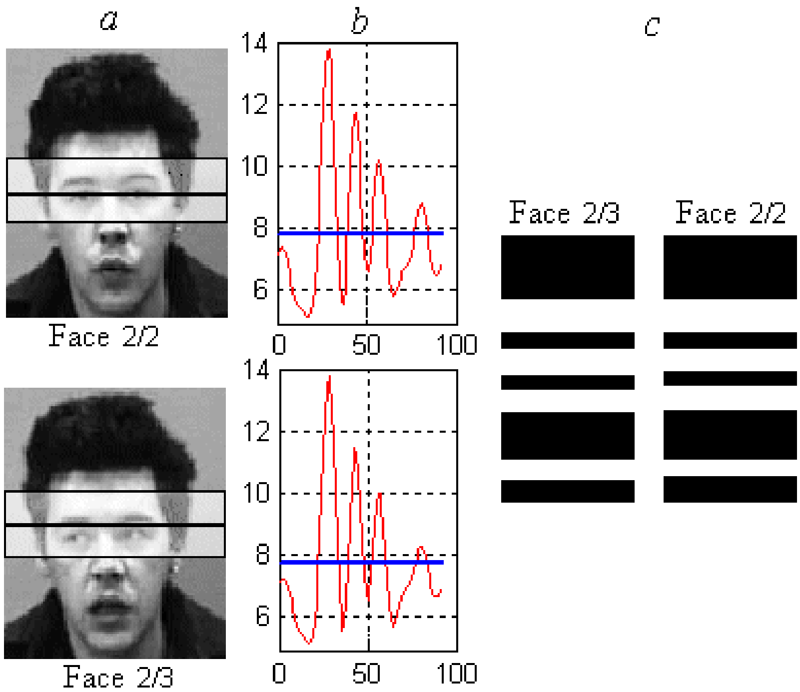

Figure 2. Explanations of binary code generation

Figure 3. Allowable variations in facial images

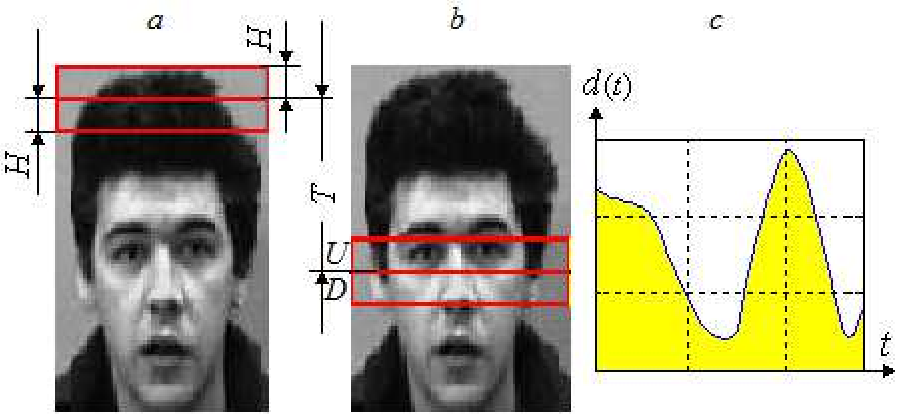

Figure 4. Explanation of the idea of the method of gradients

$$(H+S(t\text{-}1)) \le t < (M-H), \quad (3)$$

where S is a sliding step.

Now we define the distance $d(t)$ between the windows:

$$d(t) = \| U(t) - D(t) \|, \ \forall \ t=1, 2,..,T. \quad (4)$$

The result of (4) is shown in Fig. 4 *c*). This result is the input from block 2 to block 3 where the normalization and coding of the values of a distance vector are carried out.

The idea of this part of the algorithm is shown in Fig. 5, where *a*) shows the normalized distance values and their thresholding over averaging intervals A; *b*) shows the representation of the result of thresholding in the form of a 7-digit barcode.

In block 3 the following operations are implemented: elements of vector d are normalized on max(d):

$$d(t) = d(t)/\max(d), \ t = 1,...,T. \quad (5)$$

The results obtained in (5) are averaged within the interval A and quantized in the range of decimal digits from 0 to 9 using the scaling factor *scale:*

$$\overline{d}(l) = f[\frac{scale}{A}\sum_{j=1}^{A} d(A(l-1)+j)], \quad l=1, 2,..., L, (6)$$

where: $f[\cdot]$ is the nearest integer value (removing the remainder); *scale* is a scale factor, $9 < scale < 10$, which is not an integer.

The result (6) is shown in Fig. 5*b*. This result from block 3 goes to block 4 where the final 8-digit barcode is generated. The 8th digit is the checksum for the first 7 digits from block 4. An example of the final barcode is shown in Fig. 5*c*.

5. EXPERIMENTS

The proposed method for generating barcodes for facial images was tested on a database of photos Faces94 [Fac94] and a database of composite faces at different ages.

Test 1

The first 100 classes with 11 images in each class were used for generating EAN-8 barcodes. We used 112×92 pixel images in the GRAY format. We generated barcodes for the first images from each class with the following coding parameters: H=23 (width of sliding bands); S=1 (step of sliding); T=56 (feature vector length); L=7 (code length); A=8 (module for averaging); *scale*=9.5. For the other ten faces of each class we generated barcodes with the same coding parameters. Moreover, we did not perform any preprocessing of the test images to level the eyes' positions and normalize the scale of facial anthropometric characteristics. As a result of test 1, about 70% of barcodes for faces of the same class matched.

An example of the result of test 1 is shown in Fig. 6. Here *a*) and *b*) are two facial images of the same class. Column *c* contains phase correlation between the corresponding distance vectors (we see almost 100% similarity). Correlation was intentionally introduced into test 1 as an additional verification tool. Despite the different facial expressions both faces have the same barcode (see *d*)).

Fig. 7 demonstrates the results of generating barcodes for facial images with different facial expressions. From the results of test 1 we can conclude that facial expression changes, as well as changes in the eyes (open or closed), do not influence the generation of barcodes.

Test 2

The purpose of test 2 was to test the stability of barcode generation in case of changes in the brightness of test images. The parameters of test 2 were the same as the parameters of test 1. However, in contrast to test 1, the brightness of the test images ranged from 140% to 60% relative to the brightness of the original images in the database Face94 [Fac94]. The results of test 2 are shown in Table 1. It may be noted that when brightness changed by ± 20% relative to the initial brightness the result was quite stable; however, when brightness changed by ±40% relative to the initial brightness the number of identical pairs of barcodes increased almost by half.

Test 3

The purpose of test 3 was to check the stability of generated barcodes in case of mirror reflection of the original image and in case of scale, pose and facial expression variations and the presence of shadows on facial images from local lighting. In test 3, in addition to test 1, facial images of each class (from 2 to 11) were flipped along the vertical axis. Other parameters were the same as the parameters in the test 1. The test showed that the barcode remains stable in case of flipping the facial image along the vertical axis, changes in facial expressions and eyes.

The resulting barcodes are shown in Fig. 8. As we can see the barcode remains stable in case of mirroring the facial image along the vertical axis, changes in facial expressions and eyes.

Test 4

The aim of the test was to check the robustness of the generated barcodes to aging of faces. The experiment was conducted on 38 composite faces, representing age changes in humans [Mic95] from 20-24 up to 61-64 years of age. The following encoding parameters were used:

$$\{H = 22;\ L = 7;\ A = 7;\ T = 49;\ scale = 9.7 \div 9.9\}, (7)$$

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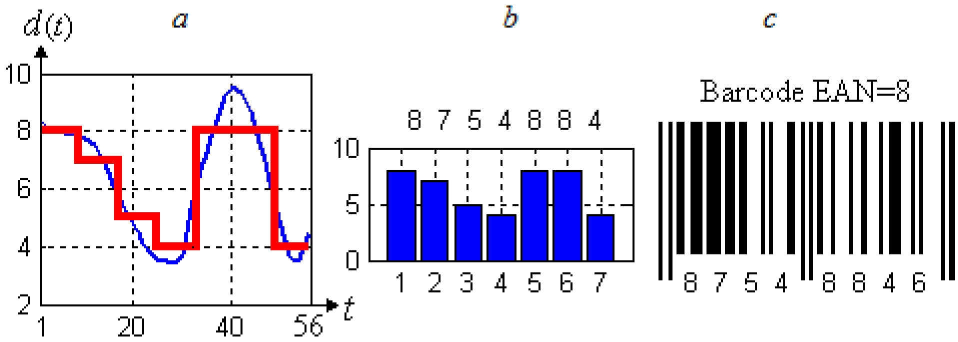

Figure 5. Illustration of the normalizing and coding stage

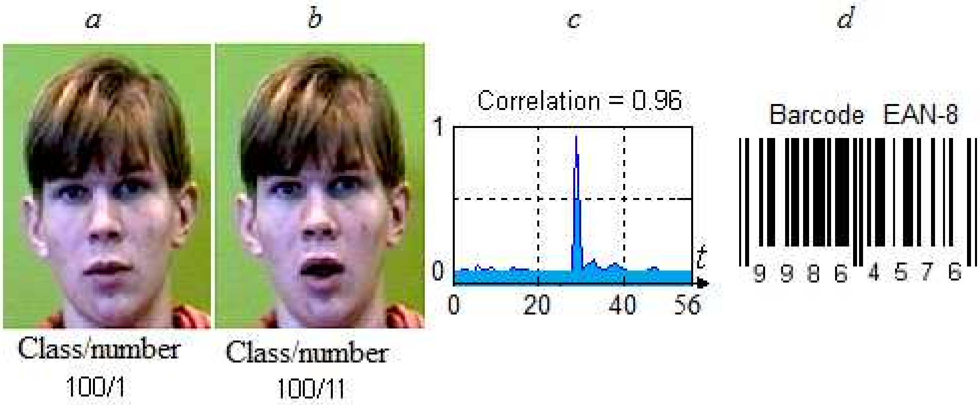

Figure 6. Results of generating facial barcodes based on the gradient method

Figure 7. Results for images with different facial expressions

Test	1	2	3	4	-	5	6	7	8
Image									
Intensity %	140	130	120	110	100	90	80	70	60
# of pairs	487	584	639	744	775	746	699	560	385

Table 1. Results of Test 2

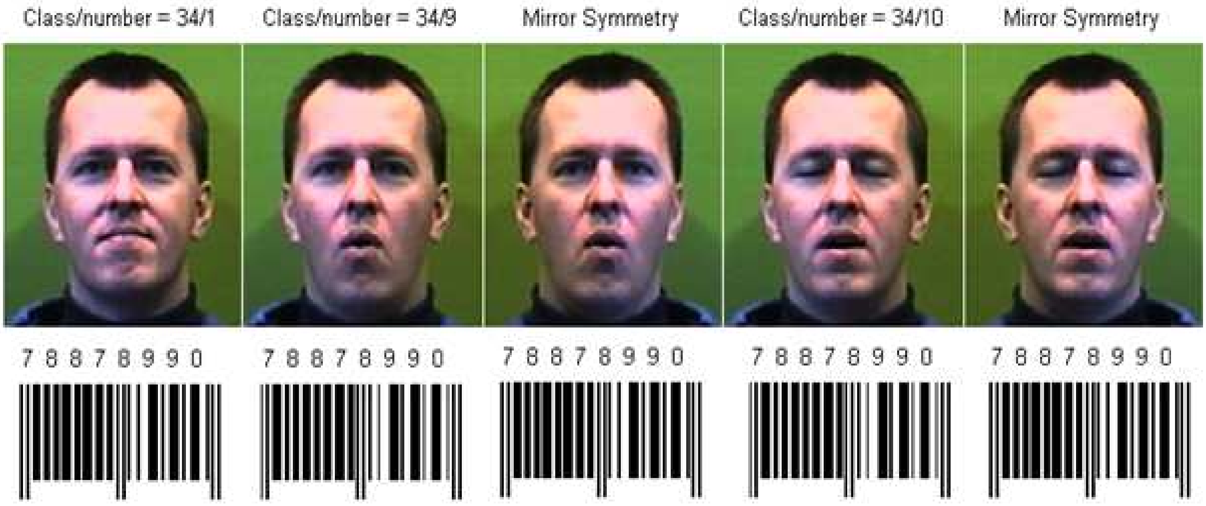

Figure 8. Example of results for facial images with mirror symmetry

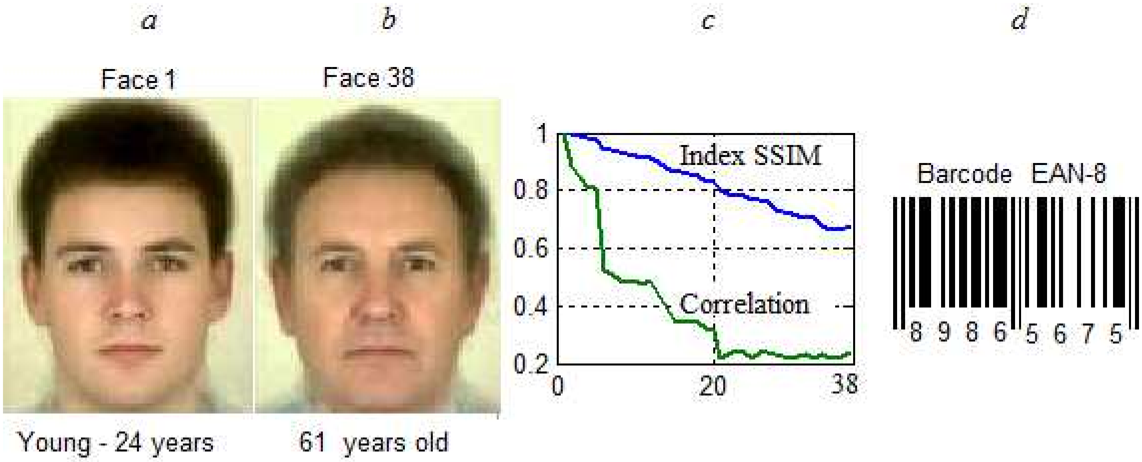

Figure 9. Barcodes for face aging

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and the parameter *scale* could have any value in the indicated interval. It can be noted that for faces of different age we got the same barcodes. The final results are shown in Fig. 9: *a*) and *b*) are faces for the ages 20-24 and 60-64 years; *c*) shows the phase correlation change and the similarity index [Dos11] for the whole range of image changes (face ages), and *d*) is the corresponding barcode.

This experiment shows that in the framework of difference in gradients, the barcode remains unchanged in case of face aging modeling.

6. CONCLUSION

The paper discussed the problem of generating linear EAN-8 barcodes for facial images. We provided the history of the problem and the known approaches. The proposed method of generating standard type linear barcodes from facial images is based on the use of the difference in gradients of image brightness. It involves averaging the gradients on a limited number of intervals, quantization of the results in the range of decimal numbers from 0 to 9, and table conversion into the final barcode.

The proposed solution is computationally low-cost and does not require the use of specialized software for image processing, which makes it possible to generate facial barcodes in mobile systems. Tests were performed on the Faces94 database and a database of composite faces at different ages. Test results showed that the proposed method is a new solution for use in the real-world practice. It ensures the stability of generated barcodes in case of mirror reflection of the original image and in case of scale, pose and facial expression variations and the presence of shadows on facial images from local lighting.

Furthermore, the method is based on generating a standard barcode directly from the facial image, and thus contains the subjective information about a person's face.

7. ACKNOWLEDGMENTS

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