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Facial Image Recovery Model

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Abstract

For the issues of facial image modeling study, the key aspects of recognition (identification) are considered, differences between recognition and identification of facial images are considered. To solve identification difficulties, a model to recover a face image has been developed. The model novelty is that it represents a 3D-type object. Due to the fact that the object is presented in a 3D format instead of a 2D one, like the image, it enables generating basic object characteristics in whole. The proposed model can also be used to recover other image spatial objects. The recovery model of a facial image is trained through a multilayer neural network, "knowledge" is obtained sequentially. The practical significance of the model developed is the ability to solve the issue of human facial image identification in general, under conditions of hindrances and regardless of the angle transformation.

Disciplinary: Information and Software Engineering.

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1 Introduction

The approaches to facial identification should be considered established, as evidenced by many academic pieces of research and international experience (Zimin and Kirsanova, 1999; Kukharev, 2001; Samal, 2002; Perepechina, 2015; Ilyin, 2017; Fitzgerald, 2018; Rubínová *et al.*, 2020). However, firstly, the issue to optimize the accuracy and time-response characteristics of the current methods, algorithms, and software identification will always be of relevance. Further facial identification system development should be targeted at creating subsystems with a set of video sequences formed by facial images read out from video cameras, as well as creating integrated interface systems. In the future, integration can be used as input information for an identification system.

Secondly, despite the fact that a significant range of studies are also devoted to the issue of facial recognition (Maximov and Tuchkin, 1987; Visilter, 2007; Shah *et al.*, 2013; Tropchenko and Tropchenko, 2012; Bulgakov, 2014; Zemlevsky, 2017; Noyes *et al.*, 2018; Kortli *et al.*, 2020), it cannot be considered completely clarified. The key difficulties relevant to the facial identification method are that the system has to identify a person using the facial image, regardless of the change in lighting conditions, angle and other face external changes. In addition, there are still challenges, such to evaluate image compression to reduce the required volume by the recognition probability, to evaluate special algorithms to store and search for key image features, etc.

The facial recognition issue is most closely correlated with the identification issue. In fact, image recognition is the signs of a certain object on a photo or video recording. In turn, identification is the process of correlation of what is found on a photo or video recording with the help of image recognition with the image that is stored in the identification system.

Within the framework of this article, the object is a face image. The key issue relevant to the facial identification method is that the system has to identify a person even under conditions of the "hindrances," that is, external facial changes (plastics, cosmetics, etc.), angle, etc. An object image viewing (reprint) model proposed in the article is the solution to this problem, in the framework of which methods to restore three-dimensional object characteristics out of two-dimensional objects are used. The model can be used to reprint any spatial objects.

2 Results and Discussion

A representative object image reprinting model (OIRM) can be used to reprint any spatial objects. The model is a sequence of $E_0 \ldots E_n$, presentation levels that consist of the object image reprinting level and the local detector, and each of these levels consists of local feature detectors (hereinafter - FD) and input data.

To train OIRM, the image should use a multilayer neural network, which, in turn, should be trained sequentially.

When data are processed at the previous level, the received result is transmitted to the subsequent level input. This will ensure a final result from input data processing, which is represented not only as a value of a local detector activation function but as an array of object parameters processed by the local detector.

The E_0 input level should be supplied with data from local frame-by-frame image sequences, which are extracted from the video image (Figure 1). After the first level training is completed, the video fragments are presented as graphs.

Thus, local detectors that have been learned at the first level are presented as graph nodes. Each i-level, for $i \neq 0$ groups data locally. Other levels are trained in the same way. As a result, the trained model can form an image that is extracted from the video segment as a limited number of local detectors, each containing an integrated object representation.

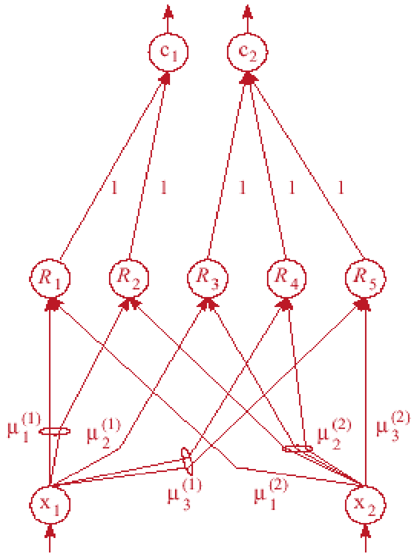

Figure 1: A video fragment presented as a graph.
x – input image, R – a set of frame-by-frame sequences, c – output result.

The OIRM includes the following components: the first is the number and local detector location (D_1), the second is the number of clusters K_c for each E_c level, the third is the number of $E_0 \ldots E_n$ representation levels (reprints), and the fourth is the internal detector parameters. An example is the $x_n \in X$, image, the image recognition function of which has – $g: X \rightarrow Y$ – represented as a vector of the length n of the function attribute. The set of y ∈ Y classes that are used in this function are represented as its value, and, in turn, it is modified for a certain task.

To verify the OIRM, we suggest using the function h: X →Y for a subset of paired attributes and values D = {(x0, y0), . . . , (xm, ym)}, which, in turn, approximates the g recognition function to all ranges of definition. The image must be applied to the first OIRM layer so as to calculate h(x). This is followed by the activated local detectors for each of the subsequent model levels. Here, the binary value is the result of the OIRM processing output, which is activation and determines the ratio of a particular image to a particular class corresponding to it.

Binary value:

1 - at the model output, an image parameter probability estimate is calculated. To solve classification tasks, the original form of the model can be used. The set of classes y ∈ Y consist of two elements; it equals to {0.1}. If the image depicts an object belonging to the desired class, the g = 1 function is used.

0 - in the reverse case.

The task to identify the object image among a set of classes includes the sequential object image check multiplied by correlation to an image of the facial identification model, in other words: the function g′ ∈ X′, the magnitudes of which are the sum of classes Y', for i-class Y ′ = {yi, Uj ≠ i yj}. Model training is carried out for each of the classes. The diagram of the two-level model is presented in Figure 2.

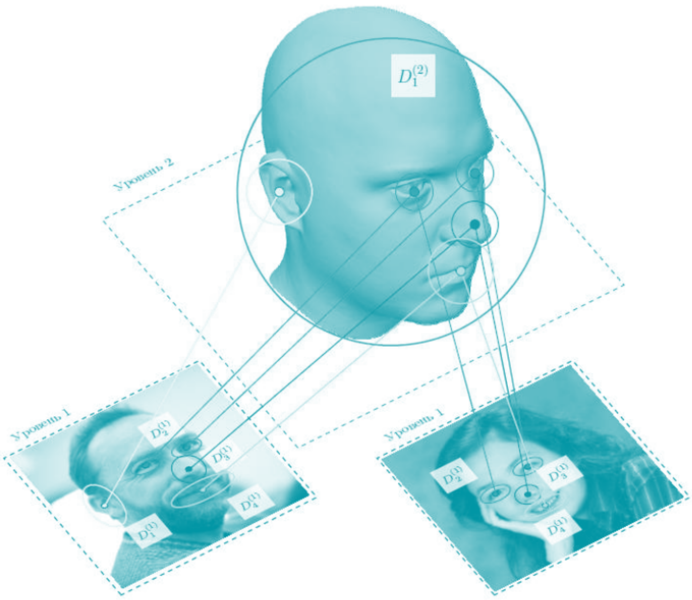

Figure 2: Object representation model with two reprint levels

It is important to consider the fact that a local detector is not only the key element of the object image reprinting model, but an individual mathematical construction as well. Its role can be compared to that of artificial neural network neurons (Stadnik, 2004; Vasin, 2011; Alghaili *et al.*, 2020). The results of local detector data processing obtained from the previous level are transmitted to the local detector input. The output data are subsequently sent to the next OIRM level.

The following definition to a local detector can be given: let us assume that there is a particular n-aggregation of 3D points with given vector coordinates. This aggregation is a 3ûn matrix, in turn, it is a set of B. The 3D point plane projection is represented as follows: *Br(B) = CB*, where C is the matrix. Based on the local detector definition, the matrix solution will consist of an array of points b with coordinates (x, y). Such a definition for the local detector accurately describes its structure, behavior and the result in the facial image identification model (hereinafter referred to as the FIIM). $Mr(M,B) = M$ – is an affine transformation operation in the three-dimensional space. The object projection is – $b0 = Br(B)$. Let us give the following example: suppose that there is some set of transformation matrices *T1..Tm*, and some set of projections b1..bm, such that $bj = Br(Tr(Tj,B))$. For such sets, the FIIM will use the functions $DI(bj) = b0; DM(bj) = Mj$, which, in a particular case, is a local detector.

The local detector interpretation universality will help get rid of the object shape when there is no need to use it. For example, when $b_i = T_iB, b_j = T_jB$, b_i, b_j – is the object representation, the following formula will be suitable:

$$\begin{cases} D_I(b_i) = D_I(b_j) \\ \frac{D_T(b_i)}{D_I(b_j)} = \frac{T_i}{T_j} \end{cases} \qquad (1)$$

Let us supplement the local detector definition for objects belonging to different classes. Thus, let us assume that $B_0 \ldots B_n$ – is an aggregation of three objects, $Y_0 \ldots Y_n$ – is an aggregation of classes, and $y(B) = Y$ – is a definition of a three-dimensional object belonging to a specific class. Such a definition of the local detector in FIIM will enable the most accurate comparison of a 3D object to a certain class.

Let us give the one-component classification function y_k' , for a certain class Y_k such that

$$y_k`(B_i) = \begin{cases} 1, y(b_j) = Y_k \\ 0, \text{in the reverse case} \end{cases} \tag{2}$$

Then $(D_I^k D_T^k)$ – is a discriminative local detector for the class.

Y_k, if predefined by functions D_I^k , D_T^k , such that

$$\begin{cases} D_I^k(B_i) = y_k`(B_i) \\ D_T^k(B)_i = \begin{cases} T_i, D_I^k(B_i) = 1 \\ \emptyset, \text{in the reverse case} \end{cases} \end{cases} \tag{3}$$

A local detector must firstly ensure object recognition, secondly, it should define a specific transformation applicable to the image.

To evaluate the local detector efficiency, the concept of the transformation recovery error function is defined:

$$J(D_T, b, T) = \frac{1}{2} \sum_{i=1}^{m} | D_T(b^{(i)}) - T^{(i)} |^2 \tag{4}$$

The local detector receives input data in the form of 2D images. The images, and therefore the local detector, have no data on the object vector properties, i.e., the additional coordinate Z. Provided that this coordinate is known, to determine the object transformation would be a simple task that does not require specialized models using a local detector.

For such a specific local detector characteristic, the following features are defined:

Let us take the number of the transformed facial image objects b_i, b_j, to which T_i, T_j are consistent with. For the case where $b_i \approx b_j$,but $T_i \neq T_j$ the local detector will not be able to optimally correctly recover the modified object from the image. Therefore, $D_T(b_i) \approx D_T(b_i)$.

When 3D objects B and Q which belong to different classes Y_1, Y_2 produce similar projections b ≈ q, the similar result is achieved for the identification function D. That is: $DI(b) \approx DI(q)$.

There are such options for object transformation (T) and imaging when a local detector can't be built ($J \rightarrow 0$). Any possible deviations of the facial image object 3D forms on different projections (facial images) have an adverse effect, while the object facial image variability increases the average error value within the class. Theoretically, there is a negative relationship between the recovery accuracy of the modified image object, the face image size, and face image aggregation. Reprinting of the whole facial image object with a local detector only is a very difficult task, more difficult than the recognition task.

At the first level of the model, a local detector $DI(0)$ is presented, the ensembles and values of which are different for each particular object of the face image, capable to respond to the object face image sections at one angle or another. Data obtained from the first level of the local detector model are required to train a high-level local detector $D_j^{(1)}$, representable for local detector composition, a 3D feature map in particular - the first level local detector, where local detectors are located in accordance with the equivariant transformation data. The relevance of the object to the category determines the identification function for the second level local detector.

Therefore, the proposed OIRM can completely solve the issue of facial identification in general, in conditions of various hindrances and regardless of the change in the angle.

3 Conclusion

In this article, the issue of facial image identification methodology is focused on, pointing out the fact that the system has to identify a human facial image under various "hindrances" that integrated facial changes (including cosmetics, plastic surgery, etc.), as well as the object angle. To tackle the problem, an object image reprinting model was developed and justified, using methods to recover 3D object characteristics using 2D characteristics.

4 Availability of Data and Material

Data can be made available by contacting the corresponding author.

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