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Modern Problems of Face Recognition Systems and Ways of Solving Them

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ABSTRACT

Currently, the face recognition system is applied in various fields such as classified materials, file transferring, and general human interaction and innovative technologies, including cell phones with owner recognition function. The relevance of this research lies in the need to consider problems touching upon the increase in the efficiency of such technologies. The objective of this study was to improve the algorithm of the face identification system from different sides in order to demonstrate appropriate results. In the course of the study, a method based upon deep neural networks was applied through the projection of layers. As a result, a receiver operating characteristic curve was constructed to evaluate the quality of binary classification, and loss functions for deep learning, data distribution, and algorithm accuracy were demonstrated. Proceeding from the results obtained, it was found that the selected face identification system is resistant to each of the influencing factors (make-up, lighting, posture, etc.) considered separately in the work. The operation principle represents an original technical solution for face recognition problems when images in the database have discrepancies, which is a typical scenario in the actual world. The testing accuracy in this work reaches 95.04%.

1. INTRODUCTION

Self-driving vehicles, manual labor automation, robotics, data monitoring and other automated devices depend on the formation of facial recognition technology. The face recognition system occupies a significant position in the area of computer vision and in the intelligent collection and processing of image-based data. Thereby, the face recognition system in the modern world plays a significant role, since owing to this technology it is possible to establish a certain individual. For this purpose, the software makes adjustments to biometric ID-cards (identification card), as facial features in a digital template, with the further use of an algorithm for evaluating and comparing two images [1, 2]. Existing face recognition technologies differ from each other in terms of image identification methods, however, most of them use the following course of action – establishing and fixing an image, standardising it (to remove background excesses) and comparing the image with an existing database for convergence. Most of the algorithms use either the facial matching principle or an appearance-based mechanism where the entire face is matched with database images. More up-to-date methods include facial distortions, 3D recognition, thermal cameras, and subcutaneous scanning (vein matching) [3, 4]. However, in some cases, the face recognition system may erroneously match two different images, which is called a false result. With various object identification problems, the functions taken will directly affect the system output. As an alternative, a false result means that the same face does not match in two different photographs. These kinds of errors have negative consequences for democratic management. That is, it creates a privacy issue being acutely touched upon in controlled environments [5-7].

For instance, in the work of Johnson et al. [8] it is indicated that the use of facial recognition systems could lead to further inequality during federal security forces arrests. For such measures, attention should be paid to the development of policies and supervision that restrict the discretion of officers while using facial recognition systems. Indeed, security is of utmost importance, whether it is the security of data, human life, etc. Also, in the work of Revathy et al. [9] it is noted that face recognition technologies provide a secure online voting process. In the research of Bagchi et al. [10], where the face recognition system was developed, the results of the study show that the implementation of such a system may be effectively used for human security, as well as for commercial and domestic purposes. It is also worth considering that in recent years due to the Covid-19 pandemic, in their daily lives people have been using face masks in public around the world. In this regard, face recognition with masks has become a crutial duty of computer vision. That means, it is necessary that the system recognises a face along with the mask in the photo or video. In the work of Tamilselvi and Karthikeyan [11], the authors suggest a face recognition system that can be applied in the field of healthcare. This developed algorithm can be implemented in poorly lit situations in which face fixation is disrupted due to external factors (poor illumination, weather conditions). In the research of B. Nassih et al. [12] a 3D approach to face recognition to overcome many problems is

suggested. The results of using it depict an efficiency reaching up to 99.11% in recognition rate.

Thus, in the aspects of computer vision, face identification technology has developed and formed significantly. However, there are a number of problems and challenges, as well as social factors that may affect the reliability of the system. These factors were selected based on an examination of previous studies that noted problems with previous face recognition systems. Facial recognition systems need to be improved in several ways in order to achieve better results. In this regard, this study addressed several problems in this area.

2. MATERIALS AND METHODS

The research methodology was based upon a method of deep neural networks due to the flexible design of layers and the effectiveness of the results. The advantage of the method of deep neural networks is that they can model complex nonlinear relationships. Architectures of deep neural networks generate compositional models, where the object is expressed as a layered composition of image primitives. Additional layers allow compositions to incorporate features from lower layers, providing the potential to model complex data with fewer nodes than an equally efficient flat network. The screening process takes place through the analysis of 80 nodal points of the human face. This method is widely used to solve the problem of face recognition.

For the start a face image database was used with a set of photographs of 77 models. For this, participants of different ages, genders, complexions, nationalities and types of faces were selected. The photographs have been pre-edited in order to reduce external hindrances in the background of the images. Editing consisted of correction of curves and lighting. The point of image editing is to not face the loss of the necessary data that can be extracted from photographs or that function as key factors in face recognition during their further exploitation. Each set displays a range of emotional expressions: rage, discontent, fright, fun, anguish, surprise, and neutrality. The FaceApp program was used in order to cover the issue of the impact of applying makeup on the performance of the face recognition system. The software works without the need to connect to the Internet, which guarantees the reliability of the confidentiality of photos without transfering to third parties [13-15]. When using this application, make-up is applied to the face automatically. To compare the empirical distribution functions of two samples, the Kolmogorov-Smirnov test was applied with α equal to 0.05. Thus, for FaceApp, the selection will look the following way:

1. H1: F_notmakeup.
2. F_ yesmakeup.

The results demonstrate ROC curves (receiver operating characteristic) where the following code was applied:

1. TPR “true positive model rate sensitivity” = TP/P.
2. P = Positives.
3. FRP = FP/N.
4. N = Negatives.

The loss function selection was expressed using the formula:

$$L_i^{det} = -(y_i^{det} \log(x_i) + (1 - y_i^{det})(1 - \log(x_i))) \quad (1)$$

where: x_i is the probability of a face suggested by the network; $y_i^{det} \in \{0.1\}$ refers to the calculation of the original image about the results of the face annotation.

A regression loss function based on a photograph of a face is expressed the following way:

$$L_i^{box} = \left\| \hat{y}_i^{box} - y_i^{box} \right\|_2^2 \quad (2)$$

where: L_i^{box} stands for network output; $\hat{y}_i^{box}$ demonstrates the candidate's position prediction; y_i^{box} demonstrates the actual position of the candidate.

The lower detection pixel limit for face size was set to 70, with some photo sizes scaled down to reduce the input size. This technique may be useful for increasing the speed of the recognition module. Further, after the photo combinations have been generated, the appropriate photo data may be applied as an input to the neural network model. The input photo initially passes through the entire convolutional network. Then the photos go through a smaller network model - Pnet. As a result, it is possible to get the boundary field of all potential similar faces and the probability of being in the database. Following the principle of output sources acquired through Pnet, editing without the maximum checks allows one to remove images of candidates for a face with a high level of match. In general, this optimisation algorithm is based upon image compression.

At the last stage, an algorithm for classifying photos was introduced in terms of the degree of quality and efficiency of face recognition. That is, the photographs were subdivided by partial consideration of the features of the images, which can mainly affect the time reduction within which aspects of the image are processed. Also, the latest achievements in the field of face recognition systems were analysed, current research papers were presented, where the authors suggest innovative developments in the field of this technology.

3. RESULTS

Facial recognition systems exploit either offline data or real-time objects. Hence, in this research, at the initial stage, the process begins with uploading photographs of faces to the database for subsequent analysis. While parsing, the system considers the following facial features: the presence of cheekbones, eye shape, the length of the nose, etc. For this, the algorithm is used in such a way that the photos are divided into small parts for comparison. And further the face images are stored in the database for comparison. During the comparison, the face is either detected (with an accuracy of more than 90%), or remains unknown. The objective of the recognition algorithm is to separate face characteristics that are determined by the internal shape and surface texture of the face, as well as external image rendering conditions such as lighting and posture. Depending on how to deal with extrinsic imaging parameters, there are two major face recognition methods strategies: a model-based approach and a statistics-based approach. Model-based approaches consider extrinsic parameters as separate variables and explicitly simulate their functional role. Statistics-based approaches analyse images directly using statistical methods and technically do not distinguish between intrinsic and extrinsic parameters.

Face recognition volatility. This factor is associated with social problems, including the aging process, changes in facial expression, make-up, which includes changing hairstyles. Therefore, the reliability of a face recognition system may be affected by the moods of users. In this category, the objective

was to extract features that are identical to facial make-up. Based on the results obtained, an ROC-curve was constructed, which makes it possible to evaluate the quality of the binary classification. For this purpose, first the problem and thresholds were separated. Next, the data need to be imported and then generated using Jupyter. The estimates of the regression model were obtained, with the help of which the ROC curve itself is visualised (Figure 1).

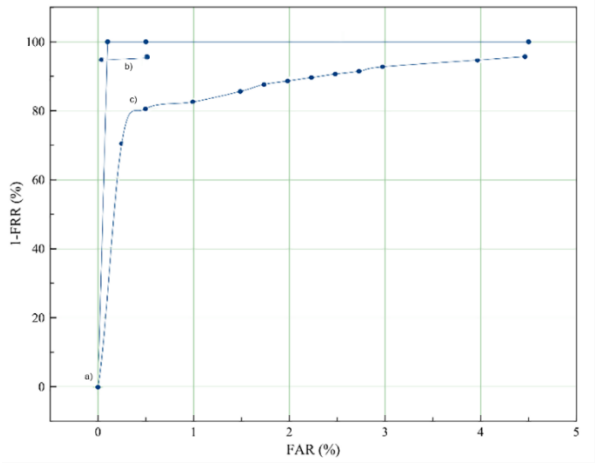

Figure 1. ROC curves for: a) faces with no make-up; b) faces with make-up; c) faces with and without make-up

Analysing the raw data in Figure 1, about 5% error rate will be observed in the identification of people wearing full make-up. That is, the selected face verification system is resistant to each of the influencing factors separately. Basically, if the individual effects of each are not that significant, the combined effect is. Also, in the course of study, it was noticed that the use of lipstick cannot change the accuracy of face recognition. However, make-up may drastically change the look of a face, and it requires manual techniques to achieve a face recognition system that ignores make-up on faces. In other words, it is necessary to introduce programs into the database that have the ability to automatically apply make-up to faces from databases with further comparison.

When applying a deep convolutional neural network, the system characterised the input face photo using the output vector signals. That is, the main function was to extract information. Figure 2 depicts the results of the deep learning loss function, as well as the distribution of the data and the accuracy of the algorithm. Based on the data obtained, it can be concluded that the performance throughout the entire operational period remains unchanged, despite the fact that the loss function has a decreasing character. At the next stage, the accuracy data of the face recognition system is obtained, showing a high accuracy of 95.04% (Figure 3). Tests were carried out for each tested sample. Thus, calibration and image pre-editing were unrelated.

The majority of the designed face recognition systems consist of two main modules - feature extraction and classification. The face is an essential biometric component in identity verification and identification. Typically, it is used as a secure confirmation measure. The network itself usually consists of several layers of connected artificial neurons that perform various kinds of calculations. Connections between neurons are weighed and form network parameters.

Database matching is a tested and reliable method of face recognition which exploits still images of an object as the basis for matching a live photo or video using a cascade classifier designed to compare photos. In this work, generally, the method used is not innovative due to the long processing time. The database includes mainly people's faces where emotions are not expressed. Therefore, the problem of expression recognition is significant for improving the quality of daily life in various applications. And to quantify the emotional state of a person, emotions are mainly divided into 6 types: happiness, surprise, disgust, fear, anger and sadness. The Ada-boost and Vioal-Jones classifiers may be used to recognise people's faces given the amount of information and processing power to train a model to distinguish faces, although they were designed for solid objects. After identifying the face on the test image, all noises are removed from it. Afterwards, the model highlights the shape of the face in the photo and then tries to match the edited image sample with the ones in the database. At the last stage, the magnitude of similarity considered, the accuracy of matching is assumed. The accuracy of correlation with the database is increased due to the usage of neural networks for training the rubricator model, the quality of the trained model for face recognition from the database is improved by correct setting number of the activation layers and the number of neurons in a separate layer of the neural network.

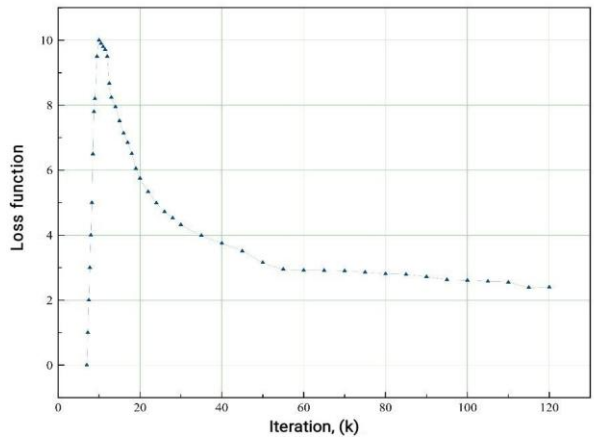

Figure 2. Algorithm performance tests

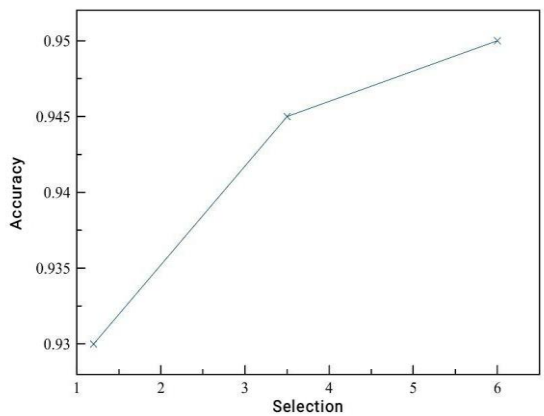

Figure 3. Algorithm performance tests

Faces are matched by using vectors facilitation based upon training test photos. Any face image may be represented as a point in the space of intrinsic images, and is reconstructed by their linear combination. As the number of intrinsic images increases, the quality of the reconstruction improves. It is

worth considering that the image consists of a large number of pixels, which have the ability to rearrange into a matrix depending on the intensity of the pixel in relation to neighboring ones. This matrix can systematise human facial features using suitable algorithms, such as Principal Component Analysis (PCA) or Linear Discriminant Analysis (LDA). PCA is applied in order to extract features from a photograph that have the highest chance of correct distinguishing of a person's identity, and LDA seeks to find certain areas in the matrix that can be used to identify a person's face. These algorithms combine a non-basic matrix into a primitive column vector, forming a vector of training and test photographs, which are then adjusted to determine the exact match of the two photographs. Although, converting a photo to a column vector favors the best matching facial features through careful checks and errors, it is the most simplified way to check for accuracy of facial matches by using a single column vector.

Deep learning. In the area of computer vision, human identification technology is an algorithm that has the ability to detect an object in a video or photograph. Modern recognition algorithms are mainly based upon high-performance chips built upon a multi-level neural network and software structure through connected stream processors. In fact, object detection is divided into three phases: a specific zone selection, feature extraction, and regression classification. At these stages, a number of problems may also arise, for instance, the low efficiency of the strategy for selecting a recognisable area. A considerable quantity of tasks in the field of computer vision is formed on the basis of deep learning and neural networks. Deep learning is classified as a branch of representational learning based on artificial neural network data. Deep learning includes supervised, semi-supervised and unsupervised learning. Face recognition system with deep learning application can be divided into two kinds: two-step, and one-step face detection. Two-step detection is based upon the selection of possible areas of faces with the extraction of certain features, followed by classification and regression. One-step face detection consists of performing the task of identification and systematisation without including step-by-step training. Therefore, deep learning has made significant progress in the systematisation of faces and has a wide scope of application due to its versatility.

When creating face recognition systems, it is necessary to focus upon particular attention to the analysis of instruction generation in face detection and recognition modules. Based on the results obtained, it follows that the calculation process occurs within a short period of time. The integrated face recognition system has efficient performance also in online mode. However, it is worth mentioning that one may encounter an issue having a considerable database, since face photos may be of low quality due to poor lighting or other obstacles when capturing a face, which complicates the computing. If the volume of images is violated, the error leads to a violation of the system, i.e., that affects all modules of the algorithm. With a large data set, the even distribution over all stages is violated. This leads to the problem of the performance algorithm of the system. In this case, it becomes complicated to detect differences between photographs, since the faces in the photographs may look identical. Generally, the major issue in the face recognition system is the degradation of the photo quality or the appearance change of a person. In this regard, the final inserted algorithm conveys the correspondence of key points in partial face recognition due to the unique features of reliable matching due to the distance between specifically selected points. When the last algorithm was enabled, the photos were sorted into groups according to the presence of similarities between them. The input variables were entered according to the following principle:

$$k * a * b * c \tag{3}$$

where: k is the number of photographs; a – the width of the photo; b – the length of the photograph; c – the height of the photo.

At the next stage, the algorithm combines the images that were received from the previous module. The merging layer is designed in order to actively reduce the spatial volume of the image, reduce the number of parameters and the space they occupy, as well as the processing speed. Having received the input data, the algorithm classifies the images according to the similarities between them and sends the result to the output source. The major idea of this technique is to recognise faces under various interventions or changes (for instance, posture, poor lighting, make-up). The application of this process reduces the processing time required for face recognition. In general, the applied deep learning has proven to be excellent in the system. Deep learning neural networks are spread throughout the algorithm, and therefore it is impossible to fully process and explain the mechanism, since each neural network has millions of unique parameters and neurons. When properly applied, the recognition system can be actively used for security purposes. The suggested technique helps to achieve high accuracy and can be applied in many areas, such as the underground, entry and exit control in the organisation, in security services, etc.

4. DISCUSSION

In general, a lot of progress has been made in the field of face detection and recognition for various purposes in scientific activity. But each system faces a number of problems that have been analysed in this research. These problems represent the changeability of a person's appearance, their emotions, improper lighting, etc. In addition, in face recognition systems, the use of cameras as a method of obtaining a face image is essential. The camera is used to capture images of faces through face recognition and then edited using normalisation, feature extraction, and classification methods to identify or recognise the identity of the face. In the work of Azimi and Pacut [16], it was noted that images of faces expressing dissatisfaction are fundamentally different from expressions without emotions, and the results show that the effects of makeup and various mood expressions are insignificant themselves, so there is a joint effect.

The results of the experiment justify the effectiveness of the proposed method. Sharma and Patterh [17] proposed an efficient system of invariant face recognition under various conditions and image quality, implemented on the Matlab platform. At that, each face image in the database is represented as a feature point in the face space. Within classification, the representativeness of a face database depends on how the prototypes are chosen in order to account for various modifications, as well as the number of prototypes [18, 19]. The choice of prototypes and their number affect the error rate. In practice, only a small number of them are available, usually from one to several dozen.

In the work of Ge et al. [20], the authors offer the combination of other multimodal simulations with a recognition system based upon deep learning for the technology improvement. There are a number of automatic face recognition algorithms, some based upon features and others upon deep learning. To solve such problems, a neural network is embedded, which enhances the effect of features that directly interact with facial expressions. A deep neural network combines appearance and geometric features to produce more accurate and reliable recognition results [21]. Deep learning development brings promising potentials in face identification. There exist several face recognition algorithms based upon deep learning. One of such algorithms is the Multitasking Cascaded Convolutional Neural Network, which combines face recognition and detection of facial key points. This method uses three various deep neural networks in order to generate a face recognition system through a cascade. This incremental calculation filters out background information, which gives focus to the face area at a premature stage of face recognition processing. Further, it achieves ultra-accurate prediction results through increasing the amount of calculations in the subsequent network. Using this algorithm, it is possible to recognise faces in real time. The neural network has a unique receptive field size, and in order to generate images of different sizes, it is necessary to go through the image pyramid processing method [22]. Multiple face detection is performed by generating more image pyramids based upon face detection.

In the research of Zhao et al. [23] a deep neural network for deep coding of facial areas was designed, where a new face alignment algorithm is used to localise key points within faces. In addition, such a system can reliably handle various facial recognition attacks in different contexts. However, a combination of multiple algorithms, each of which handles a particular variation well, will not necessarily result in a robust system opposed to all variations.

Convolutional neural networks are becoming increasingly popular. There images function as input data, which makes it possible to encode certain features. In their research Lv et al. [24] suggested a multitasking cascade convolutional network algorithm for simulation reorganisation and pre-editing of a face image, the results of which show that the accuracy of the algorithm demonstrates excellent applicability. A convolutional neural network maximises face recognition by extracting features from images and sorting them into categories, as well as by passing through various channels using a linear sequencing operation. Commercial interests in the field of facial recognition technologies are gaining momentum due to the requirements in security systems. In general, such technologies have the potential for widespread use in various fields of activity. Facial recognition systems may also be used in mobile devices as user authentication or identification in social networks, but even there they face such problems as limited bandwidth, privacy and security [25-26].

Thus, the look of a face is influenced by external factors, including lighting, posture, expression, etc. The options caused by external factors provide different variants, due to which it can be difficult to determine a person. It is complicated to achieve high identification accuracy with traditional methods, which forces the development of algorithms that can cope with adverse influences due to external factors. That is, the actual world is in need of systems being able to recognise any face images that are recognisable by a person.

5. CONCLUSIONS

In the study, the authors focused on such a problem as data-limited face recognition tasks where face images are captured under various adverse conditions. To this end, the study offers a technique where the system considers facial expression, its change with the application of decorative cosmetics. The results obtained on a manually collected primary data set show that the selected face identification system is resistant to each of the influencing factors considered separately in the work. The principle of operation represents an original technical solution for face recognition issues when images in the database have discrepancies, which is a typical scenario in the actual world. The testing accuracy in this work reaches 95.04%. Around 5% error rate will be observed in identifying people with full make-up.

The computing process as a whole takes place in a short period of time. The embedded personal identification system has decent performance also in real time. The merging layer showed a reduction in the spatial volume of the image, a reduction in the number of parameters and the space they occupied, as well as in the processing speed. The application of this process reduces the processing time required for face recognition. The suggested technique assists in achieving high accuracy and may be applied in several areas, such as the underground, entrance and exit control in any organisation, in security services, etc. The results presented serve as the basis for the development of face recognition systems. If properly applied, the recognition system can be used for security purposes. In general, the applied deep learning has proven to be excellent in the system. For further research, it is necessary to develop a network with an extensive storage space with a compact encoding in the feature set.

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