

ANALYSIS OF CONVOLUTIONAL NEURAL NETWORK METHODS FOR FACIAL RECOGNITION

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Nurjanov Furqatbek Reyimberganovich

PhD, associate professor, Nurjanov Furqatbek Reyimberganovich
University of Military Security and Defense of the Republic of Uzbekistan

The article discusses the main stages of the process of analyzing and recognizing facial images using a convolutional neural network and their advantages, including eliminating uncertainties that arise during facial recognition. Also, from a scientific and practical point of view, the architecture, requirements, and systems for developing convolutional neural network models for facial recognition are described.

Key words

images, face recognition, methods, identification, neural networks, artificial intelligence.

Introduction

In the course of developing and improving methods for image preprocessing, recognition, and identification using modern computer technologies and artificial intelligence worldwide, special attention is being paid to the creation of increasingly complex applied projects. In this context, the demand for technologies and software tools for facial recognition based on convolutional neural networks (CNNs) has been growing rapidly. These technologies are widely used in various fields, including security systems, the military sector, healthcare, monitoring and control at airports and metro systems, access control to buildings or software systems, video surveillance, forensics, and a number of other areas. [1].

Today, in many foreign countries, including the United States, Germany, the Russian Federation, China, Japan, the United Kingdom, France, South Korea, India, and other countries, extensive research is being conducted to address scientific and practical issues related to the development of facial recognition systems using artificial intelligence-based convolutional neural network methods for facial recognition and identification.

In particular, in our Republic, special attention is being paid to the development of measures for creating and widely implementing automated

personal identification systems based on biometric technologies (such as facial images, ear shape, fingerprints, iris, palm prints, gait patterns, and voice characteristics). Based on the analysis of the presented data, systems for facial image preprocessing, processing, storage, and personal recognition and identification using artificial intelligence methods occupy a prominent place.

Indeed, based on the reviewed sources, convolutional neural networks are currently considered one of the most effective and widely used approaches for facial recognition. However, an analysis of research conducted in the field of convolutional neural networks—one of the scientific directions of facial recognition—shows that the problems arising in the development of automated facial recognition systems have not yet been sufficiently studied.

Adaptability and challenges in facial recognition using convolutional neural networks. Facial recognition systems optimize the allocation of computational resources, enabling deployment in modern biometric and security applications with real-time operation. Currently, widely used convolutional neural networks (CNN) demonstrate high performance in extracting local features from facial images.

However, CNN have certain limitations in fully capturing the global context and the complex geometric relationships within facial structures. These limitations are particularly evident when parts of the face are occluded (masks, glasses, headwear), under low-light conditions, or when images are captured from challenging angles.

Thus, although convolutional neural networks are highly efficient in automatic facial image processing and feature extraction, significant challenges remain in both the scientific and practical development of facial recognition systems. Addressing these challenges through the development and improvement of new approaches, architectures, methods, and algorithms aimed at enhancing accuracy and reliability remains a key task in the field.

Convolutional neural networks used in facial recognition belong to a class of artificial neural networks designed for image processing and computer vision tasks. In general, convolutional neural networks automatically learn features from images, enabling high-accuracy analysis of data (Figure 1). In addition, by processing layers of facial images using convolutional neural networks, complex features can be extracted.

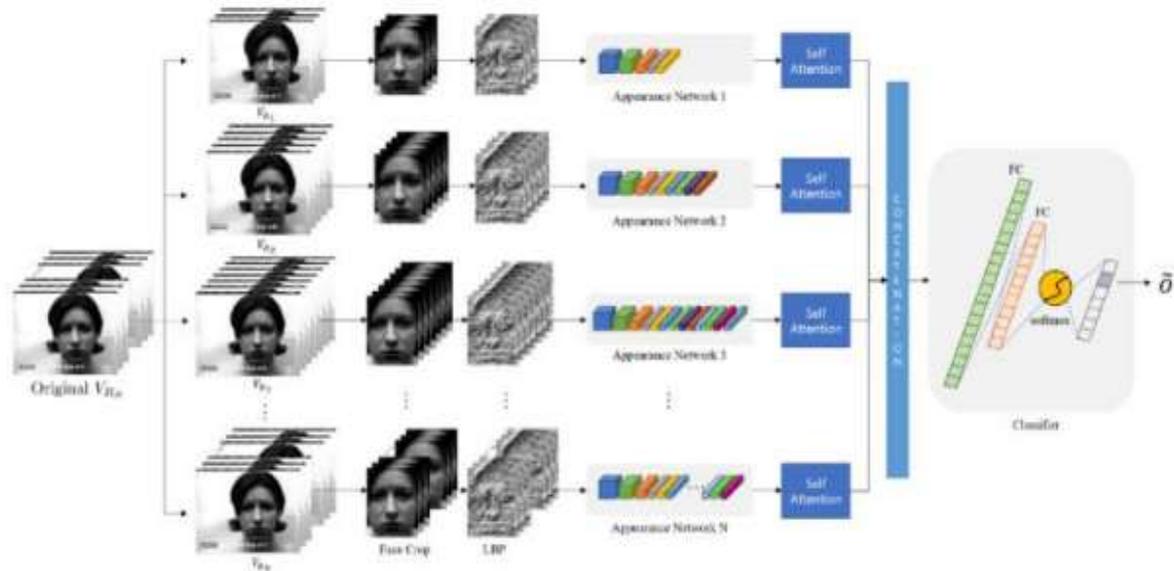


Figure 1. CNN architecture for feature extraction in facial images

In Figure 1, convolutional neural networks divide an image into multiple layers, with each layer detecting different features of the image (edges, shapes, and faces). The networks learn from the input image, modifying the necessary features or propagating them through the layers to achieve the final result required for facial recognition. In this context, face and object detection systems necessitate the development of methods to identify and process information present in images or videos [2]. These requirements are crucial for ensuring the efficient operation of the system, achieving high-accuracy results, and optimizing the facial recognition process.

Material methods

To ensure the effective operation of face and object detection systems, the following requirements need to be developed:

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The convolutional neural network system must possess strong learning capabilities to adapt to variations in facial expressions and poses.

A training dataset that accounts for the diversity of facial images, including variations in lighting, angles, and expressions, is required.

Methodologies need to be developed to consider the 3D position of the face, enabling the system to account for differences in angles during facial recognition.

2. Requirements for large datasets in object and facial recognition

Large and diverse datasets: Facial images should be trained on extensive datasets that include a variety of conditions, such as different lighting, facial expressions, age, gender, ethnicity, clothing, and other external factors.

Study of facial anatomical features: Comprehensive datasets are required to capture variations in facial structures, such as the eyes, nose, mouth, and cheeks, to enable accurate recognition of individual facial features.

3. Requirements for high accuracy and distinguishing between faces and other objects.

Distinguishing between faces and objects: The convolutional neural network system should be specifically focused on facial recognition and must include specialized layers and filtering techniques to separate the face from other objects.

Object separation without altering the face: The system should also include layers that allow it to detect objects while isolating the face from external elements without incorrectly modifying facial features.

4. Requirements for reducing uncertainties and handling errors

Facial variations (aging, injuries): The system must accurately account for natural changes in the face, such as aging, injuries, or alterations in features like eyebrows, during facial recognition.

System robustness and uncertainty mitigation: The system should operate reliably not only based on facial images but also by incorporating additional information, such as micro-expressions and geometric measurements, to ensure accurate recognition.

5. Computational resources and efficiency requirements

Optimization of computational power: The facial recognition system must properly allocate and optimize resources to ensure efficient operation, which, in turn, is essential for enabling real-time performance.

System speed and efficiency: The system should be optimized to increase processing speed and provide an effective user interface, allowing for real-time operation and high overall efficiency.

Based on the requirements outlined above, each requirement contributes to reducing uncertainties in system performance and achieving a high level of efficiency[3]. These requirements form the basis for the development and improvement of facial recognition systems, necessitating scientific and technological approaches. In facial recognition, factors such as facial expressions, angles, lighting conditions, and facial dynamics lead to variations in images, which in turn create challenges during model training. Addressing these issues and analyses can be effectively achieved by optimizing convolutional neural networks.

Problem solution. Thus, to improve accuracy in facial recognition systems, it is necessary to develop an effective model. Utilizing existing convolutional neural networks can significantly enhance system performance; however, proper training

and optimization of these networks, as well as a precise approach to preparing datasets, are required.

Moreover, the datasets used for facial recognition can be extremely large. To structure this data correctly and enable its integration into models, new methodologies and architectures are needed. To enhance the effectiveness of these approaches, the following solutions have been developed:

Results. Selection of CNN architectures: Popular convolutional neural network architectures, such as ResNet, VGG, and Inception, serve as the foundation for facial recognition systems. These architectures enable deeper feature learning from images and facilitate accurate extraction of facial characteristics.

Optimization of model architecture: The convolutional neural network model can be made more efficient by adjusting architectural parameters. For example, optimizing the number of layers, filter sizes, and incorporating specialized layers such as batch normalization or dropout can enhance model performance.

Data augmentation on facial images: Applying data augmentation techniques helps to further stabilize the model. These methods include rotating, cropping, transforming, and modifying images under various conditions. For instance, the dataset can be expanded by altering lighting, orientation, and facial expressions[4]. This approach is particularly effective when working with limited datasets, as it significantly improves model performance.

Transfer learning pre-trained convolutional neural network models on larger datasets, such as models trained on ImageNet, are used for facial recognition. This approach reduces model training time and conserves computational resources.

Based on these solutions, uncertainties arising from facial variations, lighting conditions, and angles can be effectively analyzed using architectures such as ResNet, Inception, and VGG. By employing techniques like data augmentation and transfer learning, the model can be further optimized and its efficiency enhanced. Therefore, developing software based on convolutional neural networks (CNN) for facial recognition is essential. These approaches significantly improve the accuracy of facial recognition and the efficiency of real-time operation.

The facial recognition software consists of the following stages:

1. Data Collection and Preparation:

a. Downloading and pre-processing datasets used for facial recognition (LFW, CelebA).

b. Normalizing and transforming the sizes of facial images, including the application of data augmentation techniques.

2. CNN Model Creation and Training:

a. Building the CNN model by selecting an architecture such as ResNet, Inception, or VGG.

b. Feeding the images into the model for training.

3. Model Evaluation and Optimization:

a. Measuring model accuracy and applying optimization techniques to improve performance (transfer learning, dropout, batch normalization).

4. Model Testing and Facial Recognition:

a. Detecting faces in test images and displaying the results.

The scientific outcomes achievable through the use of convolutional neural networks in facial recognition can be realized in the following key areas:

Firstly, convolutional neural networks enable high accuracy and low error rates in facial recognition. Scientific studies have shown that convolutional neural networks achieve significantly higher accuracy compared to traditional methods [5]. In facial recognition systems, experiments demonstrate that the overall error rate can range from approximately 1% to 5%, while also reducing the training time required for the models.

Secondly, convolutional neural networks provide the capability to recognize not only faces but also facial expressions (such as happiness, sadness, surprise), gender, age, and even specific individuals. Beyond facial recognition, their application in identifying facial expressions, estimating age, or determining gender demonstrates the versatility of the technology and highlights its practical potential from a scientific perspective.

Thirdly, Using the **transfer learning** technique, pre-trained convolutional neural network models with access to multiple datasets can be adapted for facial recognition systems in other domains, such as security systems, marketing (face-based analytics), healthcare (disease detection), and more. By leveraging a pre-trained model, facial recognition can be deployed in real-time systems or integrated into automated security monitoring systems.

Fourthly, convolutional neural networks can enhance the adaptability of facial recognition systems to varying lighting conditions, physical changes in the face (such as masks, hair, aging, etc.), or environmental variations. Scientific studies have confirmed that facial recognition systems using CNN maintain high accuracy even under changing lighting conditions and varying face angles.

Fifthly, convolutional neural networks and other advanced neural network architectures offer opportunities to improve the efficiency and speed of facial recognition. This encourages scientific research focused on optimizing network

architectures, determining hyperparameters, and developing new technologies aimed at creating novel architectures.

Sixthly, convolutional neural networks enable facial recognition systems to operate in real-time[6]. From a scientific perspective, this capability allows for effective applications of facial recognition in autonomous vehicles, public security monitoring systems, and online platforms.

Seventhly, from a scientific perspective, the use of convolutional neural networks contributes to high efficiency, speed, and accuracy in facial recognition. Furthermore, these technologies provide opportunities for further development, the exploration of new scientific directions, and broader applications across various fields.

Moreover, based on the seven solutions developed during the research process, advancing this direction opens new scientific avenues. For example, it enables the development of facial expression recognition, face-based diagnostics, or the integration of facial images with other biological data. These opportunities pave the way for creating and advancing new technologies.

When considering the use of convolutional neural networks for facial recognition, it is essential to understand both their advantages and limitations to ensure effective application of the technology. While the advantages of CNNs provide high accuracy and efficiency in performing real-world tasks, their limitations—such as high computational resource requirements, the complexity of the training process, and dependence on the quality of data—must also be taken into account.

Conclusion

In conclusion, firstly, general analytical information was provided on convolutional neural networks and biometric systems for facial recognition, including their definitions, architectures, advantages, functioning, and their applications across various fields, with several illustrative examples.

Secondly, by applying convolutional neural network methods, requirements and solutions were developed for analyzing facial image data, mitigating uncertainties, determining parameters, and structuring information. To achieve high-accuracy results and optimize the facial recognition process, CNN models were constructed step by step using object-oriented programming languages such as Python.

Thirdly, based on the models developed during the improvement of convolutional neural network methods for facial images, a seven-stage system of practical outcomes was created. Moreover, taking into account the developed

requirements and models, the use of convolutional neural network methods was deemed appropriate, resulting in precise and effective outcomes.

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