Ministry of Education of the Republic of Belarus
Educational institution
BELARUSIAN STATE UNIVERSITY OF INFORMATICS AND RADIOELECTRONICS

UDC 004.93'12

Wei Hengbing

Hardware-software complex for face recognition based on machine learning

ABSTRACT
For master's degree

Specialty 7-06 0611 -02 «Information security»

Scientific supervisor

Sergei Nikolaevich Petrov
Candidate of Engineering Sciences,
Assistant Professor

Minsk 2025

INTRODUCTION

Face recognition, as one of the core tasks in the field of computer vision, is widely applied in scenarios such as security surveillance, identity verification, and smart device interaction. Over the past few decades, facial recognition technology has made significant progress. Early methods primarily relied on geometric features to identify individuals. While these methods were simple and straightforward, they were often limited by their inability to handle factors such as pose, expression, and lighting changes. With the rise of machine learning, more complex techniques were developed, such as support vector machines (SVMs), which utilize linear algebra to reduce the dimensionality of facial images and extract features usable for classification.

Traditional facial recognition methods (such as SVM-based systems) rely on manually designed features (such as HOG, LBP, or PCA dimensionality reduction) and process them through shallow classifiers. While these methods perform stably on small-scale datasets, they are limited by the constraints of feature engineering: their shallow features perform poorly in complex scenarios.

However, the true breakthrough in facial recognition technology came with the rise of deep learning. Convolutional neural networks (CNNs) are particularly adept at learning hierarchical features from raw pixel data. These networks can automatically learn low-level features such as edges and textures in shallow layers, while learning more complex patterns such as facial landmarks in deeper layers. This ability to learn features directly from data makes CNNs one of the most advanced facial recognition methods. In recent years, facial recognition methods based on convolutional neural networks (CNNs) have significantly outperformed traditional machine learning methods in terms of accuracy and robustness. Additionally, this end-to-end feature learning mechanism completely eliminates the reliance on manually designed features (such as HOG, LBP) in traditional methods, enabling the model to adapt to complex scenarios such as lighting changes, gesture differences, and facial expressions. This paper systematically analyses the advantages of deep learning methods over traditional machine learning methods by comparing a facial recognition system based on convolutional neural networks (CNN) and TensorFlow with a facial recognition system based on support vector machines (SVM).

An examination of the dissertation for the correctness of the use of borrowed materials using the «Antiplagiat» network resource in on-line mode on June 11, 2025 showed the correctness of the use of borrowed materials (originality is 88%).

GENERAL DESCRIPTION OF WORK

Objective and tasks of the research

The objective of this research is to design and implement a face recognition system based on Convolutional Neural Networks (CNNs) and TensorFlow framework and to verify the advantages of CNNs in terms of recognition accuracy, robustness and generalization ability by comparing them with traditional methods based on Support Vector Machines (SVMs).

To achieve the above objectives, the thesis accomplishes the following tasks:

1. Collect and preprocess the face dataset, and construct the training and testing samples;
2. Construct the CNN-based deep learning model, and use the TensorFlow framework to complete the network structure design, training and optimization;
3. Implement the traditional face recognition method based on SVM, including the feature extraction and classification process;
4. Design the comparison experiments, and evaluate the performance differences between the two methods in terms of recognition accuracy, training efficiency, etc.;
5. Analyze the Analyze the experimental results and summaries the advantages of CNN in face recognition.

Connection with the priority areas of research and requests of the real sector of the economy

The topic of the thesis corresponds to paragraph 6 Ensuring the security of humans, society and the state (means of technical and cryptographic information protection, cryptology and cybersecurity) of the list of priority areas of scientific, scientific-technical and innovative activities for 2021–2025, approved by the Decree of the President of the Republic of Belarus dated 07.05. 2020 No. 156.

Personal contribution of Master's degree student

My specific contributions in this research are as follows:

1. Model construction: completed the design and implementation of CNN-based face recognition model, used TensorFlow framework to build the network structure and training;
2. Algorithm implementation: wrote the complete code flow for image pre-processing, feature extraction and classification recognition;

3. Comparison experiments: Implemented the traditional face recognition system based on SVM, and designed the experiments to verify the advantages of CNN;

4. Data analysis: systematic analysis and visual display of the experimental results, and drew persuasive conclusions;

5. Cooperation with the supervisor: In-depth discussions with the supervisor on the research ideas and the experimental design and result analysis, and reached convincing conclusions.

Dissertation advisor S.N. Petrov, doctor of philosophy, assistant professor, is a co-author of main publications. In-depth discussion with the supervisor on the research idea, experimental design and result analysis to ensure the scientific and innovative nature of the research work.

Practical approval and publication of Dissertation results

The 10th China-Belarus Youth '2023 New Horizon' Innovation Forum «Image recognition system based on convolutional neural network », Minsk, 9 November 2023.

The 23th International Scientific and Technical Conference «Technical means of information protection», Minsk, 8 April 2025.

Publication of dissertation results

Based on the research results presented in the paper, two publications were published in the collection: The 10th China-Belarus Youth '2023 New Horizon' Innovation Forum« Image recognition system based on convolutional neural network»; The 23th International Scientific and Technical Conference «Technical means of information protection»

Structure and size of the work

The thesis consists of an introduction, General characteristics of the work, the main part of the three chapters, conclusion, references. The full volume of the thesis is 87 pages, including 33 illustrations, 8 tables, list of references of 17 titles, including 2 publications of the author.

SUMMARY OF THE WORK

The introduction contains a brief description of the work and the reasons for conducting the research. This paper implements both CNN-based and SVM-based facial recognition methods and compares the two approaches, concluding that the CNN-based method is superior.

In the first section, a deep learning-based facial recognition system is implemented, combining image processing techniques with graphical user interface design to provide an efficient and user-friendly facial recognition solution. The core functionality of the program is divided into two parts: model training and image recognition. The model training component uses the Keras to build a convolutional neural network, which pre-processes, trains, and evaluates image datasets to generate a high-performance facial recognition model, which is then saved as an H5 file. The image recognition component uses the PyQt5 framework to build an interactive GUI interface that supports users in uploading static images or accessing the camera for facial and recognition. Recognition results are presented in a visual format, including annotated face regions, identified identities, and their confidence levels.

In the model training module, the program first preprocesses image data using the DataSet class, including operations such as grayscaling and size standardization. Subsequently, the program constructs a CNN model comprising convolutional layers, pooling layers, and fully connected layers, using stochastic gradient descent (SGD) as the optimizer and the cross-entropy loss function for multi-classification tasks. After training, the model is saved in H5 file format for subsequent use. In the image recognition module, the program implements face detection using OpenCV's Haar cascade classifier and inputs the detected face regions into the pre-trained CNN model for feature extraction and classification.

In the second part, a face recognition scheme based on lightweight support vector machines (SVM) is implemented, achieving efficient recognition through the deep integration of feature embedding and machine learning classifiers. First, the OpenCV SSD deep learning detector is used to locate the face region, and the pre-trained nn4.small2.v1.t7 model is used to extract a 128-dimensional face feature vector. Subsequently, LabelEncoder is used to numerically encode the labels to construct a feature-label dataset. During the model training phase, a linear kernel SVM is selected for classification training, maximizing the inter-class interval to enhance generalization capability, while supporting probabilistic output to quantify recognition confidence. The trained SVM model and label encoder are saved in pickle file format for quick retrieval. The system supports two modes: static image analysis and dynamic video stream processing. In real-time inference,

the system first performs face detection and feature extraction on the input image, then inputs the feature vector into the pre-trained SVM model to complete the classification prediction. The recognition results are overlaid on the image in the form of 'name-confidence,' forming visual feedback.

In the third part, both approaches were tested on the same test set, and the results were compared in a visual format. Through comparative analysis, it was concluded that facial recognition based on convolutional neural networks (CNN) has a more significant advantage.

Conclusion

This paper systematically designs and implements two facial recognition solutions: an end-to-end deep learning model based on convolutional neural networks (CNN) and a feature embedding classification method based on support vector machines (SVM). In the CNN scheme, a network architecture comprising convolutional layers, pooling layers, and fully connected layers was constructed using Keras. The model was trained using the SGD optimizer and cross-entropy loss function. An interactive GUI interface supporting image upload and real-time camera recognition was developed using PyQt5, enabling an integrated workflow of detection, recognition, and visualization. In the SVM scheme, the OpenCV SSD detector was used to locate faces, and a pre-trained deep neural network (nn4.small2.v1) was used to extract 128-dimensional feature vectors. A linear kernel SVM was then employed to complete the classification task. Both methods support both static and dynamic recognition modes.

Key comparative experiments demonstrate that, on the same test set, the CNN-based method significantly outperforms traditional SVM-based methods in terms of recognition accuracy. The CNN model, with its powerful hierarchical feature extraction capabilities, overcomes the limitations of the SVM approach, which relies on predefined feature embeddings, thereby achieving higher-precision facial representation and classification. This study validates the superiority of deep learning technology in complex visual tasks.

LIST OF OWN PUBLICATIONS

1–A. Wei H, Qian L, Zhang C.Image recognition system based on convolutional neural network[C]// «НОВЫЕ ГОРИЗОНТЫ»2023: - P.137-139.

2–A. Wei H. Methodology for studying the influence of face rotation angle on the face detection accuracy // матер. XXIII Междунар. науч.-техн. конф.

(Республика Беларусь, Минск, 08 апреля 2025 года) / редкол. : О. В. Бойправ [и др.]. – Минск : БГУИР, 2025. – С. 43–46.