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METHODOLOGY FOR STUDYING THE INFLUENCE OF FACE ROTATION ANGLE ON THE FACE DETECTION ACCURACY

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Abstract. The analysis of face detection methods in images was performed. For comparative analysis of efficiency, the Viola-Jones method based on the use of Haar cascades, the method of histograms of directional gradients and the method based on convolutional neural networks were selected. The angles of head tilt in the image were selected as variable parameters. The accuracy and speed of detector operation were determined as measured parameters. For the purposes of the work, the "Labeled Faces in the Wild" (LFW) face database and the "Head Pose Image Database" dataset were selected. Convolutional neural networks showed the best results.

Keywords: face recognition; biometrics; authentication; OpenCV.

Introduction

Facial recognition is an automated process of identifying or verifying an individual based on facial image analysis. Compared to other biometric methods, facial recognition has a number of advantages, including the absence of physical contact and the ability to be implemented using standard equipment: a video camera to obtain an image and a computing device to process it. For successful identification in most applications, a short period of time for an object to be in the camera's field of view is sufficient. Despite the significant amount of research in the field of facial recognition, this topic still contains many unsolved problems. The main difficulty is to ensure reliable identification that does not depend on changes in the angle, lighting, age and appearance of a person.

Face detection in an image is the first step and is an important one, the correct implementation of which determines the success of further steps and the recognition process as a whole. Face detection can also be used to automatically count various objects (people, cars, etc.).

Today, there are numerous methods for detecting faces in an image [1]. A comparison of three methods was made:

– Haar Cascades
– Histogram of Oriented Gradients (HOG) method based on image representation.
– Classifier based on convolutional neural network (CNN).

Main Part

To determine the most effective method of face recognition, it is necessary to evaluate the accuracy and speed. Speed was assessed by the number of detected or recognized faces per second.

The Python 3.12 programming language was used as a development tool. The PyCharm IDE was used as a development environment. The Dlib library formed the basis of the software implementation of the directional gradient histogram method. The Viola-Jones method (Haar detector), as well as face capture, was performed using the OpenCV 4.7.0 computer vision algorithm library. The DNN model for face detector (dnn_samples_face_detector) project was taken as the basis for the neural network. The detector is built on the topology of a deep convolutional neural network.

To study the overall performance of detection algorithms the Labeled Faces in the Wild [2] face photograph database on the Kaggle platform was used. This database contains 13233 images of 5749 people that were collected from the Internet, detected and centered by Viola Jones's face detector. Each image is 250x250 in jpg format.

To study the efficiency of detection algorithms depending on the head tilt angle, the Head Pose Image Database [3] was used. The database contains 2790 images of fifteen people's faces with different rotation and tilt angles from -90 to +90 degrees (Fig. 1). For each person, 2 series of 93 images are available. There are images with and without glasses for each person. The database was created for training and testing machine vision algorithms. The values of the head rotation and tilt angles are combined. The vertical tilt angle "Tilt" can take values from the range {-90°, -60°, -30°, -15°, 0°, +15°, +30°, +60°, +90°}. The horizontal rotation angle "Pan" takes values from the range {-90°, -75°, -60°, -45°, -30°, -15°, 0°, +15°, +30°, +45°, +60°, +75°, +90°}. If the vertical angle is -90° or +90°, the person is looking from below or above, and the horizontal angle is 0°.

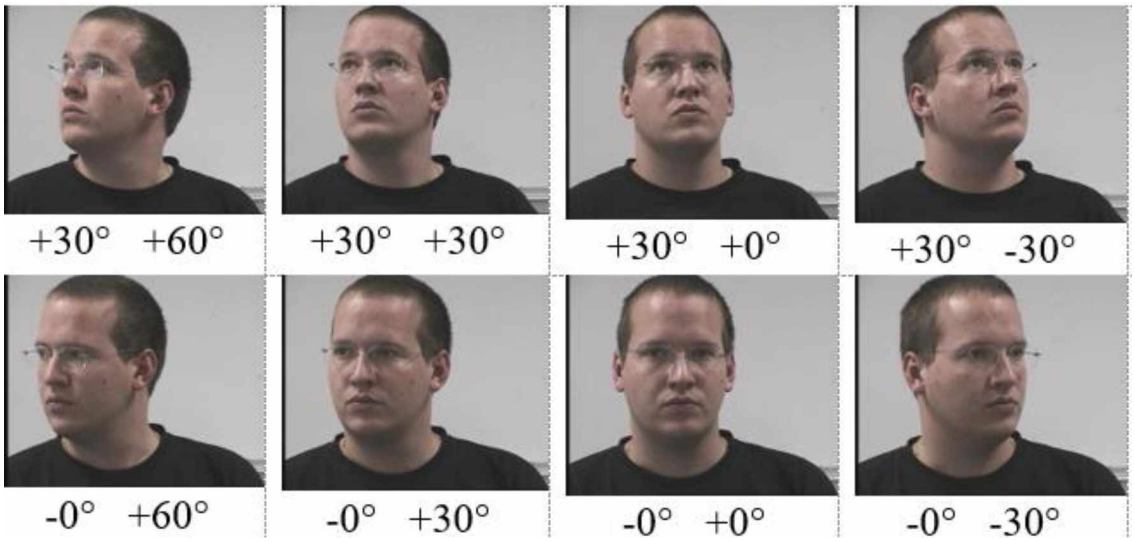

Fig. 1. Different head tilt and pan angles in the "Head Pose Image Database" dataset

The images were fed to the detectors, and the output was a result of 1 or 0 (face detected, face not detected). Accuracy indicators were calculated (the ratio of the number of detected faces to the total number of faces in the sample). Then the head tilt angle indicators were changed and similar calculations were repeated. The results of the evaluation of the speed and accuracy of detection algorithms are presented in Table 1.

Table 1. Performance of faces detection algorithms

Algorithm	Performance, persons/sec	Accuracy, %
Haar Cascades	13.7	47.66
HOG	22.88	55.91
CNN	35.38	93.54

Haar detector was effective at small horizontal and vertical rotation angles (30° in the horizontal and 45° in the vertical planes). The convolutional neural network showed very high results in face detection. A negative result is seen in the face down position and with a rotation of 60° (or more) to the right. All algorithms showed good results in a head position close to the frontal position. A drop in face detection accuracy occurred at head rotation angles to the right or left in the range from 60° to 90°. The detector based on Haar cascades showed the lowest accuracy and speed. shows the result of the detector. The detector based on histograms of directional gradients showed 56 % accuracy and was 1.6 times faster than the Haar detector. In turn, the detector based on the convolutional neural network was about 1.6 times faster than the HOG detector and showed the highest accuracy.

Conclusion

The efficiency of all considered face detection algorithms was high when the face was located close to the frontal one. A decrease in detection accuracy was observed when the head was turned to the right or left by an angle exceeding 60°. The detector based on Haar cascades demonstrated satisfactory results only at head tilt angles of up to 30° in the horizontal and vertical planes. The conducted studies indicate that convolutional neural networks (CNN) are the most effective approach to face detection and recognition within the framework of this work. This fact opens up prospects for using CNN in practical face recognition projects, which is additionally stimulated by the availability of hardware support for the execution

of neural networks in modern smartphones, as well as the availability of a wide range of frameworks for developing and training CNNs.

References

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