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ANALYSIS OF MODERN FACIAL RECOGNITION SYSTEMS

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Abstract

Nowadays, recognition and identification of a person based on biometric features is one of the urgent issues facing the manufacturers of information technology products. In this field, the development of systems for the automatic recognition of a person through facial images occupies a special place. The purpose of developing such products is to establish control in public places (airports, train stations, subways, exam halls), control access to buildings (buildings of educational institutions, hotels, government offices, banks, security agencies, and other organizations), and others. It consists of the implementation of software and hardware tools that are convenient for carrying out such actions. This paper is devoted to the analysis of facial recognition systems widely used in the world today.

Keywords: recognition, identification, verification, face image, video, software application, database, biometric system.

Today, many companies in the world are developing systems that detect and identify a person's facial image through their video and surveillance cameras. They differ from each other in terms of architecture, image recognition speed, system hardware and software requirements, usage patterns, cost, and other factors.

Before any face recognition system, solving the following issues is the main task:

- face recognition;
- identification of the person;
- verification;
- creation of a database consisting of entered data;
- mutual comparison of two or more face images in the database.

The quality of the face recognition system depends on the efficiency of the image processing algorithms [1-13] used in it, and data is entered into the face recognition systems in the following ways:

- through video files (MPEG, avi, mp4, mkv, 3gp, flv extension files);
- through surveillance cameras;
- through image files (jpg, jpeg, bmp files).

Manufacturers deliver their products based on user requirements: SDK (Software development kit), API (Application programming interface), open or closed system library, software application, or ready-made hardware-software complex. In turn, consumers can be divided into two groups based on their requirements: users who integrate the products of companies producing widespread SDKs, APIs, and open or closed system libraries into their software applications, and consumers who purchase ready-made hardware and software and use it. Systems in the form of SDKs, APIs, and libraries are typically used by developers or software companies. Below are the most popular of such systems.

NeoFace Suit. This system was developed by NEC Corporation, which has been dealing with biometric technologies for 30 years. In addition to facial recognition, NEC has also developed fingerprint, palm, and eye recognition systems. The NeoFace Suit complex consists of a video camera (IR or analog), a video analysis server, and a database. In addition to video surveillance, NeoFace Suit can also handle issues such as access control and management. This allows you to create a "black list" and a "white list" through NeoFace Suit. The system can solve the following issues:

- monitoring and control;
- searching for an image from the database;
- sending a warning signal in the form of audio or text when a violation or a wanted person is captured by the camera;
- creating a list of facial images included in the database;
- 2D image recognition using 3D technology;
- improving image quality.

Areas where the NeoFace Suit system can be used:

- places where people gather a lot: stadiums, cinemas, shopping centers, etc.;
- transportation: airport, train station, port, subway, etc.;
- border areas;
- entrance-exit control branches.

NeoFace Suit has a high base image verification performance, it can verify 1 million images per second. Today, the system has more than 1000 users in more than 30 countries around the world.

Cognitec FaceVACS is a system developed by Cognitec that competes with other companies in several aspects of face recognition. Its main advantage is its efficient operation in large-scale databases [14]. In addition, the FaceVACS system offers the following services:

FaceVACS-DBScan with Examiner – examines images from various sources against multi-million database images. Examiner offers high-performance tools for improving and managing image quality. Key Features of FaceVACS-DBScan with Examiner:

- comparing images from many sources with images in a large database;
- when comparing images, first check the most similar indicators [15];
- management of users' demographics and other data;
- Image quality improvement and mutual comparison using Examiner filter and other tools;
- integration as a ready-made software application or in the form of an SDK or API into an application developed in another programming language.

FaceVACS-VideoScan can extract, track, recognize, and analyze the human face area from the currently incoming video stream or video file, and it has the following features:

- finding, tracking, recognizing, and analyzing the area of a person's face from a video file or current video stream coming from the camera;
- save and display every view of the facial image from the video at the current time;
- real-time comparison of persons under observation and in the database;
- receiving signals about the happening event in real-time;
- view and send information about human traffic, visitor demographics, and customer behavior;
- data acquisition and analysis through mobile devices;
- integration as a ready-made software application or in the form of an SDK or API into an application developed in another programming language.

FaceVACS-PortraitAcquisition – capable of generating high-quality images suitable for ID cards and future facial recognition and verifying them for compliance with ISO-19794-5 and other standards, it has the following features:

- simplify the development of high-quality images for face recognition;
- control and management of the extraction process;
- assessment of special situations such as front view, and light distribution, with and without glasses;
- checking portraits for compliance with international standards (ISO 19794, etc.);
- integration as a ready-made software application or in the form of an SDK or API to an application prepared in another programming language [16].

VeriLook SDK. This facial recognition system was developed by Neurotechnology Corporation, which deals in biometric systems. In addition to the VeriLook SDK, Neurotechnology Corporation is the developer of the VeriFinger SDK, VeriEye SDK, and VeriSpeak SDK for fingerprint, eye, and voice recognition systems [14]. This system is also able to work in a web environment, and it has the following features:

- to be able to distinguish a live human face from a picture on the camera;
- VeriLook 10.0 is very accurate and fast in finding a face and identifying faces from the image in the frame from 0.01 to 0.86 seconds, and after identifying the face areas, it takes only 0.6 seconds to bring them to a sample;
- separation of human gender in the staff according to the specified indicator;
- analysis of emotions such as anger, hatred, fear, joy, sadness, and happiness on a person's face;
- extraction of the facial area according to a template of 68 points;
- analysis of certain features such as smile, open mouth, closed eyes, glasses, beard, and mustache when extracting the face area;
- age determination based on the face image in the template;
- to determine the quality indicators when writing an image to the database and to separate the best quality from the images and write it to the database to increase the accuracy of recognition;
- recognition even when the head is turned to the side 45 degrees and up 15 degrees relative to the front camera;
- writing templates for the database, saving multiple views of one person's face to different sources at different times. This, in turn, increases the accuracy of recognition when comparing photos;
- VeriLook can work in one-to-one and many-to-many face comparison modes and the ability to compare 40,000 faces per second;
- VeriLook can compare files from 4kB to 7kB in size;
- Work on operating systems such as Microsoft Windows, Android, iOS, Linux, and Mac OS X [55].

Table 1.

Minimum requirements for VeriLook 10.0 (Intel Core 2 Q9400 2.67 GHz)

The minimum distance between the rods	32 pixels
The recommended distance between the rods	64 pixels
The time it takes to find a face and make a template	0.6 seconds
Face image comparison speed	40,000 per second
Template size	4.0-7.2 KB

FindFace software complex. The FindFace software complex was developed by the Russian company NtechLab, which uses deep neural network technologies enriched by training 20,000,000 photos, which are the fastest and most accurate in terms of performance and quality in performing face image operations. This made it possible to bring the speed and accuracy of facial recognition to a new level. In 2017, the American Institute of Standards and Technology (NIST) took first place in terms of speed and accuracy among the algorithms of leading facial recognition companies worldwide. The error rate was 1/1000000. If more than 10,000 items are included in the database, the

accuracy rate has been observed to increase to over 95% [17]. The following are the main features of FindFace:

- determination of face area;
- identity verification based on facial image;
- identification;
- separation of emotions;
- determination of gender and age;
- work with video in real-time.

The set of software applications provided by the FindFace software complex consists of:

- FindFace Cloud API;
- FindFace Security;
- FindFace Enterprise Server SDK.

FindFace Cloud API is a REST API interface where the application is launched by the user. However, this product does not yet have a GUI for facial recognition. However, for the added convenience of users, a web environment has also been developed, with the help of which users can perform activities such as account verification, payment, inquiry account, and payment history from anywhere. FindFace Cloud API is available for free for 14 days.

FindFace Security is recommended for large government organizations, financial and banking offices, and hotels to improve their security services. FindFace Security detects and recognizes the face area from the current video stream. If the wanted person is caught in the camera, it will alert the security agencies within 5 seconds. This system also has the option of creating a "black" or "white" list. The technical and software requirements of FindFace Security are listed in the table below.

Table 2.

Technical and software requirements of FindFace Security	
Supply	Indicator
Processor	4-core (AVX, min frequency 2GHz Intel x86-64)
Quick memory	8 GB
Minimum size	20 GB
Operating system	Ubuntu 16.04

With *FindFace Enterprise Server SDK 2.0*, the user can run the system on his local network, and all user data is stored on his local network. FindFace Enterprise Server SDK 2.0 REST API allows easy integration into any mobile, web, or desktop application. The new version of FindFace Enterprise Server SDK 2.0 can correctly determine the gender of a person by 99% and the age within 3 years within 95% of the image. Minimizing the size of the face image (1.28 KB) allows you to perform a very fast search. It is possible to search for the desired image from a database containing a billion files in half a second, and the high speed does not affect the accuracy of the result in any way. The minimum server requirements are listed in the table below.

Table 3.

Minimum requirements for Server	
Supply	Indicator
Processor	INTEL Core i7 (AVX, min 2GHz Intel x86-64)
Quick memory	4GB
Virtual machine	VMware vSphere 5.0
Operating system	Ubuntu 16.04

FaceR. Animetrics has created its own FaceR family of systems, which are based on the conversion of 2D images into 3D images. Its main customers are the US Department of the Interior, the armed forces, and police services of various countries. Its main product is the FaceR Identity Management System (FIMS), which detects facial biometrics through a web environment and serves one or more customers through a hosted or cloud system. This allows customers to conveniently access their smartphone, tablet, or computer, and it works equally well with FIMS MYSQL and NoSQL. This system can solve the problems of image processing and recognition over the network. System

licensing is determined in order of increasing number of users. In this case, 10,000 users can be included in the first type of license.

Manufacturers have attached additional VideoID applications to FIMS, and the application is effective for video surveillance systems. This web application can stream video sequences from webcams and IP cameras compare faces and display the analyzed results. VideoID also has the function of creating an identification or comparison list. Another app that's handy for viewing a list of compared images is FaceR Mobile ID, which can capture and analyze images via iOS and Android systems. In addition, the FaceR Facengine SDK system has been developed by this company, through which it is possible to create a new application in another programming language by integrating FIMS. FaceR compares images by scaling them to 3D. Therefore, a single front camera can recognize images from rear +45 to -45 angles. A typical sample image file size is 6kb on average, and this does not affect the image comparison speed. However, the cloud system architecture, server software, and hardware directly affect the image analysis process.

Notiface II was developed by FACE-TEK and has several limitations compared to the systems discussed above. For example, this system usually supports low-quality CCTV (closed-circuit television camera) cameras compared to modern IP cameras. In addition, the images in the base are selected using the operator, and the images compared to it are displayed in separate windows. Notiface II is designed for access control and facial recognition and is increasingly used in older devices and mostly in developing countries [18].

Acsys FRS. Acsyss FRS, owned by Canadian company Acsyss Biometrics, has a facial recognition software product and SDK. The system architecture consists of several computers, in which the reception and processing of biometric data is carried out through a central server. In this case, the server is enriched asynchronously with the data on the client computers. Acsyss FRS SDK can be integrated with Windows operating system-supported languages Visual C++ 6.0 or higher, Visual Basic 5.0 or higher, Borland Delphi 5.0 or higher. SDK and BioApi have also been developed by this company, which can be integrated into other systems based on certain rules.

Acsyss FRS SDK is capable of creating a list of users in the case of a file or video surveillance system. If it is necessary to create a template from an image file, then the size of the image is 4kb, if it is created from a video, the size of the template is 8kb. Uses eye location to extract features. To compare the images, the distance between the eyes in one image is 40 pixels, and the distance between the eyes in the video image is 15 pixels. Image comparison speed is also done according to the type of templates. The speed of comparing a single image on a computer is 100,000 per second, and when comparing video, this indicator is 25,000. According to the manufacturer's instructions, the system is capable of detecting 16 user movements in real-time (30 frames/second). However, the speed at which the client computers and templates are compared to detect user actions depends on the parameters of the central server. The Acsys architecture consists of up to 4,000 client computers and supports approximately 1,000,000 users. Each client computer can analyze up to 16 video streams, and this figure may be lower when operating in real-time mode [19].

OpenCV (Open Source Computer Vision Library) is an open system free library developed by Intel company in 2000, which is an assistant in solving problems such as computer vision, and digital processing of images. This library can be integrated into programming languages like S/S++, Python, Java, Ruby, Matlab, and Lua, and it runs on platforms like Windows, Mac OS, Unix, iOS, Android, CUDA, and OpenCL.

OpenCV is loaded with more than 2,500 classic and state-of-the-art algorithms [20], used by more than 47,000 developers, and downloaded 14 million times from the Internet. Based on OpenCV, it is possible to create applications with the following features:

- detection of face area from current video;
- recognition of a person by facial image;
- comparison with base images;
- building 2D and 3D models of the object;
- image segmentation and recognition;
- determining the position of the object in motion from the current video;

- recognition of a person through body movements.

Face-intellect was developed by AxxonSoft, a Russian security and video surveillance software company, aimed at video surveillance in crowded public places (hotels, train stations, airports, etc.). The following issues can be solved through this system:

- face extraction from video;
- real-time monitoring of images;
- comparing the extracted face image with base images;
- allowing or prohibiting actions after facial image detection (such as unlocking the door, allowing access);
- automatic setting of user check-in and check-out times;

The system has the following capabilities:

- detection of several faces in one frame;
- parallel work with several cameras at the same time;
- determining the number of personnel by age, gender;
- warning the security authorities about the violation detected in the protected area;
- to be able to distinguish between a human image and a live image;
- automatically extracting the most original option from the frame and writing it to the database;
- work in the web environment;
- image filtering;
- Availability of software for 32-bit and 64-bit versions of the Windows operating system;
- ability to work on the network.

Face-intellect consists of the following software modules:

- facial area extraction detector;
- facial image recognition server;
- face search and recognition module from the database.

The face-intellect software package can be integrated with Cognitec 8.8 (manufacturer Cognitec), Tevian 1.8.1, and VisionLabs facial recognition modules.

The facial area extraction detector performs the following tasks:

- extracts a face from a video;
- sends the highlighted area to the face recognition server.

The facial recognition server performs the following tasks:

- write images containing the face area in the frame to the base;
- identification of facial biometrics;
- checking extracted face images;
- entering the standard face image into the database for verification;
- searching for a face from the database;
- determination of the actual number of visitors according to the checked facial areas;
- to determine the total number of persons who passed through the cell.

The face detection and search module performs the following functions:

- search for the face captured by the camera from the video archive;
- search in the video archive for the downloaded file;
- export search results;
- working with the database;
- Checking people by gender and age using the Tevian module.

Vocord - developed by the Russian company Vokord, is designed to solve problems such as facial recognition, license plate recognition, and digital image and video processing based on deep neural networks. Vocord consists of the following components:

- VOCORD FaceControl – recognition based on face biometric data, separation by gender and age;

- VOCORD NetCam.AI is a special hardware and software package developed for recognizing a person's face and license plates;
- VOCORD Recognition SDK – a system that identifies the face area from the image, analyzes biometric data, compares it with the standard face image in the database, and includes the functions of separating by gender and age;
- VOCORD FaceMatica - "cloud" platform of facial recognition;
- VOCORD Traffic – recognition of vehicle license plates and recording of traffic violations;
- VOCORD ParkingControl – control of vehicle parking places;
- VOCORD ParkingS – recording violations of rules in the parking lots in the form of images or videos;
- VOCORD Tahion – video surveillance and video analysis system;
- VOCORD NetCam – a high-quality camera designed for recognition and analysis of a person's face and vehicle license plate;
- VOCORD video expert is a video and image accuracy assessment system [21].

Conclusion

Several face area detection and recognition systems have been studied in the research. Among them, it was found that there are systems in the form of free SDKs, APIs, and libraries. Typically, customers focus on technical and software requirements, licensing, performance, multitasking, and flexibility when using such systems. Therefore, we believe that it is appropriate to use the OpenCV open system library when creating a face recognition system based on facial images, and it has the following features:

- OpenCV open system and free library;
 - the library is specifically designed for the mathematical processing of images, it consists of more than 2500 algorithms;
 - the program developed using the library can work in all popular operating systems today;
 - the library can be integrated with modern programming languages such as C++, Java, Python, and Ruby;
- supports parallel execution architectures (CPU, GPU, DSP) with high-performance and distributed tasks.

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