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Overview and Exploration of Standardization in Facial Recognition System Evaluation Technology

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Abstract

This article provides an overview of the development of face recognition technology, evaluation techniques, and the exploration of standardization. Face recognition technology, as a biometric identification method, identifies individuals by analyzing facial features in images or videos and has been widely applied in various fields such as public safety, finance, and community management. With the advancement of technology, the market size of face recognition has grown rapidly, while facing complex recognition challenges. The article reviews the historical development of face recognition algorithms, including traditional Eigenface algorithms, Fisherface algorithms, elastic graph matching algorithms, local feature analysis algorithms, and the application of modern neural network algorithms, especially convolutional neural networks. In addition, the importance of large-scale face image databases in the performance testing of face recognition systems is discussed, and internationally renowned face databases such as FERET, CMU, LFW, etc., are introduced. The article also explores the progress of international and domestic face recognition system performance testing projects, emphasizing the fairness and authority of testing, and proposes directions and suggestions for standardization research in this field in China.

Keywords Face Recognition Technology; Biometric Identification; System Performance Testing

1. Introduction

Face recognition technology is a widely used biometric recognition technology, through the image or video acquisition equipment to obtain the crowd image and extract the face from the face, then the recognition algorithm to calculate and analyze the face features, adopt a certain matching strategy and compare the face template in the existing database to determine the face identity information to be recognized. With the rapid development of image acquisition technology, Internet technology and big data technology, face recognition technology has been widely used in large-scale public security prevention, entry-exit inspection, public behavior supervision, attendance management, intelligent finance, intelligent community, intelligent security, smart home and other important scenes. In recent years, a series of social terrorist attacks, campus security incidents, and personal information leakage incidents have occurred frequently, and face recognition systems have played an important role in the process of preventing and correcting these incidents. The development of core technologies has promoted the explosive growth of China's face recognition market, especially since 2015, China's face recognition market directly jumped from 1.67 billion yuan in 2012 to 7.5 billion yuan in 2015, and reached 12.3 billion yuan in 2016. In 2018, China's face recognition market will exceed 40 billion yuan. From the application field, the current attendance access control application in China's face recognition market accounted for about 42%, security applications accounted for about 30%, the financial field accounted for about 20%, the future of more market segments will be reflected in the smart city, smart community, smart transportation, smart home and other fields. With increasingly broad market prospects and increasingly sophisticated field needs, face recognition technology in the modern information society is facing more complex identification scenes, identification of people, and service environment problems from public security, finance, community, transportation and other all-round fields. In the recognition of portrait dimension, real-time recognition, data cross-regional linkage, system stability and reliability will face great challenges. A variety of face recognition systems for different subdivisions and nominal indicators are emerging in this background. How to conduct scientific testing and evaluation of face recognition systems in a unified and standardized manner, so that the evaluation conclusions can be applied in a timely and effective manner to system optimization, supplier qualification recognition and government procurement, is the main focus of modern face recognition research.

2. Policies and Regulations

In May 2016, the National Development and Reform Commission, in collaboration with the Ministry of Science and Technology and three other departments, introduced the "Three-Year Action Plan for 'Internet Plus' Artificial Intelligence," which pointed out that by 2018, the basic establishment of artificial intelligence foundational resources and innovation platforms, industrial systems, innovation service systems, and standardization systems would be achieved. In September 2016, the General Office of the National Development and Reform Commission clearly stated in the "Notice from the General Office of the National Development and Reform Commission on Organizing the Application for the Special Project of Innovation Capacity Construction in the Field of 'Internet Plus" that it is necessary to build a "National Engineering Laboratory for Deep Learning Technology and Applications, to support the research and development and engineering of technologies such as large-scale computer vision, biometric recognition, complex environment perception, and new types of human-computer interaction." In the second half of 2016, the State Council successively issued the "Innovation Plan for the 13th Five-Year National Science and Technology" and the "Notice on the Development Plan for National Strategic Emerging Industries during the 13th Five-Year," advocating for the vigorous development of the new generation of information technology that is ubiquitously integrated, green, and intelligent, promoting the large-scale application of artificial intelligence, and carrying out pilot demonstrations in key areas such as manufacturing, education, environmental protection, transportation, commerce, healthcare, network security, and social governance. In 2017, the State Council issued the "Development Plan for New Generation Artificial Intelligence," proposing to "promote the extensive application of artificial intelligence in fields such as education, healthcare, elderly care, environmental protection, urban operation, and judicial services, to enhance the precision of public services." In 2017, artificial intelligence was also written into the national government report for the first time. As an important subfield of artificial intelligence, it is expected that the policy support for face recognition will continue to strengthen. Research on face recognition system testing methods, as one of the three key factors in the field of face recognition, will make a significant contribution to accelerating the construction of standardization systems, improving the industrial system of face recognition, and innovating the public service system.

3. Overview of Face Recognition System Evaluation Technology

Since facial recognition research began in the 1960s, Its development has gone through the first stage (1964-1990) of institutional recognition focusing on face recognition facial features, the second stage (1991-1997) of semi-automatic recognition focusing on manual algorithm recognition, and the third stage (1998-2014) of non-contact based on robustness such as light posture. At present, it has entered the Internet application stage supported by a large number of mature technologies, and large-scale application promotion is emerging in an endless stream. Throughout the historical evolution of face recognition technology, the future development of face recognition technology mainly depends on three factors: face recognition algorithm, large-scale face image database, face recognition system performance test method.

4. Face Recognition Algorithm

Beyond the front-end face image acquisition and preprocessing nodes, the facial recognition algorithm process involves face detection and tracking, face alignment, facial feature extraction and learning, feature similarity matching, and facial identity recognition. Based on the type of resource of the recognition image, facial recognition algorithms can be divided into two-dimensional (2D) and three-dimensional (3D) facial recognition algorithms.

Currently, facial recognition algorithms are mainly focused on two-dimensional image recognition, which primarily utilizes feature points distributed on the face and measures the distances between different feature points for identity recognition. The main two-dimensional facial recognition algorithms include:

Eigenface algorithm: In the 1970s, Kanade and Kelly proposed a method based on the geometric structural features of the face, using the shape and geometric relationships of facial feature points for facial recognition, known as the template matching method (Correlation). This method is simple and intuitive but has obvious shortcomings, such as the need for locating facial feature points, and the feature extraction process is also susceptible to the effects of facial deformation and shooting posture.

Fisherface algorithm: In 1997, Ronald Fisher proposed the Fisherface algorithm, which first uses Principal Component Analysis (PCA) to reduce the dimensionality of the image's appearance features. On this basis, it applies Linear Discriminant Analysis (LDA) to transform the reduced principal components to try to extract distinctive features between different faces for final recognition. It generally shows better recognition effects than template matching and Eigenface methods and is a mainstream approach.

Elastic graph matching algorithm:Which was introduced by L. Wiskott et al. in 1999. This algorithm defines a distance in two-dimensional space that has some invariance to common facial deformations and uses an attribute topological graph to represent the face, where each vertex of the topological graph contains a feature vector, recording the information of the face in the vicinity of that vertex.

Local feature analysis algorithm:Since the 21st century, various facial recognition systems and applications internationally and domestically have been continuously integrated into social and economic life and have played a role, which also puts forward deeper and more refined requirements for facial recognition technology. On this basis, the main line of facial recognition algorithm research has shifted from appearance modeling to local feature representation.Ahonen (2004) and Liu (2002) first studied the robustness of facial local feature representation to lighting conditions and facial posture; Simonyan (2013) introduced the commonly used SIFT feature representation method in the field of computer vision, extracted SIFT features from facial images, and then performed Fisher Vector encoding to obtain local facial feature expression; Zou (2007) and others verified the effectiveness of Gabor features and LBP features for facial recognition through comparison; Chen (2013) and Roy (2009) used the relatively low computational complexity and strong discriminative characteristics of LBP features to achieve great success in research and tasks such as facial recognition, face detection, and facial expression attribute recognition.Local features enhance the recognition performance of the algorithm under constrained conditions, but at the same time, the performance of these features also often depends on human experience and knowledge, and the robustness of local feature extraction is reduced due to changes in portrait background, posture, and occlusion under large-scale unconstrained conditions.

Neural network algorithm:Using neural network algorithm, are another active research direction in the field of facial recognition algorithms since the 21st century. Compared with other facial recognition algorithms, general neural network algorithms avoid complex feature extraction work, and the core lies in summarizing the implicit expression of the facial recognition system through sample training and learning. In recent years, inspired by the successful application of Convolutional Neural Networks (CNN) in many fields of computer vision, the mainstream research field has introduced convolutional neural networks to learn facial feature expression. Among them, the representative methods include the DeepFace facial recognition method proposed by Facebook and the DeepID series of facial recognition methods based on CNN proposed by Professor Tang Xiao'ou's team at the Chinese University of Hong Kong.

In daily real-time face monitoring,detection, and comparison applications, two-dimensional facial recognition algorithms are often challenged by factors such as facial posture,lighting conditions, expressions, and facial occlusion, while three-dimensional facial recognition can greatly improve recognition performance and accuracy at this time. The research on three-dimensional facial recognition began in the early 1990s of the last century. Limited by the three-dimensional imaging technology level at that time, the accuracy and scale of the three-dimensional facial data obtained could not support the comprehensive development of three-dimensional facial recognition technology. At the same time, the performance of data processing equipment and storage equipment could not meet the computational requirements of three-dimensional facial recognition, and it remained in the theoretical research stage as a whole.At the beginning of the 21st century, with the development of material science and electronic circuit technology, the image video collection equipment and computer performance have made a qualitative leap, making the research on three-dimensional facial recognition truly cross from theory to practical application. In the "Facial Recognition Grand Challenge Plan" jointly proposed by the FBI and other departments in the United States in 2006, three-dimensional facial recognition was proven to be robust under the influence of factors such as lighting and angle, and the shape features extracted from the depth map are also light-insensitive.In recent years, with the further development of three-dimensional facial data acquisition technology and the continuous improvement of public facial databases, the research on three-dimensional facial recognition technology has entered a specialized stage under special conditions (expression, occlusion, posture changes). Renowned domestic and foreign research institutions include Microsoft Research, MIT AI Lab, University of Surrey Visual Research Center, and computer vision and pattern recognition laboratories of Peking University, Shanghai Jiao Tong University, and other universities in China. As a future development direction of facial recognition, three-dimensional facial recognition faces practical application limitations such as difficulty in data acquisition, susceptibility to expression deformation, and low real-time facial recognition compared with the current mature two-dimensional facial recognition.

5. Large-scale Face Image Database

In the research process of face recognition technology, large-scale face image database is an indispensable key factor for algorithm implementation, model training, algorithm testing and system performance testing. The size of the portrait library used for model training and the changes of portrait environmental conditions have a significant impact on the accuracy and robustness of the recognition algorithm, and the size of the test set and face attributes on which the algorithm and system performance test depend have a decisive impact on the scientificity and effectiveness of the test. From the perspective of algorithm model training and performance testing, this project summarizes the main large-scale face image databases at home and abroad as follows:

5.1. International face image database

In the face recognition algorithm model training and performance testing for international face applications, the most widely used large-scale face image databases mainly include FE▪ RET, CMU, LFW, MegaFace, IMDB-WIKI and FRVT series test sets, which are basically designed and published by universities or scientific research institutions.

FERET face database:The pentagon Counterdrug Technology Transfer Program (CTTP) in the early 90s, has launched a facial recognition engineering (FERET Face Recognition Technology), it includes a general face library and universal test standard. By 1997, it contained more than 14,051 photos of more than 1,000 people, with each character including photos of different expressions, lighting, poses, and ages. The FERET project is one of the most widely used face database s in the field of face recognition, which strictly divides the training set, Gallery, and different test sets.

CMU & PIE face database:CMU&PIE face database was created by Carnegie Mellon University in the United States in November 2000, containing 41,368 photos of 68 volunteers, including 13 pose conditions, 43 lighting conditions and 4 expressions of each person. The existing multi-pose face recognition research is basically using CMU&PIE face database for testing.

LFW face database:LFW face database is a public face data set published and maintained by the University of Massachusetts in 2007, which is mainly used to study face recognition in unrestricted environments. The dataset consists of more than 13,000 facial images, collected from the Internet and dominated by public figures. Each face was labeled with a name attribute, and about 1,680 of them contained more than two images. LFW dataset is widely used to evaluate 1:1 face verification and is one of the authoritative face verification test sets in the world.

IMDB-WIKI face database:The IMDB-WIKI facial database is composed of the IMDB database and the Wikipedia database. The IMDB facial database contains 460,723 facial images, while the Wikipedia facial database contains 62,328 facial images, totaling

523,051 facial images. Each image in the IMDB-WIKI facial database is annotated with the person's age and gender, which is of significant importance for research on age recognition and gender recognition.

MegaFace face database:MegaFace face database is an open face data set published and maintained by the University of Washington in 2015. The face images in the data set are collected from Flickr creative commons dataset, including a total of 690,572 identities and 1,027,060 images. It was the first test set to reach the million-scale level. Like the LFW dataset, the images in the MegaFace dataset are generated from natural scenes with interference factors such as lighting, expression, pose, and occlusion. However, unlike LFW, the identities of people in the MegaFace data set are ordinary people rather than public figures, and the resolution of images is selected in the collection process, and the uniform distribution of image sources is ensured around the world. MegaFace focuses on 1: N face recognition performance in million-level databases. As a result, MegaFace is more practical than LFW datasets.

FRVT face database: National Institute of Standards and Technology, NIST, since 1993, held in face recognition supplier testing for many times, and provide a series of face test set. FRVT face recognition test series collection from the United States Department of Homeland Security in the criminal investigation process, immigration and other real business scenes of the image, the scale of millions. Unlike other face libraries in the world, FRVT series test sets are not public, effectively avoiding algorithm overfitting and even cheating in the testing process of multiple suppliers.

5.2. Asian face image database

Due to the significant differences in facial features between Eastern and Western people, the application of the international face image database in the face recognition field in Asia, which is dominated by Westerners, may have a negative impact on the research and application. In recent years, Asian researchers have created some large-scale, multi-attribute Asian face database s to meet the specific needs of the detailed field. The more famous ones are the Korean KFBD face database, the Chinese University of Hong Kong CelebA face database, the Chinese Academy of Sciences CASPEAL face database, CASIA-WebFace face database, etc.

KFBD face database:The KFBD face database contains 1000 characters, a total of 52,000 multi-pose, multi-light, multi-expression facial images, in which the attitude and light changes of the images are collected under strict control conditions, the source of the figures are mainly Korean people.

CelebA face database:CelebA face database is a large facial recognition dataset published by Professor Tang Xiaoou's team at the Chinese University of Hong Kong. The dataset contains 202,599 face images from 10,177 people, each image contains more than 40 annotated attributes, covering multiple pose and lighting conditions, and is mainly used for face attribute recognition.

CAS-PEAL face database:The CAS-PEAL face database was created by the Institute of Computing Technology of the Chinese Academy of Sciences and the Yinchen Joint Laboratory of Facial Image Recognition in 2003, collecting and sorting 99,450 facial images of 1040 volunteers (595 male and 445 female). The database is divided into seven sub-databases of change modes, such as attitude change, expression change, ornament change, illumination change, background change, distance change and time span change.

CASIA-WebFace face database:CASIA-WebFace face database is a large-scale face database published by Li Ziqing's team at the Chinese Academy of Sciences in 2014. The library contains 10,575 face categories, a total of 494,414 face image samples, with an average of 47 images per category. Among all categories, the minimum sample size is 2, and the maximum sample size is 804.

6. Face Recognition System Performance Test Project

In recent years, with the rapid development of artificial intelligence, cloud computing and big data technology, the field of face recognition has begun to enter the harvest period after a long period of technology accumulation. The industry has emerged a number of innovative companies based on face recognition, the internationally well-known CognitecSystem in Germany, NEC in Japan, Facebook in the United States, google, Bioscrypt, etc. In China, there have also been a number of face recognition system suppliers led by Sensetime Technology, MegVII Technology, Cloud Cong Technology and IFlytek. The variety of system suppliers, a wide variety of face recognition systems and the nominal performance of different good and bad in meeting the needs of the rapid development of society and economy, but also put forward urgent requirements for the test and comparison between different systems. For the testing of large face recognition systems, especially commercial systems, fairness and justice are the basis and premise, and the test results and reports can be used as guidance for enterprise and government procurement. Therefore, well-known large-scale face recognition tests are generally conducted by third-party independent testing agencies, and accept funding and supervision from government agencies, such as FERET, FRVT, MBE and other testing projects. In order to ensure the fair and authoritative test results, large face recognition system testing generally relies on a confidential test face database, and only a small part of the test data is available for manufacturers to debug the system before formal testing.

6.1. International test program

FERET is the world's first large-scale face recognition system evaluation project. The FERET project, funded by the Anti-Drug Technology Development Program of the US Department of Defense, collected and created the aforementioned FERET face image database as a test set, and set the performance benchmark for face recognition algorithms for the first time and defined a series of evaluation standards. The evaluation standards and evaluation protocols formulated by FERET have been influential to this day. From 1994 to 1996, the FERET project held a comprehensive evaluation of face recognition algorithms and systems for three consecutive years, which greatly promoted the development of face recognition technology.

Since the FERET project, the National Institute of Standards and Technology has led the evaluation of face recognition supplier systems, and has formed the most authoritative position in the international scope. So far, we have held FRVT2000, FRVT2002, FRVT2006, FRVT2010, FRVT2013, On▪ goingFRVT2017 series evaluation, and are currently organizing FRVT1:N2018 evaluation work. On the one hand, these evaluations test and compare the performance of well-known face recognition systems; On the other hand, a comprehensive summary of face recognition technology development status and key issues, indicating the future development direction.

The earliest FRVT2002, FRVT2006, FRVT2010 and other evaluations were successively launched for medium-high level algorithm testing, face recognition prototype system and mature commercial face recognition system testing, mega scale testing, etc., with a time span ranging from three to ten years, for phased inspection of the industry's top level and future development direction.

FRVT2013 summarizes the development trend of intelligent face recognition, and focuses on the evaluation tasks of 1:1 face verification, 1:N face search recognition, twin recognition, video sequence face recognition, gender estimation, posture estimation and age estimation. By 2015, NIST had compiled the results of the FVRT2013 test and published an overall evaluation report on gender estimation, age estimation, and 1:N face search recognition.

The OngoingFRVT2017 evaluation project started in February 2017, and unlike previous FRVT evaluation projects, OngoingFRVT2017 is an ongoing evaluation project. System vendors can submit algorithms for testing at any time, and NIST will timely compile the latest evaluation results and publish evaluation reports every month, the latest evaluation report is currently published in February 2018. The continuous evaluation and timely announcement model introduced by NIST in OngoingFRVT2017 is a huge breakthrough compared to the 2-4 years between evaluation and release of reports required by previous FRVT evaluation projects. OngoningFRVT2017 compares the recognition performance of different scenarios, different races, different genders and different ages for the test. The test data provided by OngoningFRVT2017 corresponds to actual application scenarios such as entry-exit management, identity access control authentication, and safe city monitoring. The data scale reaches millions by sampling tens of billions of samples. The test data is blind and not disclosed, which effectively avoids model training or live cheating in advance, and finally evaluates the model speed, feature database size, comparison threshold and other indicators in detail. In the test report released in June 2017, Yitu Technology, a reference unit from China, won the first place in four major test scenarios with an accuracy rate of 95.5% under one in 10 million false positives (sampling 10 billion pairs of samples), 2% higher than the second place, Russia's Vocord algorithm accuracy rate of 93.5%. Compared with the Japanese NEC algorithm that won the first place in the same kind of test in FRVT2013, the accuracy rate has been greatly improved. OngoningFRVT2017 evaluation report points out that in the past four years, from the open LFW and MegaFace test projects to the authoritative confidential FRVT test projects, the test indicators have developed from the false positive rate of 1 in 1,000 to the first hit rate of millions of test sets, and the false positive rate of 1 in 10 million. The algorithm and system recognition performance of various research institutions or suppliers has been improved by 10,000 times, and intelligent technology will unlock more application scenarios, from building buildings to city-level, and even multi-city linkage and nationwide face comparison will become possible.

6.2. Domestic testing progress

At present, there are no government departments and authoritative institutions in China to carry out blind testing of face recognition algorithms and systems based on private face image databases. In the process of testing and optimizing face recognition algorithms and systems, research institutions, experts and scholars generally rely on publicly available test sets and protocols such as LFW, MegaFace, CelebA, etc. Government departments, demand enterprises in the face recognition system research and procurement, generally only refer to a few national standards and industry standards put forward the specific system technical requirements and manufacturers nominal performance indicators, the system testing means still stay in the functional testing and information security testing, can not carry out effective, fair, authoritative algorithm system performance testing.

Faced with the aforementioned challenges, research institutions, suppliers, and government departments in China that specialize in facial recognition technology have preliminarily shifted the focus of comprehensive evaluation from data confidentiality, authoritative qualifications, and technical feasibility to basic aspects such as testing methods and technical standards in various application fields, laying a theoretical foundation for achieving systematic, standardized, and technically feasible evaluations across multiple application fields in the future. Research on facial recognition testing methods and technical standards in China is mainly concentrated in the field of security and defense, with relevant work led by the Ministry of Public Security, in conjunction with several research institutions and suppliers such as the Chinese Academy of Sciences. They have issued industry standards and national standards such as GA/T922.2-2011 "Security Facial Recognition Application System Part 2: Facial Image Data," GA/T1344-2016 "Technical Requirements for Video Facial Image Extraction in Security Facial Recognition Applications," and GB/T31488-2015 "Technical Requirements for Video Surveillance Facial Recognition Systems in Safety Prevention." These standards regulate the requirements for facial image data, functional indicators of facial recognition systems, performance indicators of facial recognition systems, and testing methods for the functionality and performance of facial recognition systems. The issuance of these standards is conducive to the scheme design, project acceptance, and product development of facial recognition systems in security video surveillance, and can also provide references for facial recognition applications in other fields.

7. Face Recognition System Evaluation Standardization Exploration

In Throughout the research status and development trend of face recognition technology, the current work of face recognition technology and system test specifications has the following characteristics:

the face recognition system test standards for face model training and algorithm testing are generally carried out for individual fields, and the test protocol is open source, without authoritative guidance.

Standardized and common face recognition system test standards are carried out by a few international authorities, and are mainly applied to industry analysis. For example, FERET, FRVT series test sets and evaluation standards led by the U.S. Department of Defense and NIST indicate the direction of authoritative testing of face recognition algorithms and systems, but the main purpose of these institutions and test projects is to carry out historical stage technical evaluation of global large-scale face recognition algorithm systems and analyze industry development. Unable to focus on daily, real-time industry-wide large, medium and small face recognition system testing, time-consuming.

There is a lack of systematic, standardized, authoritative and qualified general performance test specifications for face recognition systems in China.

In view of the above characteristics, the research work of face recognition system evaluation methods and technical standards in China can focus on the following aspects:

Facing the heterogeneous test requirements and methods of two-dimensional, three-dimensional, video surveillance and other different ways of face recognition systems, exploratory research on comprehensive multidimensional face image test standards.

According to the two main characteristics of the current large-scale face recognition system test: the test project of open source data is mainly used for independent testing and research optimization. And all kinds of data confidentiality test projects are mainly used for industry testing, industry analysis and. Combined with the characteristics of public testing and authoritative results for a large number of face recognition testing requirements in the future, a test theory system of face recognition system suitable for public testing, test data confidentiality and test feedback reverse time is studied.

Based on the previous research foundation and hardware strength, the multidimensional face recognition system test method is applied to carry out miniaturized test model testing, optimize and improve the system test theory system, and form a standard system.

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