

Application of Face Recognition Technology in Security Surveillance Systems: Postprint

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Abstract

Currently, facial recognition technology has become increasingly mature, and enterprises both domestic and foreign have developed security monitoring products employing this technology for deployment in industries such as public security and border defense, finance, public transportation, and big data analytics. As the application of facial recognition technology in the security monitoring domain constitutes an emerging development, users harbor reservations regarding this novel technology and the practical implementation of related products; the maturity of new products and the stability of the technology must both undergo user validation, and related products must also align with user requirements. Therefore, beyond requiring enterprises to articulate users' actual needs, relevant enterprises must likewise possess robust technical capabilities in facial recognition to resolve practical challenges confronted in security systems for users. Given that facial recognition technology finds increasingly widespread application across various industries, this technology is destined to usher in vigorous development.

Full Text

Application of Facial Recognition Technology in Security Monitoring Systems

Abstract

Facial recognition technology has reached increasing maturity in recent years, with domestic and international enterprises developing security monitoring products that incorporate this technology for deployment in public security and border control, finance, public transportation, and big data analytics. However, as the application of facial recognition in security monitoring remains relatively new, users harbor concerns about the practical implementation of this technology and its associated products. Both the maturity of new products and the

stability of the technology require validation through real-world user testing, and 相关产品 must align with user requirements. Consequently, enterprises must not only clarify actual user needs but also possess robust technical expertise in facial recognition to address practical challenges in security systems. Given its expanding adoption across various industries, facial recognition technology is poised for vigorous development.

Keywords: Facial recognition; Security monitoring; Biometric recognition; Face detection

1. Development Status of Security Monitoring Systems

Driven by advances in information technology and growing security demands, the need for security monitoring systems has intensified in recent years, spanning traffic violation monitoring, natural disaster surveillance, bank security, and residential area protection. This vast market demand has attracted numerous enterprises and companies to research and develop security monitoring solutions. Security monitoring systems represent an integrated, 联动 system primarily based on video surveillance, supplemented by subsystems such as access control, fire protection, and command and control. The evolution of these systems has progressed through three main stages: fully analog manual-control systems, semi-digital systems, and intelligent systems (encompassing multifunctional cameras, intelligent control centers, video servers, and data analytics services). Contemporary security monitoring systems have achieved functional integration, networking, and IP-based architecture, yet they suffer from a significant deficiency in data processing capabilities, requiring substantial manual intervention to maintain real-time and proactive monitoring. The integration of advanced recognition technologies—including facial recognition, multimodal biometric identification, and infrared recognition—will elevate security monitoring systems to new heights.

Human facial information has long been a critical acquisition target and data source, attracting focused research from security domain enterprises. As an emerging biometric technology, facial recognition offers advantages over voice recognition, fingerprint identification, and iris recognition in practical applications, including higher stability, better intuitiveness, and superior user experience. Its emergence marks a new milestone in security monitoring development and has been successfully implemented in various high-profile international security projects, such as the demonstration of new facial recognition technology by Alibaba at the PyeongChang Winter Olympics. The proliferation of facial recognition-enabled products demonstrates the technology's increasing maturity and vast application potential.

2. Technical Challenges of Facial Recognition and Influencing Factors

Facial recognition technology, as an emerging biometric identification method, authenticates identity based on facial features. Its development integrates computer image analysis, video processing, pattern recognition, and multiple other technologies, encompassing the following aspects:

- (1) **Face Detection:** In diverse environments, terminal acquisition captures complex data including background information, positional data, and facial information. Upon confirming the acquisition of facial data, the system determines the face's relative position and extracts facial feature information such as hair, facial proportions, tilt angles, lighting intensity, accessories, and various occlusion factors. Excessive interference factors increase the difficulty of facial recognition.
- (2) **Face Tracking:** After facial detection confirms the presence of face data in the stream, the system continuously tracks changes in facial position, proportions, and tilt angles.
- (3) **Feature Identification:** This process involves comparing data generated from detected facial information through recognition algorithms against existing data in facial databases, yielding comparison results through comprehensive indexing.
- (4) **Expression Processing:** The system analyzes and digitally models expression information (sadness, fear, surprise, anger, happiness) obtained from facial recognition data, using self-learning to classify and summarize patterns.
- (5) **Classification and Profiling:** The system analyzes relevant physiological characteristics obtained through facial recognition information, such as age, gender, ethnicity, and occupation.
- (6) **Comprehensive Processing:** Based on facial analysis algorithms, the system intelligently processes and compares comprehensive facial recognition data, verifies conclusions, and produces final analytical results, completing the entire facial recognition workflow.

For computers, facial recognition remains considerably challenging, unlike human perception. The technology's bottlenecks stem from multiple interference factors that affect recognition accuracy. Primary issues include:

- (1) **Illumination:** Lighting intensity is a critical factor affecting facial recognition performance. Facial information captured under overexposure or low-light conditions rarely meets recognition requirements. Therefore, acquisition devices should be selected based on actual application environments, with consideration for supplementary lighting or shading.
- (2) **Pose Angle:** Different facial angles significantly impact recognition, as

profile and frontal views exhibit fundamental differences.

- (3) **Facial Scale:** Facial images that are too large or too small cannot generate clear proportion information, affecting recognition performance. Within a reasonable acquisition range, more pronounced proportional features yield higher recognition performance.
- (4) **Accessories and Makeup:** Accessories and cosmetics that do not alter facial feature information have limited impact on recognition performance, but excessive occlusion drastically reduces data completeness and recognition effectiveness.
- (5) **Acquisition Completeness:** Affected by acquisition device efficiency, intentional occlusion, rapid movement, or deliberate head-lowering prevents complete facial information capture, consequently impacting recognition performance.
- (6) **Original Data Quality:** Even with ideal acquisition conditions, incomplete original data or low image resolution prevents achieving satisfactory recognition results. Therefore, high-quality original data substantially improves facial recognition accuracy.

Analysis of these issues reveals that illumination intensity exerts the greatest influence on facial recognition. Consequently, the technology's adaptability and control capabilities regarding external lighting environments constitute a key technical bottleneck limiting widespread adoption. To address this challenge, emerging infrared recognition technology largely compensates for illumination deficiencies in facial recognition. Combined with leading multimodal biometric fusion algorithms, facial recognition can achieve high accuracy rates. The comprehensive application of these new technologies has established a solid foundation for deploying facial recognition in intelligent security monitoring.

3. Architecture of Facial Recognition Security Monitoring Systems

The widespread deployment of video surveillance systems demonstrates their evolution into a ubiquitous monitoring methodology. Traditional security video surveillance systems comprise terminal acquisition modules, data transmission modules, and data storage modules. Systems enhanced with facial recognition technology incorporate an additional data analysis module for processing, tracking, and analyzing acquired data. The complete architecture of a facial recognition security monitoring system is illustrated in Figure 1 [Figure 1: see original paper].

The facial recognition-enabled video surveillance system includes the following modules: data acquisition terminals, video processing and analysis modules, data storage modules, and alarm processing modules. **Data acquisition terminals** identify facial information from captured data and transmit high-quality data to the video processing and analysis module. **Video processing and**

analysis modules extract feature point locations from acquired image information and compare them with data in the storage module. **Storage modules** preserve relevant data and analysis results in databases, establishing facial recognition archives. **Alarm modules** generate alarm information based on analysis results, such as displaying alerts on monitors, activating audio-visual alarms, or triggering 联动 with other terminals.

Currently, data acquisition terminals are implemented through two approaches. The first approach employs facial recognition-capable devices within video surveillance systems. These devices directly capture facial images from video frames, transmit them to the analysis module for comparison, and store processing information and facial recognition archives. This model, suitable for newly constructed surveillance systems, offers high functional integration and controllable costs. The second approach utilizes traditional video acquisition devices, with recognition equipment extracting facial information from the data stream for transmission to processing modules. This method enables upgrading existing video surveillance systems by adding facial recognition modules rather than replacing acquisition devices, thereby controlling costs and reducing system upgrade expenses.

From a data flow processing perspective, facial recognition algorithms handle data acquisition, facial feature point localization, data modeling, and analysis processing. The specific workflow is illustrated in Figure 2 [Figure 2: see original paper].

Among numerous facial recognition algorithms, neural network-based approaches are particularly prominent in the industry. Inspired by human neural systems, neural network recognition algorithms construct complex systems through interconnected primitive processing modules, analogous to human nervous system architecture. These algorithms possess self-learning capabilities, enabling them to derive laws and expressions about facial recognition through machine self-learning (similar to human cognitive processes) that surpass other methods. After training on extensive baseline data, neural network-based facial recognition algorithms demonstrate superior performance in accuracy, fault tolerance, and robustness compared to alternative approaches. As an efficient self-learning algorithm, it is well-suited for addressing current challenges in facial recognition.

4. Application Prospects

Facial recognition technology has been deployed across multiple industries, primarily manifested in intelligent video surveillance systems with facial recognition capabilities. These intelligent systems find application in two categories: security-related industries and non-security industries.

In security-related sectors, intelligent video surveillance systems are widely used in security markets, such as prison management, airport administration, military restricted zones, and government facilities. Products integrating facial

recognition technology with video surveillance have achieved the broadest adoption. For instance, in prison management, the complex and spatially dispersed environment contains numerous surveillance dead angles and visual blind spots that personnel cannot fully cover. The implementation of intelligent video surveillance with facial recognition technology...

Note: Figure translations are in progress. See original paper for figures.

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