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**SCHOOL OF BUSINESS DEPARTMENT OF INFORMATION SYSTEMS AND COMPUTING**

**TOPIC: ADVANCEMENT IN FACIAL RECOGNITION SYSTEMS**

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**ABSTRACT**

Biometrics industry especially facial recognition technology has continued to gain more importance in recent years due to its security, Health, Finance and Consumer Electronics industries. This paper aims at reviewing recent developments of facial recognition systems; however, the concentration is made on the application of deep learning approaches, advanced algorithms, and better hardware systems.

The advent of Convolutional Neural Networks (CNNs) and Deep Neural Networks (DNNs), the recognition of face images has moved from a slow pace to a faster one and at the same time more accurate. These systems have brought ability to better recognize the subject consistently, not just in low light, from different angles or even under partial occlusion.

Nevertheless, increasing dilemmas of ethical issues and privacy are still seen since this technology has already starting gaining popularity. This paper also discusses the limitations of the work that is still present, namely the dataset bias and vulnerability to spoofing. Taken collectively, the research indicates that facial recognition technology has come a long way but there is a need to press on with development to overcome current shortcomings and promote the proper use of the technology.

Facial recognition technology has evolved significantly since its inception in the mid-20th century, transitioning from simple mathematical systems to advanced solutions powered by artificial intelligence (AI) and deep learning. Initially reliant on techniques like Eigenfaces and Fisherfaces, modern facial recognition leverages Convolutional Neural Networks (CNNs), deep metric learning, and generative adversarial networks (GANs) to enhance accuracy and robustness, even under challenging conditions such as poor lighting or obscured features. Achieving over 99% accuracy in ideal scenarios, it has become a cornerstone in security, commercial applications, and healthcare.

Despite its advancements, facial recognition faces criticism for biases in recognizing demographic groups and ethical concerns regarding privacy. Efforts are underway to address these issues using diverse datasets, differential privacy, and federated learning to balance technological innovation with morality and trust. Applications range from security and crime detection to customer personalization and healthcare, emphasizing the need for ethical and legal frameworks to guide its use.

**I**n conclusion, the future of facial recognition technology lies in addressing its ethical challenges and fostering trust alongside technical improvements. Future research mustprioritize transparency, fairness, and ethical solution designs to ensure equitable implementation and societal benefit.

**INTRODUCTION**

***Background information***

Advanced facial recognition technology has undergone impressive positive changes in the last several decades moving from an innovative concept to an indispensable element in securities, commercial, and individual uses. First developed middle of twentieth century as simple systems based on mathematical calculations and face dimensions, these systems have undergone significant changes thanks to development in machine learning, artificial intelligence, and large computing resources. Modern society is already surrounded by facial recognition technologies starting from unlocking smartphones passing through securing airports and becoming one of the main successes in the sphere of computer vision. Therefore, the further development of this category of technologies has increased, being aimed at enhancing the recognition’s performance, stability, and potential concerns in various and complex conditions.

The main technique progress in facial recognition is chiefly rooted in the change from the image processing method to the deep learning approach. Traditional facial recognition methods included Eigenfaces where key points of an image were extracted and matched or Fisherfaces where similar processes involving stored data were involved. However, these methods proved to have limitations in that they changed with the lighting conditions, facial expressions, and angles of the subject that was being examined.

Convolutional Neural Networks (CNNs) and deep learning architecture have made recent advancements which have better enable systems to learn these patterns with high accuracy independent and in an enhanced robust manner from facial data. Subsequently, other methods like the Siamese network, deep metric learning, and generative adversarial networks (GANs) have extended facial recognition’s options to ensure that it succeeds even when the lighting is poor, facial angles are diverse, and facial features are partially obscured. The modern facial recognition currently relies on deep learning frameworks and achieve individual identification with exceptional accuracy, which sometimes is above 99% if all circumstances are perfect.

***Significance of the study***

Although there are many benefits associated with innovation of technical progress in the field of facial recognition, many questions arise. One of the major issues with such systems is provable bias concern in how the developed algorithms and artificial systems fair across the various demographic categories. Experience has revealed that some algorithms used in FRS behave worse in recognizing specific ethnic type, which causes ethical and social problems related to violation of privacy. In this regard, the researchers are currently focused on working on a dataset with a less restricted sample of people and the approaches that minimize or eliminate the possibility of the bias and increased model interpretability. Furthermore, the enforcement of facial recognition technology for security purposes noticed privacy, rights issues. Such issues have raised the need for privacy-protective approaches like differential privacy and federated learning, which are appreciating the correlation in-between technology and morality.

***Problem Statement***

Biometrics facial recognition systems have experienced innovative development over the last few decades in security, authentication, surveillance, and Human computer interactions. Nonetheless, the advancement achieved in this area is inadequate in handling certain challenges such as accuracy, fairness, security, and privacy.

Current facial recognition systems pose certain challenges with regard to lighting, pose, expression or age that cause false identifications, especially concerning people of color. Further, there has been live facial recognition implemented across different areas of safety that has attracted ethical and privacy issues such as mass surveillance and data misbehave.

Moreover, the use of such systems increases prejudice in one way or another across different sample sections (gender, ethnicity, age) to give disparate outcomes a shot, particularly in sensitive sectors, including policing, immigration control, and the like. Despite the outstanding performance enhancements by deep hallucination approaches, the necessity of large marked datasets and huge computing power remains a challenge for small entities and less privileged circumstances. Based on these challenges, it is imperative that there is enhanced, sound and privacy enhanced facial recognition system. Thus, the goal of this research is to explore the latest advancements in facial recognition technology while addressing the following core problems:

***Objectives***

1. **To analyze**:
   * The state-of-the-art techniques in facial recognition, focusing on advancements over the past decade.
   * Comparative performance metrics of existing algorithms and systems.
2. **To evaluate**:
   * The societal, ethical, and legal implications of deploying facial recognition systems at scale.
   * The role of government regulations and standards in mitigating biases and protecting user privacy.
3. **To propose**:
   * Recommendations for enhancing the accuracy, inclusivity, and security of facial recognition technologies.
4. **To identify gaps**:
   * Existing challenges that hinder widespread adoption and trust.
   * Areas of future research necessary to address current limitations.

***Scope***

**The scope of this research paper is to explore the advancements in facial recognition systems, focusing on the evolution of technologies, methodologies, and applications. It aims to provide an in-depth analysis of the integration of artificial intelligence, machine learning, and neural networks in enhancing the accuracy, speed, and reliability of facial recognition technologies. The study will also examine diverse applications, including security, healthcare, and retail, while addressing the challenges related to privacy, ethical concerns, and bias in algorithms. The objective is to assess the current state of the field, identify emerging trends, and propose recommendations for future research and development. Additionally, this paper seeks to highlight the societal implications of these advancements and explore the potential for innovation in creating a balance between technological benefits and ethical responsibility.**

**LITERATURE REVIEW**

**Theoretical Framework**

Things like Automated Face Recognition in applications such as security, personal devices, and healthcare have made facial recognition technology fundamental in most applications recently because of the artificial intelligence and the machine learning that have developed. The purpose of this literature review is to collect present literature on the topic of developing facial recognition systems, covering methods, technology advancements, and topics for future research. Thus, this paper presents a synthesis of the current trends based on analyzing a set of scholarly articles, books, and other credible sources, highlights the main research gaps, and outlines potential research directions.

The initial phase of this literature review entailed using Galileo libraries, web-based articles, books, academic journals, conference papers, and other ranked online sources. Specific attention was paid to the selection of the primary and most recent studies to disclose the modern developments in the area of facial recognition systems. Publications available from identifiable databases such as IEEE Xplore, ScienceDirect, SpringerLink and Google Scholar were considered. In order to limit the review to the most significant sources in the fields of computer vision and machine learning, this review includes only the results that best characterize the current state of facial recognition technology.

There are a number of developments and trends that can be noted in the case of facial recognition technology with special focus on the revolutionary submission from traditional methods to deep learning and neural forecasts. Building on the earlier Turk and Pentland (1991) work on Eigenfaces, foundational techniques for facial recognition were in the analysis of facial features as different data. This approach, however, proved to be sensitive to environmental factors like lighting and facial expression, thereby giving poor scalability when tested in unconstrained environment.

**Current Findings**

The year of 2012 has been a turning point in the field through having impressive performance by the convolutional neural networks and many other deep learning models. Taigman et al. (2014) presented DeepFace that heavily relies on a deep convolutional neural network and Schroff et al. (2015) proposed FaceNet, which also relies on the deep convolutional neural network. Deep Metric Learning is employed in these models to generate embeddings of facial pictures to recognize faces through projecting facial features in a high dimensional space in order to reduce inaccuracies in real-world scenarios. Moreover, with the revelation of Generative Adversarial Networks (GANs) by Goodfellow et.al in their study, the models became capable to generate impressions that supplement the training of the facial recognition frameworks, especially if there are few samples.

In spite these advancements, several weaknesses and research gaps are perceived in the existence of facial recognition systems. Another important yet less developed direction is the use in a wider range of environmental conditions: low light environments, extreme angles of facial view, or partial occlusion. Even though contemporary False Rejection Rate (FRR) exhibit great results in perfect environment, they transfer poorly to conditions like these.

There is a need for more flexible models as was suggested by Wang et al., 2020 and Zhu et al., 2021**.**

***Research gaps***

Another gap is actually in the sphere of privacy-preserving approaches to face identification. Smaller scale MIFS while demonstrating normalization capability fails in terms of privacy consideration, overall, as privacy infringement and data security remain significant threats, there is a growing concern about developing systems and methods that can recognize faces while embedding sufficient privacy considerations. Privacy-preserving solutions like differential privacy and federated facial recognition algorithms are work in progress, promising, but not fully ready for mega-scale commercialization solutions at the time of doing this research. Lastly, despite effort to increase impartiality in facial recognition, more studies have to be made in regard to the moral and societal impact of these systems in society, and policing, in particular. For instance, Raji et al. (2020) suggested that there is a need to develop models with clear accountability, which is also fair but also learns different social norms regarding privacy and ethics.

**RESEARCH DESIGN AND METHODOLOGIES**

***Research design***

Choosing the research design is an important stage of the work since it determines further actions in data collection and analysis. An exploratory type of design which is likely to yield only a few qualitative results that could then guide subsequent quantitative analysis designs, while the other one is an experimental type of design in which alternatively, hypotheses are tested in a very controlled manner.

In facial recognition research, how data is collected depends on the research design as well as the type of data being required.

Common methods include: Image Databases and Benchmarking Datasets: The most common data source which is widely adopted in facial recognition papers is the existing image datasets including LFW dataset, MS-Celeb-1M, VGGFace2. These datasets constitute examples of standardized sets of images for assessment and performance calibration of facial recognition systems.

***Data collection methods***

Surveys and Questionnaires**:** In case the concern is about the User perception, their privacy or Social effects of

Face recognition technology, surveys and questionnaires give a quantitative measure of users’ opinion and experience. In this context, this method can be employed by researchers in order to establish public opinion, or test usability and/or ethical perspectives from different subjects across the population.

Interviews and Focus Groups: For the qualitative data, the researchers may interview experts in computer visional, laws enforcement, ethics among others.

Additional focus groups may be also used to get some insights from the lay users, such that the researchers interested in nuanced attitudes to privacy, consent and trust in facial recognition technologies can explore.

Case Studies:There are also rich case descriptions in many forms, like case of facial recognition applied to airports or law enforcement. This approach is especially helpful for exploring such practical problems as system preconceptions, legal aspects, and organizational effectiveness.

Acquisition of data is an essential process in both the scientific studies on features of facial recognition and the accurate identification of faces themselves. The body of quantitative data applies the findings to a more wide-appealing population, while qualitative data gives more details and circumstances and, therefore, the usage of both approaches contributes to the progress in the field of facial recognition.

Sample Size Definition and Participants’ Selection Sample size and participants’ inclusion criteria differ with the purpose and scope of the study and the method of data collection.

On a quantitative level, large sample sets are sometimes required to obtain satisfactory reliability coefficients, especially given the usage of images in experiments. For example, a study comparing the error rate of an algorithm between different genders and age groups and ethnicity or even skin tone may need thousands of images that represent age, gender, and skin tone.

Thus, while conducting a quantitative research, the total number of participants for the data collection system, for example interview or focus group is comparatively small. Purposive sampling is usually applied by researchers in order to include participants who are knowledgeable in a subject being investigated.

When choosing participants of the survey it may be effective for researchers, for instance, to involve members of privacy advocacy organizations, representatives from the police, as well as representatives from firms that develop facial recognition software.

Apart from sample size, there is the issue of population representation, especially in regard to the results obtained in a study.

Much of the current facial recognition studies suggest the need to incorporate diverse datasets since previous research has established that some of the algorithms offered low accuracy to persons of certain ethnicity or age brackets.

Making sure to have a converse sample is therefore not only a methodological principle but also an ethical imperative that fits into work on inclusive facial recognition technology.

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