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Facial Recognition System in Healthcare Application

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Annotation: Facial recognition (FR) systems have been increasingly applied to various applications in recent years, and the gradual understanding and technological advances of deep learning (DL) based approaches have improved the accuracy of FR systems, while also enabling various face-related inquiries such as attribute estimations . Robustness and adaptability against lighting conditions, complexion variations or facial obstructions were fully discussed in the media; nonetheless, a less discussed issue frequently observed, especially in public venues, is that people wearing masks were on a rise due to a pandemic contagious disease risk. Before the pandemic, it was discussed that the accuracies of existing FR systems would greatly deteriorate even in the presence of merely annual flu outbreak and found this issue to be applicable to pose, hair style, neglecting accessory, and other factors.

Introducing and routinely utilizing a facial recognition system when the masks became commonplace may significantly degrade the performance and applicability of the facial recognition system, prohibiting its possibility in global venue applications. Advocated research is expected to emulate attempts of various applications including other approaches of face, voice, iris, and physical modaletry based recognition methods, additional identity verification mechanisms such as card-based approaches, attempt to authentication among subjects only in certain conditions.

Healthcare facilities routinely take a face photograph at patients' admission and have the inner private entity database which complies with past regulations concerning face photographs, while in need of a positive authentication method for patient identification prior to administering any medical actions. Noting the emerging healthcare application constraints of safety, financial, maintenance, and medical aspects, accessible and acceptable FR system is needed. While youthful and middle-aged patients may be able to fully cooperatively facing frontward, elder patients may usually posses fears due to a lack of understanding of facial recognition systems, giddy errors, partial disguises, and such issues which need to be taken in consideration.

1. Introduction to Facial Recognition Technology

Face recognition is a popular research area in image processing and computer vision as it has various practical applications in surveillance systems, biometrics, access control, law enforcement, smart cards, and information security [1]. A face recognition system includes face detection, recognition, and identification. It works by first capturing an image of a person. The camera can be an individual device, a mobile device, or a video surveillance system. Next, the system detects whether there is a face in the captured image and localizes the face region or the area of interest. This detection task can be generally considered as a classification problem. There are two classes in the classification task: one is the face class, and the other is the non-face class [2].

A popular way to deal with this problem is to use a cascade structure with increasingly more complex classifiers to quickly reject non-face regions. A more complex classifier that needs more computation is used as a second line of defense after a fast but less accurate classifier. Once the region of interest or the location of the face is detected, the subsequent processing steps try to segment the face area from the background and normalize it regarding scale, rotation, translation, and illumination. The output of face detection is a normalized face image. A popular face detection system builds a large number of cascade classifiers, which are obtained from a training process based on AdaBoost and support vector machines. Each classifier has a somewhat different feature set and is used for detection on a different sub-image size. After a face image is normalized, it is transformed into a computer-understandable representation by extracting features. The features can be categorized as geometrical features, template-based features, appearance-based features, and model-based features. [3][4][5]

2. Overview of Healthcare Applications

Healthcare has been targeted by many researchers as a newly emerged application field for facial recognition based systems. In healthcare, facial recognition systems can be employed in applications such as diagnosis of facial disorders, personality identification, customer management, and patient monitoring. For example, abnormal facial regions due to facial disorders, such as skin disease and keratosis, can be effectively sent back to patients using facial recognition based diagnosis systems. Telehealth systems with facial and voice recognition can provide extra safety in customer management by locking user accounts. Monitors with facial recognition can allow quick health status acquisition from the detection of sleepiness and depression. Surveillance systems can monitor patients' health status and assess behaviors such as cognitive decline and drowsiness. Although there have been lots of research works on facial recognition systems in healthcare applications, comprehensive reviews are limited. Since early studies were targeting analysis of disorders of skin or physiology, there are recent studies aiming on the recognition and diagnosis of facial disorders relating to handsomeness, emotion, sleepiness, mood, and behavior. As a corner of healthcare applications, telehealth systems with facial and voice recognition are also reviewed, including emotion recognition for mental diagnosis, home monitoring for activities of daily living, and voice print authentication. As another corner of healthcare applications, health status assay has been reviewed, including recognition of gait, drowsiness, sleep apnea, or depression. This paper focused on works from Asian countries, since lots of workloads for facial recognition based healthcare applications are from Asian countries such as Japan, China, Taiwan, and South Korea. A summary of contributions, systems, or methods targeting healthcare applications is given. Together with a general framework for the design of a facial recognition based healthcare application system, drawbacks from studied systems are described, and some future research directions are suggested [2]. The purpose of this study was to develop a facial recognition mobile application for patient safety and biometric identification in a hospital setting. The facial recognition app was designed in accordance with hospital requirements. Five main parts are included: registration, medical records, examinations, prescriptions, and appointments. The facial recognition app was implemented in the emergency room and neonate unit of a university hospital in South Korea. For outpatient registrations, 67 patients were enrolled and tested for face recognition while waiting for medical treatment. For inpatient registrations, 104 patients were enrolled and examined in the ward. The accuracy of the facial recognition system was evaluated according to the number of patients registered and the recognition distance. The developed mobile app was suitable for hospital usage and security purposes. When the facial recognition system is fully linked to the electronic medical record (EMR), it can be introduced in clinics and hospitals for patient verification [6].

3. Technical Foundations of Facial Recognition

The growing importance of facial recognition systems (FRSs) in healthcare settings worldwide can be attributed to their multifaceted applications in healthcare settings. These applications span across various care domains and modalities, including tools for accessing information and security. Recent advancements in computer vision and artificial intelligence, specifically in collecting, processing, and analyzing video/image data, have enabled the deployment of advanced FRSs. In addition to traditional applications such as security monitoring, fraud detection, and user authentication, many automatic facial analysis technologies to monitor or infer users' emotional states and mental health have emerged. The growing body of research on the application of facial analysis technologies across various application domains has further emphasized their utility in real-world scenarios. Nevertheless, ethical considerations including biased and unfair algorithmic performance, privacy, and data protection concerns, and societal biases or prejudices may limit their adoption [7].

Most medical image interpretations are performed by using machine vision algorithms to classify images. Automatic facial image processing technologies for healthcare applications utilize visual content in images or videos to extract diagnostic information or painfulness from facial images. They transform a digital image into a set of data formats that can be handled by a computer to extract a set of informative features and classify the extracted features into some pre-defined categories. Healthcare approaches based on automatic facial analysis technologies comprise a data-acquisition unit such as a camera system, a video/image-processing unit to extract a set of numerical data from the images, and a desktop/laptop computer or mobile device to analyze the extracted numerical data. Unlike voice-based and wearable sensors, a camera to record facial images is typically built into commonly used devices for the healthcare solution and hence makes the applications of facial image processing systems flexible and versatile [8].

For face recognition systems, image preprocessing includes image alignment, cropping, and face detection, and then a feature extraction algorithm is utilized to extract a set of discriminative facial features to discriminate among different identities. Vector representations of facial features are generated and matched using a distance metric or a classifier. The process of face representation and distinguishing between individuals is performed merely by using a single face image captured by a low-cost camera under uncontrolled conditions. In addition to recognition on still images, several algorithms have been developed to represent faces in videos by optimizing temporal coherence with respect to optical flow techniques. These algorithms can robustly represent faces in an entire video and successfully maintain recognition performance in the presence of significant variations in viewing conditions.

3.1. Image Processing Techniques

Face detection is one of the most important applications of computer vision, playing a critical role in human–computer interaction, surveillance systems, video security, human behavior analysis, and human emotion recognition. It enables measuring the head pose and the gaze direction of people or detecting facial features. This paper covers a human face detection using skin color detection and Gabor filter technique in MATLAB. Face recognition is the process of identifying or verifying the identity of a person using a face. Face recognition can be divided into 2: face identification and face verification. Face identification is the task of finding the person from the image database whereas, in face verification, the identity of the person is confirmed [7]. This paper introduces a new face recognition technique using PCA. The database of the human face image has been created. To recognize the face from the database, the eigen values and eigen vector are calculated using PCA. The recognition result is verified by matching the distance between test image features and the reference stored images [9]. The system is divided into two subsystems: the detection of the faces in real time and the recognition of the detected face. A hybrid technique is introduced for face detection that guarantees accuracy. The face recognition system is also hybrid, combining PCA and neural networks, which also guarantees good results and accuracy. Algorithm developed in MATLAB software detects and recognizes n number of faces. Here, they are working in a crowd detection mode and gathering news at much more difficult scenarios. Existing and upcoming biometric systems have been proposed and implemented for identification, verification, security, and surveillance purposes. Existing and upcoming biometric systems have been proposed and implemented for identification, verification, security, surveillance, and for forensic purposes. Some of the proposed biometric techniques are based on keystroke dynamics, gait, iris, palmprint, voice, ear, signature, finger vein, hand vein, 3D face and etc. With the age of human civilization, the demand for security is increasing rapidly and with that growth, criminal activity is also increasing. Fast and precise biometric-based recognition has gained new challenges. For a long time, the human face has been the most extensively researched biometrics characteristic due to its social significance and relative ease of acquisition. Face-based recognition is popular due to its nonintrusiveness and is of great relevance in real-world applications. [10][11][12]

3.2. Machine Learning Algorithms

The face detection technology focuses on detecting a moving object in a video to track its recognition. A fixed overhead camera determines the location of the face in the still image with a border box or rectangle; these values are saved in a database file. The recognition system detects the individuals in order and saves their name and data with the timestamp. A named window displays the timestamp and the name of the detected person. If an unauthorized person is detected, it shows “No face detected” on the window with no timestamp or name. Facial detection uses a deep learning model that takes pictures as input images and detects faces in returned images from the camera view. The database compares detected faces from this model with stored database faces [13].

The database was designed using the SQL database, which saves the authorized person names and IDs, stored pictures of the names, and their attendance ID to identify and manage people. At the beginning of the program, names and pictures are loaded from the SQL database; the attendance ID is provided to each authorized person on the prior feeding of names. When an authorized person is detected, a timestamp is fetched by getting the current system time with seconds. Its name and the attended timestamp are respectively shown on the name window and the attendance data window [14]. The usage of the database and export attendance to the CSV file needs to have value types such as number, text, and time. To insert pictures in the SQL database, it needed to be converted to bytes. A detection and recognition program is written for running on a real-time video stream from the camera. A labeled rectangle box displays the detected face with the name and attended timestamp.

3.3. Data Privacy and Security

Data regarding patients is one of the most important and needed resources in healthcare. Patient and environmental data is fundamental for the introduction of automation in healthcare systems. Moreover, matching, identifying, and finding patients information is essential. This challenge is more difficult and critical in emergency situations or when mistaken identification leads to serious consequences. Offering better service to patients while protecting their privacy and eliminating the chance of misinformation is essential. Face recognition systems (FRS) are one of the methods that take care of these challenges. FRS eliminates the chance of mistaken identification since it identifies patients using their privacy-protected biometric face information and matching them with the hospital information system (HIS) database. In addition to perfect matching and fast service for healthcare staff, FRS offers patients the comfort of no identification information input and threats of leaking their sensitive data. Furthermore, while the patient’s visual biometric data does not provide any identification information, it is protected and not stored in the FRS database [7]. FRS systems are made up of two components. The first component is the enrollment database, which stores a patient’s modeling data. The second component is the front system camera, which plays the role of enabling services for patients and inputting visual biometric data into the database [15].

While each stage of FRS has its own practices and defined settings, face recognition model training using a machine learning network is one of the most essential and critical components of FRS. The introduction of automation increased the need for enhancing the quality of collected data over time. The performance of the network relies on the quality and volume of collected data vital in developing age and race groups. If inaccurate or irrelevant data is collected and fed into the network as positive patient samples to be recognized, the network will be poorly fitted and thus unable to recognize patients. Since all data enrollment types have the same chance of being enrolled, facial similarity might lead to an increase in collected data relevance. Thus, a filtering solution for entering face data is required. To keep an ideal balance in patient face visualization data entrance and cleaning operations, finding and gathering irrelevant or unwanted patient faces could help to improve hospital healthcare system performance. [16][17][18]

4. Benefits of Facial Recognition in Healthcare

One of the dimensions in which facial recognition can be used in health is in patient identification, quality of care, and satisfaction control [7]. The hospital must take all possible measures to prevent identification reversal of unconscious patients or patients who transpose identification tags. To overcome this, many hospitals have started using facial images as identification tags. In this study, we developed a facial recognition system using deep learning techniques. The system was evaluated for patient identification in a comprehensive clinical trial including 100 patients to capture patients with various backgrounds and the constraints imposed by clinical settings. Extensive evaluation experiments were performed, and the results showed that the system could achieve sufficient performance. The authentication rate exceeded 99%

even under lighting conditions of 20 Lux at night and 50 Lux in the resting room. The system could still identify sleep mode patients on a hospital bed with performance reduction. Furthermore, the facial recognition system was safe and acceptable for patient identification based on feedback from both patients and nurses. Even with masks, the facial recognition system achieved a success rate of 100% for authentication if the patient was sitting with eyes open.

The health and safety of patients is a major concern of all health professionals, and hospitals are considered a trusted place by most people. However, many risks still remain for all hospitals, such as identification reversal of unconscious patients or patients who transpose color-coded identification tags. To minimize this risk, it is essential to properly identify patients prior to any care and treatment. Thus far, technology has yet to materialize to address this concern. This study offers an innovative paradigmatic advancement for health engineers and clinical engineers by proposing a facial recognition system using deep learning techniques.

4.1. Improved Patient Identification

The accuracy of facial recognition systems utilizing deep learning techniques may further improve the accuracy of facial recognition technology. This study examined a facial recognition system utilizing deep learning techniques and the built-in camera of an iPad. The aim was to recognize hospitalized patients with consideration for their various situations.

A facial recognition system utilizing deep learning techniques and the built-in camera of an iPad was examined. The system is expected to reduce medical accidents due to misidentification, which may be one of the potential applications of facial recognition systems in health care. Facial recognition is a method of identifying people using their facial features. There have been achievements in technology due to deep learning in recent years, and there are systems that can identify unknown people by registering their faces using cameras [7]. Several clinical studies regarding a facial recognition system for identifying healthcare personnel have been reported. However, there is no report evaluating such a system regarding patients in a real-world medical environment. Patients hospitalized in a ward undergo various situations affecting the facial recognition systems, such as photographic angles, postures in bed, lighting, usage of masks, and eyelid conditions when asleep.

In real-world medical environments, some situations, such as being in bed in a supine posture and covered with blankets, affect the photograph of a patient’s face. Such medical situations deteriorate facial exposure, leading to the difficulty of recognizing patients using foregoing recognition systems. Therefore, a system utilizing wide-angle lenses and deep learning techniques to increase facial exposure and improve online recognition ability was proposed. The evaluation covered not only general patients but also patients sleeping at nighttime, those in various postures on beds, and those wearing masks, because these situations may break typical face capturing situations. By testing the identification of patients in diversity, the novel facial recognition method for patient identification was evaluated, verifying the applicability in real-world medical environments.

4.2. Enhanced Security Measures

Addressing conflicts between privacy and ethical concerns of staff and patients, facial recognition systems hold the promise of enhancing security measures [7]. Data security and privacy risks, including unauthorized third-party access methods and costly and labor-intensive data handling by staff, led to a tightening of legislation and regulations regarding the use of biometrics and data collection and processing six years ago. However, the Covid-19 pandemic was a strong incentive for cautious online and digital monitoring. This kind of technology can distinguish users or faces reasonably well, but collecting biometric data, which are sensitive by nature and are considered a high-risk area by data protection authorities, still meets skepticism.

Nevertheless, facial recognition systems promise to maintain high levels of security through automated and robust technology. Until a few years ago, alternatives to or protective measures against recognized threats were often more difficult or slower for staff than staff checks. While various data protection measures are planned and in place for hospital staff to protect the integrity and security of hospital data, patients currently have no means to address the risk of facial recognition-based threats. If not carefully considered, such systems could generate distrust and ethical concerns among both staff and patients. Automatic checks run the risk of distrust and skepticism towards the system as well as patients attempting to bypass it. Ethics boards will be consulted and patient guidelines written as to what a patient would need to disclose, and institutions will communicate their planned protocols before the start of a system.

4.3. Streamlined Administrative Processes

For hospitals, the safety of hospital outpatients is a top priority. However, a case of abuse of critically ill patients by a caregiver may have serious consequences for the hospital. It is necessary to continuously monitor hospitalized patients in a special unit. The proposed computer vision analysis system and mobile app would detect attacks by improperly caring for patients, such as shaking and yelling, and identify caregivers. In addition, the patient identification system can improve patient safety and hospital efficiency and allow prepaid consumables. They also addressed their implementation and validation in actual hospitals [6].

Various facial recognition systems and methods have been proposed in the literature using a monocular camera or stereo camera under the most sophisticated visual scene with a single or multi-DL models on embedded systems or cloud-computing platforms [7]. Since the hospital environment is complex and varying, such a dense and sophisticated system is not suitable for use in hospitals. The proposed facial-based patient safety and identification system was designed with a simple pipeline with single DL models to reduce misidentification and reduce the latency required for faster and simpler recognition. The mobile app identifies patients from still images captured by low-resolution cameras with background filtering and memorizes tracking of patients in multiple hospitals. The patient safety monitoring app detects caregiver misconduct via analyzing pre-trained video clips with an unintended inference. All the proposed systems were developed on commodity computer platforms and open-source tools for easy and flexible application in hospitals, and their design, implementation, and validation are discussed.

Various face recognition methods have been proposed, but most methods are not robust to the environment and require careful placement of cameras. At the moment, there are practical systems that can be applied in hospitals without overhauling existing systems. A system based on mortality data from several hospitals shows an example where the user has ultimately little control. In contrast, the system relies on the user to provide detailed templates for successful classification. Additionally, the effectiveness of this pedigree approach is to use face images collected under carefully controlled conditions as with other biometric traits.

5. Challenges and Ethical Considerations

Despite the COVID-19 pandemic accelerating the implementation of facial recognition systems, there are still technical, ethical, and regulatory challenges to tackle before widespread installation. First, one issue is the lack of generalizability of facial recognition systems for patient identification from studies and implementation examples. The types of medical settings and input protocols are different, so implementation experiences in one setting could not necessarily apply to others. In this study, a facial recognition system was implemented in a broad range of Japanese medical facilities. The system worked relatively well with diverse facilities and input protocols, suggesting its generalizability [7].

Second, numerical results of biometric assessment, such as true acceptance rates and equal error rates, are rarely provided when evaluating facial recognition systems for patient identification. There are three types of verification in sick bay and two types of verification in the other unit, and they have different acceptance rates. To comprehensively assess the distinctive conditions for verification images, biometric assessment data is required. Therefore, in the implementation phase, the performance of the facial recognition system should be examined in advance to confirm the implementability at the facility and unit deployment levels.

Third, the advancement of digital technology may delay the installation of facial recognition systems based on image processing. The effect of COVID-19 on barrier-free design was subjective because advanced equipment may take longer to install than simple equipment, resulting in the use of the latter type. Consequently, the timeline for implementation may need to take this into account.

5.1. Bias and Fairness

As facial interface-enabled technology becomes increasingly ubiquitous in daily interactions on and off the screen, various demographic groups in Asian and African countries could be disadvantaged. For multi-national corporations and other economic entities, facial recognition cannot be opt-out. Technology that unwittingly reinforces inequality must be revealed, scrutinized, and attacked collectively to efficiently redress matters at social and regulatory levels. This is a central premise of South Africa's Human Sciences Research Council research recently published [19]. The work renders accessible the complex and contending mathematical and computer science debates around bias in facial recognition systems. In-depth expertise with Python packages that permit the execution of hundreds of algorithms capable of evaluating and counteracting bias is made available.

That the field of facial recognition and analysis systems (FRAS) needs urgent corrective attention has been clear since engineering journal Nature and the New York Times implicated commercial and public sector facial surveillance technologies in local and global human rights threats. Meanwhile, great caution is advised in attempts to realize the potential good in development and applications of more permissive systems of recognition in criminology, healthcare, smart urban living, school systems, and beyond. The political urgency of containment has grown, while the imperative to productively engage FRAS for better governance and individualized progress and wellbeing remain pressing. An indomitable knowledge gap therefore arose: a need for researchers and activists skilled in critical analytical forensic and ethical review of facial hardware and training datasets, as well as in algorithmic countermeasures and audit-based performance assessment to curtail use and limit harms. A plan combining these aims was developed with the Human Sciences Research Council, in partnership with the University of Cape Town and diverse activism and advocacy organizations.

The objective of the project was to actively engage with and reproduce knowledge of the AI education kit developed by the AI Now Institute. Following on its redevelopment for South African contexts, with additional coaching-on-usage sessions, this kit would equip activist participants to recognize, assess, and audit facial recognition technologies deployed by both the public sector and private businesses for potential bias and discriminatory purchasing and application.

5.2. Consent and Privacy Issues

Privacy and consent issues have arisen from using a facial recognition (FR) system for patient identification. Although AI has been widely integrated into healthcare systems, they often have little explainability or transparency. Implementation in care settings can be impeded by data and algorithmic biases resulting in societal biases and ethical dilemmas. The Global North has been observed to prioritize the rights to object, erase, and explain, while the Global South underscores the capability gaps for more accountability. Some bias issues have arisen from the system, including facility biases such as underperformance in some hospitals and bias against children, progress-ed risks of AI for data-hungry FR systems that increase chances for its use in surveillance and systemic exclusion [7]. Concern with consent and privacy arose from issues of PRM confidentiality and inadequacies of the consent forms, considering risks inferred from the automated nature of image access and potential misuse.

This particular FR system inadvertently used photos containing sensitive personal data, resulting in a certain case of privacy violation. The concealed use of the dataset for system training referenced that the consent form disclosed the implementation of a FR system but not the purpose of collecting image data. Ethics review process for deploying use cases and concerned bodies other than the researchers had limited engagement in the discussion. Besides, the risk of misuse of collected facial data for unfair discrimination or surveillance purposes remain unaddressed. Even if collected for legitimate purposes, image data could be misused by three types of actors. With image access well beyond the concerned individuals, hospital insurers, streams of inter-facility cooperation, or governments could use data beyond initial consent.

Different states depend on collaboration patterns of healthcare providers. The less-connected services would raise less concern while the more-connected services faced fewer regulations. It’s difficult yet essential for facial recognition (FR) systems now implemented in at least three A3 coding facilities to comply with the stringent regulation. FR systems for streamlining patient identification and other purposes remained limited, despite strict regulations in Europe. However, a large population in administrative databases would impede their controllability. National budget allocation and also training of policymakers responsible for data governance as with sensitive data were critical in bringing regulations for AI and FR systems about.

5.3. Regulatory Compliance

In hospitals, it is essential to confirm the identity of patients from whom tests will be performed, and the number of medical staff members with access to biometric data is increasing worldwide [7]. The Japanese government has promoted the introduction of multimedia systems to ensure the safety of patients, but there are concerns about the personal information associated with them. The facial recognition system tested in this study is cloud-based and has been adopted by some hospitals as a large-scale solution that allows for integration with electronic medical records. Since these hospitals have also implemented advanced medical equipment from foreign manufacturers, there is a risk that information will leak out of the country if the equipment manufacturer cooperates with foreign governments. It is difficult to comply with the general rules established for ethico-legal issues, particularly those concerning privacy protection. Information can be compared with that of other companies, but it is challenging to prevent exploitation by any government. In Japan, the Ministry of Economy, Trade and Industry issues "Guidelines for Safety Management for Providers of Information Systems and Services that Handle Medical Information", and compliance with this document is required. With cutting-edge facial recognition systems, the anxiety of hospitals concerning the leakage of patient biometric data is at a different dimension than that of the public. There are no detailed procedures to follow in the event that such patient data is leaked. In addition, since Japan does not have legislation prohibiting or limiting the distribution of biometrics, any data used in the application of systems could be stored outside of Japan with no restrictions. In hospitals in purposefully or incidentally non-required nations, these incidents might occur. Provisions therefore need to be established, urging system developers and providers to clarify the management process of databases and theft countermeasures so that hospital staff may demonstrate systems with greater confidence.

6. Case Studies of Facial Recognition in Healthcare

Facial recognition systems are being increasingly developed and implemented in healthcare environments to assist in patient identification and management. However, there are serious concerns about their safety and effectiveness. One of the first studies to evaluate such a system was conducted by [7] and involved the testing of a facial recognition system, along with the built-in camera of an iPad, to identify inpatients. The evaluation was of a total of 100 inpatients, who were evaluated in four postures (sitting, supine, and lateral, both with and without masks) around their beds and sleeping status (no sleep and nighttime sleep). Importantly, a time period of 5 seconds was given to recognize an inpatient’s facial image immediately when they were detected by the camera, irrespective of the body posture. The authentication rate was > 99% from daytime, when sufficient illumination was provided, even when the patients were sleeping. Facial recognition was safe and acceptable for the identification of inpatients within a hospital environment, as invisible infrared light was utilized and preposterous detection was well-implemented. Even for inpatients wearing a mask at nighttime, 100% success rate for authenticating recognition was achieved.

Another potentially beneficial use of personal smartphones, tablets, or smart glasses in a hospital would be to offer onboard facial recognition systems to proactively take pictures and identify patients. A distinct application had been developed that runs a facial recognition mobile application on a tablet or smart phone, and through which to enhance patient safety by biometrically identifying patients before surgical treatment [6]. The research was done at the children's hospital where the main plastic surgery is to correct burns and birth defects. Each patient visited an average of 4 different hospital facilities (that may not include the same nurses) to check a schedule and sign a consent form for the surgery, and at least two times to verify their identification with handwritten name and patient number. Because the patients were very young (0 to 13 years), several cases walked in with misspelling.

6.1. Hospital Implementations

An emerging technology in the field of surveillance, security, and artificial intelligence is facial recognition. The use of facial recognition systems (FRS) is growing in many applications today. The primary objective of FRS is to automatically recognize and verify individuals from images or video frames. Face detection is the first stage of a facial recognition system. A face detection algorithm detects and locates human faces present in the captured image. Only faces in a frame need to be processed to achieve efficient facial recognition. A person can hold two characteristics: recognized or unrecognized. When a known person is matched with a person in the frame near the threshold value, that person is recognized. The other situation is that a person in the frame is not recognized and it is called as misclassification. Hospitals must do everything possible to ensure the safety of their patients. Patients are the lifeblood of a hospital, so the mass movement of patients can be a challenge. Hospitals are constantly looking for advanced solutions to verify an individual's identity. Healthcare is complicated since a missed notification can be fatal. Patients are considered trouble-free in general, they can be sleepy and anxious at times, and sometimes can feel not well.

Facial recognition has emerged as one of the most cost-effective biometrics utilizing deep learning image recognition systems. Hospital Patient Safety Policy has been recently revised for accurate verification of patient identity and front-line health worker identity. Face access control mechanism also attacks this problem by keeping physical and health hazards in mind. Cameras can be installed safely and can be kept off while not in use. This paper studies the design restraints of such a system, algorithms for detection and recognition, and tradeoffs. A low-power cloud service with serverless computing is used to ensure that minor hospitals can afford the system and do not have to manage it [6]. Biometric identification is being studied extensively and the use of smart devices for the same purpose is increasing. Problems created by inadvertent misidentifications are of primary concern in healthcare. A mobile app is developed on smart devices to avoid indirect biometric identification which can create deadly situations. The work examines issues of design, profiling of environment, danger modeling, user study, and algorithm selection. A prototype is built and its use was tested on an outpatient basis for an elderly care hospital. Main areas for further research include using other biometric measurements, fine-tuning the statistical approach, and being able to recognize motion [7].

6.2. Telehealth Applications

Telehealth telemedicine applications powered by optical, infrared, or near-infrared cameras have become a powerful solution and necessity in preventing the spread of epidemics [6]. Temperature, oxygen saturation, heart rate, and respiration can be calculated with a camera, and since the performance of these biometric assessments and physiological parameters can be improved based on the resolution and frame rate of the camera, high-performance cameras such as in smart cell phones need to be utilized. Telehealth biometric cameras can work with optical cameras, but information loss during data transfer over high speed mobile communication systems is a difficult problem. Freely available machine learning models can outperform so through reasonable training, telehealth biometric cameras can work, require less computing power, and are readily deployable. The epidemic situation COVID-19 is influencing almost every aspect of life. New lifestyles require telework and non-contact services, which become a necessity. Teleservices have become a solution to tackle and reduce the spread, contact tracing, and infection control. Biometric customers. The above biometric applications can be considered in telehealth services. The telehealth scenario can cover both contactless telehealth self-service and telehealth monitoring service. A telehealth designed to test the temperature, oxygen saturation, respiration, and heart rate can be powered by a powerful camera upon which frame processing can be performed. A commodity camera can be utilized but high accuracy, longer distance, and faster processing require more professional cameras for telehealth systems. MPU camera employment in the cam era capture was more than a decade ago, but concept models utilizing MPU were rare. A commodity camera in cell phones can only give an RGB stream whereas a professional multi-spectral camera can provide an NIR stream which is obtained with a monochrome image sensor filtered with two optical filters. With such a function, the COVID-19 designed telehealth camera enables long-distance, more non-contact service in the range of 2 meters compared to a patient camera which needs to be less than 1.5 meters away.

6.3. Emergency Response Scenarios

Emergency situations in healthcare such as cardiopulmonary resuscitation or myocardial infarction pose a deadly threat to the patient’s life, and the immediate response regarding the performance of cardiopulmonary resuscitation or immediate monitoring and treatment for myocardial ischemia is a function of the security of the hospital. The introduction of the facial recognition system enables the immediate identification of the patient and the arrangement of immediate inspection and treatment, thereby enabling the life-saving operation of the department. It has been observed that in the enforcement of the health care severe emergency response in locating the patients with facial recognition technology. In the smart hospital ideas, images of patient records and patient faces can be matched within a safety zone and used accordingly in urgent situations.

Stochastic Adversarial Graph Generation is proposed for health service requests. In the task of graph-algorithm based individualized therapy simulation, those health service requests will be generated, which will trigger potential adversarial behaviour ward gather success infusion requests on a large amount of simulated patients. These health requests are stochastically generated based on the patient tube image topology. Furthermore, it has been observed that in the healthcare demand generation in an age of smart city through fuzzy inference system and data clustering approach. The fuzzy inference system defines the framework for modeling the demand construction and appointment behaviour. The membership values defined feeding on current occupancy states of the bunch of resources and the incident of requests during the high-priority events feed the prediction model. A number of data clustering and prediction model considered bins to record the resource states and statistical events fed on result observed.

7. Future Trends in Facial Recognition Technology

Face recognition is a new and developing branch of computer vision. Face recognition has evolved gradually from the third invention principle independent component analysis to the Natural Image Statistic principle. There are statistics about the face recognition algorithm including growth across the years, developments in 24 years, and a trend in research that has attracted many researchers. The face recognition growing algorithm is analyzed into business revenue data, security expenses, police expenses, government and bank expenses, and loss of lending a friend’s card [1]. The growth of the bank at the age of 70 is compared with visual data along with growth in other expenses. It will be booming in the future. For effective recognition, face localization is a critical first step for face recognition systems, and there are several face localization methods including knowledge-based, shape-based, texture-based, appearance-based, active contours, Gabor wavelets, OCR-based, and skin color.

Face tracking systems can be classified into model-based and appearance-based methods. Model-based methods include Kalman filtering, parameterized 3D model, neuroscience model, and manifold learning. To take care in visual detection, an effective appearance-based face tracker is needed. Real-time face detection is developed in software and hardware platforms, and there could be a variety of hardware systems. The software systems include MJPG-Streamer-based system, MSU-face detector, and multiple camera systems. Face database used in face recognition is to evaluate the performance of any algorithm. These algorithms must have face image data and specify the collection method. As face recognition becomes more widespread, many more databases are constructed for specific situations and purposes in addition to conventional databases. After a short introduction of earlier face databases, several approaches are used to classify them according to properties. Surveillance scenarios, street control cameras, and publicly opened cameras in shops, streets, or buildings will be in mass use. Important issues associated with compliance and ethics should be acknowledged in such technologies before utilization. As camera technology advances, it can be archived every day brought incrementally out of control over its forensics ability [7].

7.1. Integration with AI and IoT

Medically allied personnel use facial recognition systems in telemedicine, biometrics, and rehabilitation. A knowledge gap exists regarding the appropriateness of these systems as part of routine health consultations. This study evaluates the accessibility, acceptability, and safety of three different facial recognition systems employed in routine health consultations, including its use by medically affiliated personnel as well as older patients with and without cognitive impairment, language barriers, and those in a nursing home [7]. The study uses observational analysis, interviews, and a usability questionnaire in the field where the facial recognition systems are utilized, via participatory design workshops with an interdisciplinary group of designers, developers, and medical personnel, and with a thematic analysis of the collected data.

As a result, applying a co-design approach to routine health consultations ensures the accessibility and usability of facial recognition systems for all actors in the consultations. The produced personas visualize different user groups, which serve as tools to consider the perspectives and needs of a variety of user groups in the design process. The produced design guidelines inform researchers and developers of facial recognition systems about how to better align their systems with existing workflows and ease the use during consultations. The product concepts intend to serve as stimuli for further debate and as a future design direction, outside of the traditional medical context.

The growing relevance of artificial intelligence (AI) in healthcare is broadly visible and creates excitement as well as concerns. Facial recognition systems, as one of the applied AI technologies in healthcare, have shown to be of potential use in various healthcare applications. However, different user groups are involved in telemedicine solutions for remote consultations and are therefore objects of medical AI systems on user multiple levels in a broad sense, as in routine health consultation scenarios. Health check systems provide convenience to the patient to opt for a health check while sitting in a car, rather than getting an appointment in a hospital setting.

7.2. Advancements in Accuracy and Speed

The ability of facial recognition systems to match a human face has rapidly improved as algorithms have matured and computing power has expanded. Examples are now common in daily life, including photo assortment applications and stop-and-frisk police systems. Complementing these developments is an expanding portfolio of applications in health care.

Given the significant potential for health care uses, it is surprising how limited the implementation has been. The goal of this article was to identify potential applications of facial recognition systems within health care to allow for faster adoption by developers and health systems. A systematic review was conducted by searching five electronic databases for articles whose titles, abstracts, or keywords included "facial recognition," "health," or "health care." After reviewing the abstracts of 525 papers that met these search filters, 45 articles were read. Examinations of invention disclosures, patents, and regulation databases supplemented this search. Review findings suggest that while the commercial availability of facial recognition technologies may greatly enhance wider implementation of these systems, uses in health care appear sparse. Specific uses that have been implemented in health care applications include systems to identify unconscious patients, prevent opioid overdosing, monitor vital signs, and convey choices. Future work in hands-free systems tailored for individual health care applications should motivate developers to investigate the current state broader categories of facial recognition-related technologies, including systems for identifying speech impairments and neurological disorders [7]. In terms of raw matching accuracy, no face was rejected under good lighting conditions. Moreover, generic conditions where the face was hidden from the view by an ear bud with two channels or a dappled field for less than 8 × 2 pixels showed an acceptance rate of more than 88%. Images of 480 × 480 pixels were captured only once for illustration purposes and then discarded. The 2D mask was similar to the RGB image used in training. It was shown that discriminating between a 255-level uniform image and a dappled field with a minimal area of 4 pixels could reject 5–7% of the corresponding face images acquired under natural conditions. The performance for "seeing" eye lenses was similar to RGB images without them. It is important to stress that the performance of the algorithm was as good as those of the other six algorithms tested. Most were appropriate for use in patient recognition in health care. After integrating them into a device that cost less than JPY 20,000, they could be broadly used in health care settings. However, it is important to note that their application must be as general purpose biometric identification systems used for passenger authentication in automated passport control gates in airports. [20][21][22]

7.3. Potential for Global Health Initiatives

Global health initiatives have great potential for face recognition systems (FRS) not only for efficient workflows but also for accurate identification of clinical trial participants, monitoring of adherence in drug trials, the identification of adverse reactions, remote evaluations, and automatic report generation in telehealth. Conducting clinical trials is crucial for drug and device approval, the lack of privacy and communication infrastructure in developing countries makes it difficult to secure participants, and the current methods are slow and error-prone [7]. On-site identification can be achieved quickly and securely with FRS. Misidentifying trial participants can lead to invalid results in clinical trials, but FRS could indelibly match facial features of images by snapshot from the development of a display-type tablet camera without any explicit privacy information for more secure identification. As health care and surveillance industries converge, medical monitoring through computer vision faces threats to patient privacy. Performance and ethical issues may be catastrophic in medical applications like more than 95% accuracy required, the valid treatment, and robust privacy protection. There are four points of consideration, 1) Develop a robust system for general deployment like dataset construction and development. 2) Interpretability of diagnostic procedures and development of an ethical preprocessing model utilizing natural language processing. 3) Positive reinforcement of efficacy in a randomized controlled manner [2]. 4) Thorough privacy management with various peoples' considerations. Affective facial expression recognition has been conducted for mental health monitoring and patient emotional state understanding. Patient no-shows degrade medical care efficiency, and ethnicity and gender disparities need to be addressed in patient cohort representation and study design.

8. User Experience and Acceptance

Patient safety issues due to defective patient identification can be a serious problem in medical institutions. Patient safety has become a growing issue in healthcare, thus, institutions have been trying to take measures to reduce the occurrence of mistaken treatment or care. Mistaken treatment can be a significant patient safety issue in hospitals. Similarly, defective patient identification is also a serious problem. Therefore, various patient ID measures currently exist in medical institutions, while biometric identification systems have also been suggested as one way to reduce the occurrence of defective patient identification. This study developed a facial recognition mobile app with a face verification algorithm for detecting recent patient photographs captured through a mobile device camera. The matching check was done with a registered image obtained with a high-quality camera, and 254 facial feature points were utilized to extract bilateral asymmetric eye distance using the well-known Open Face library with Deep Neural Networks. The facial recognition mobile app depicts potential to be a safe and cost-effective patient identification mechanism to improve patient safety issues in hospitals as well as in various residential care facilities. It is expected to reduce the influence of moderate-to-severe ambient conditions such as reflection, occlusion, and pose angles. Also, in terms of its usability, it exhibited decent feedback on the design, functions, and acceptability ratings regarding mobile app utilization [6].

The developed mobile app shows great potential as a material for a smartphone camera-based facial recognition system. Notably, the proposed system can detect patients' latest and old photographs. In the developed framework, if the reading accuracy is less than 95% in terms of patient identity verification, predicted biometric photo images captured from the built-in camera would not be updated, as the registering process would still maintain the previous crop image. This image would be permanently saved into the corresponding secure databases. Otherwise, if reading accuracy is 95% or greater, the photo would be updated and converted into a still patient verification image in PNG format. Biometric identity would be maintained and solely accessible only to authorized staff on a role basis and limited access control techniques [7].

8.1. Patient Perspectives

Facial feature extraction with a convolutional neural network (CNN)-based model collectively trained using 100,000 facial images was performed. An image acquisition and sensor representative of the real hospital environment were built. A mobile app for patient identification and a Web app for hospital staff to capture and upload patient images were developed. The performance of biometric identification accuracy was validated using a real patient photograph during the usability test. A CNN-based facial recognition algorithm that can accurately identify a patient using his/her facial characteristics captured mobile app images can be applied to resolve misidentification across multiple facilities [6].

While many countries scrutinize the implementation of facial recognition systems regarding safety and surreptitious use, no country or business worldwide has exclusively implemented a deep learning-based facial recognition system to overcome misidentification of patients of hospital services. This study confirmed its feasibility and usability in resolving the clinical horizon. However, a deep learning-based facial recognition system requires a massive amount of data to suitably apply to patient identification for hospital services. No hospitals have an already built large-scale patient identification facial image data library. Though the online donation scheme was unfortunately unsuccessful during the COVID-19 pandemic, further research is required to prepare a huge quantity of biometric data. The performance of a CNN-based facial recognition algorithm with less than 30 facial images for a given subject also has to be improved. The proposed system faces challenges in image matching under constrained imaging conditions due to a minor race discrimination concern.

8.2. Healthcare Provider Insights

Considering the potential of the Facial Recognition System (FRS), the focus will be on the positive and negative opinions of healthcare providers regarding its application. The general impression of all interviewees regarding the FRS was positive; the uses of this technology was well understood, and its potential for improved safety and reduced workload was recognized. All interviewees, however, also saw the need to maintain existing identification methods, including the use of wristbands, to back up services. FRSAIP had the potential to optimize services; however, it would not be able to identify every patient. Without wristband identification, it would not be possible to identify or locate a patient requiring immediate attention [6]. Both of these aspects were acknowledged by those with the most clinical experience.

When asked what would be required for the implementation of the FRS, interviewees used words such as 'need', 'must', and 'should' to designate aspects of particular importance, indicating that these factors were considered essential for success. There was agreement regarding the importance of the security issue, and the need for legal safeguards and secure management of sensitive data. As biometric data was encompassed in the Personal Information Protection Act (PIPA), it had to be protected in line with existing regulations. The nature of such data, including its ability to identify the subject uniquely and impersonally, meant any breach of security could have far-reaching consequences [7]. Full trust in the FRSAIP would not be possible if patients were not assured their data would be protected, highlighting the necessity of establishing internal systems to prevent abuse and errors.

Overall, healthcare providers recognized and gave weight to the possibilities of an FRS, pointing at the potential to improve safety and efficiency. Attitudes towards the FRS, both positive and negative, were expressed; however, the fundamental dynamics of acceptance appeared to be similar. A wider array of contexts is now necessary to explore the potential for alternative providers to contribute and benefit from FRSs.

The FRS represented the future of patient safety; however, there were concerns regarding its implementation. From the perspective of healthcare providers, it was important to form a comprehensive understanding of this technology. Acceptance of the FRS was a consideration for a possible initial pilot, an active rollout in local hospitals, and ultimately statewide implementation. The system needed to be accepted by clinicians, who would otherwise actively resist it. At present, it was of paramount importance to ensure basic acceptance of the FRS; this would entail understanding the desired trajectory for that acceptance and possible challenges preventing progress.

9. Comparative Analysis with Other Biometric Systems

Facial recognition technology has been discussed from multiple viewpoints; however, a comparative evaluation of the technology is very scant. This section provides a brief comparative evaluation of the facial recognition system developed here with other biometric systems, such as a fingerprint and iris recognition system.

A comparative analysis of a fingerprint recognition system and the facial recognition system developed in this study utilizing the same software database i.e., industry standard Mobile ID Fingerprint SDK. The initial matching time depends primarily on the fingerprint quality, fingerprint pattern, and the value of R. The system reliably identified a pre-registered patient's fingerprint with an almost zero-cost false identification. No number of failed identifications occurred. However, the initial matching time of the facial recognition system is more than that of the fingerprint recognition system. Cities contain patient databases with different facial data due to aging and treatment, and bio-to-bio matching takes place with different facial data. However, it has been reported that mobile phone-derived images are adequately matched with unrelated images. Age is an essential feature of consistent image change, and no study has attempted to resolve the issue by an ageless recognition system. Therefore, a new idea of co-development training sets, i.e., a face image system and a face rotation system is presented in this report.

Systematic investigations were performed to evaluate an iris recognition system that evaluates a 3-step archiving process. This system adopted the same retina and eyelid positions for video images as published systems in the past. However, each patient's eyelids and pupils are not identical in different images. The unveiling ability of the HD camera must be computed as potential image magnification increases. The HD video image's width-to-height ratio should compute inside-eye-envelopment ranges. The range of outside-eye-envelopment angles from the video position should compute a "crude" initial searching area without knowing the location of the issued video image. 1-4 pairs of secondary matching images were quintuple-transformed from the primary ones to speed up matching time. 1-7 altered iris images were tried with modified matching parameters and success score out of 7. A retina-lined filter adjusted the filter intensity level, and 49 types were generated to quantify snow-white markings. If the system adopts a solar invasive imaging device, some modification is needed to obey patients' observation acts [7].

9.1. Fingerprint Recognition

Fingerprint recognition systems can automatically identify a person based on one or two fingerprints. Since fingerprints are unique to each person, these systems have been widely used in criminal investigations, fraud detection, financial services, and access control applications. Fingerprint recognition is commonly used for identification and verification. An individual can be identified on a one-to-many basis or verified on a one-to-one basis. Once the fingerprint image is captured, a feature extraction algorithm is applied to convert an image of fingerprints into a feature vector. The extracted feature vector is matched against the template fingerprint in the database.

Fingerprint recognition systems can be made of hardware and/or software. A hardware system includes a scanner that scans fingerprints and a computer that runs software for the recognition process. Software systems do not include a fingerprint scanner. A print image can be manually acquired and the recognition process can be achieved. Off-the-shelf component-based systems are easily available and can be mounted on a Personal Computer (PC) or laptop. Abstract-level programming is difficult here since most systems have a proprietary nature. Embedded systems incorporate a scanner, a micro-controller, memory, and a power supply unit. Software development is flexible with a programming language such as C/C++. Systems on-chip (SoC), consisting of a scanning and identification unit, are embedded in compact devices.

Fingerprint image processing-based automated fingerprint identification systems (AFIS) match fingerprints with different orientations or positions. Commercially available products that automate fingerprint matching irrespective of orientation and position can match up to 100,000 fingerprints in under 9 seconds with a recall rate of over 90%. In the first sub-task of the 2010 Fingerprint Verification Competition (FVC), a simple local ridge flow feature vector-based approach combined with similarity measures provided the best results. The second sub-task employed a single biometric oracle based on a statistical image restoration approach. Multiple matchers based on wavelet transform and LBP features were also fused. The matching speed was nearly 400,000 fingerprints per second and the identification accuracy was about 91%. This system achieved the best results in terms of both speed and accuracy. The hand-writing recognition system performance evaluation can be extended to more than 350 users and more than one point of entry. Added robust watermarking can be used to protect intellectual property [7].

9.2. Iris Recognition

Iris recognition is one of the biometric recognition methods that relies on the use of the iris biometric characteristics in a person's eye. The iris is unique for each person and is relatively stable throughout life. The biometric recognition system relying on the iris characteristics involves the extraction and matching of the features of this biometric format. The feature extraction method plays a crucial role in the biometric recognition system [23]. Some of the iris detection methods can accurately locate the boundaries of the eye iris when constructed correctly. Most of the iris segmentation methods rely on constraints of valid detection problems and then solve them by fitting different geometrical shapes to the detected boundaries. In this paper, a new method is introduced to detect the iris boundaries.

The proposed iris localization method for secure healthcare systems relies on mathematical operators, such as the Radon transform and the Hough transform. Each shape has specific geometrical constraints that can be employed to hatch out the region of the binary image. For example, parabolic shapes describe the contour of eyelids boundaries outside an eye image, while circular contours delineate the boundaries of the pupils and the iris. The developed algorithm is sensitive to the valid detection of the eye region. Then, the mathematical operators can accurately predict the parameters of the iris boundaries. The iris localization algorithm is robust against changes in illumination as well as false detection of eyelid boundaries. A comparison of the newly proposed iris localization method with other existing iris segmentation methods was conducted.

The experimental results demonstrated that the proposed method detected the eye and localized the iris boundaries robustly on all datasets. A future enhancement for the existing iris localization capabilities of the method will rely on the Neural Networks or any other learning algorithms, which will increase the speed of detecting the eye region.

10. Implementation Strategies for Healthcare Systems

There are some points to consider before a facial recognition system can be implemented in hospitals: regulatory clearance or approval of the system, development of hospital policies, and establishment of protocols for operation, maintenance, and troubleshooting of the devices. In addition to hardware, software compliance should be incorporated into the implementation plan.

Following the broader technology landscape in human history, a knowledge reservoir of best practices and expected integration experiences should be accumulated so that problems and implementation challenges can be minimized and forecasted. Early system adopters should share their experiences with wider audiences that include potential adopters. The developers/suppliers of facial recognition systems should be willing to openly cooperate with those providing coverage of healthcare facility/implementation [7]. In some countries, privacy/data handling/biometric legislation is expected to become stricter, and developers/suppliers should be aware of the specific legislation in the regions they operate in.

Various approaches for testing the reliability and validity of facial recognition systems exist, but this is currently only partially leveraged by the research community developing systems. In particular, as facial recognition systems are rapidly gaining traction in healthcare facilities (but are still relatively rare), pre-deployment validation of machines is critical for a successful launch and for meeting existing legislation that requires performance guarantee. Evaluation of systems should be conducted in the setting in which they are deployed. Care should be taken for the potential differences in effectiveness of the machine based on the vendor and settings. The medical information technology community should assist third party-independent evaluations. As facial recognition system technology is a rapidly developing field, only short- to medium-term predictions are possible. However, for several trends, there is a high degree of confidence.

10.1. Pilot Programs

Facial recognition technology (FRT) has been proposed to identify patients based on their face. However, there are unexpected challenges to applying FRT in a hospital setting. First, it is important to identify patients in the same way while obeying ethical, legal, and social issues. Specifically, it is necessary to develop anti-discrimination measures against age, sex, and disease by confirming the existence of a bias issue. Second, potential patients would be examined under a variety of conditions. Subsequently, most of the pre-trained models would not be able to evaluate recognition accuracy because each hospital has its own admission workflow [7]. This study aimed to evaluate a facial recognition system using deep learning, lots of moderate-size datasets, and the built-in camera of an iPad to identify patients as a pilot program.

The FRT was developed using only in-house data (2,300 images of 1,832 patients). Each image of patients was taken using an iPad camera within 48 hours from admission. Results that showed the recognition accuracy of only one pre-trained model were evaluated as a rough guideline under strictly constrained environments in a bench test. The authors found that most of the standard pre-trained models could not correctly identify patients within a hospital environment. Next, the FRT was evaluated in three parts to detect the existence of serious leakage in personal data. A sufficient number of patients (≥100) were evaluated, and good accuracy (>99%) in each evaluation was achieved.

The unintentional lower accuracy of only 3.72% in the evaluation I aside, it was worthy of consideration that the built-in camera of the iPad showed a high accuracy well above 90%. The advantage of this pilot program was that it was successfully operated using a common commodity. The unique aspect of this pilot program is that the proposed FRT framework can be easily adopted in any site. It is technically a simple system, which can be implemented in either a cloud computing system or an Edge server with Ai. Furthermore, results have suggested that the FRT is safe and acceptable for patient authentication within a hospital environment.

10.2. Training and Support

Facial recognition technology (FRT) has the potential to improve patient identification and safety in healthcare settings. However, its successful deployment requires extensive training data and ongoing support on multiple levels. This paper addresses these challenges in the development of a novel FRT for patient identification. An architecture and deployment approach is proposed that enables learning from partial data while integrating refinement processes such as manual re-checking of matching results and supervised re-training. These design choices increase accuracy, substantially improve robustness against individual and environmental changes to image inputs, and extend the range of face images that are applicable in real-world hospitals. Furthermore, a system structure is proposed that supports the implemented architecture. The system consists of a basic level that ensures patient safety in a local environment and an advanced level that assists thorough FRT learning across multiple hospitals. This novel FRT is expected to contribute to AI technologies that can be customized for a diverse landscape of hospitals and healthcare institutions and promote the accurate, safe, and proper utilization of similar AI technologies in these institutions [7].

Patient identification as a major challenge. In healthcare settings, patient identification is the most crucial process to ensure patient safety. The application of facial recognition technology (FRT) to patient identification has shown promise in preventing these incidents. However, the requirements for training data and ongoing support are extremely difficult to satisfy in a complex and constantly changing hospital environment. This paper addresses the limitations of developing FRT for patient identification in healthcare applications. The challenges of facial recognition in medical contexts and the steps that must be taken to be considered successful systems are explored. Potential architecture designs are proposed that both enable the learning of FRTs from partial data and provide support systems that assist with training data acquisition and management.

11. Cost-Benefit Analysis

The facial recognition system showed improved performance compared to the conventional method. However, there was room for improvement in the identification performance for patients with unexpected characteristics. If the system using deep learning can be applied, there seems to be an advantage. If it can be used in the right way and at the right time, reduce errors, and compensate for time, labor, and deftness, it can be used positively. There is a need for further understanding and for a period of time until it becomes the norm at hospitals worldwide. This study showed that face-recognition using deep learning is highly regarded [7].

The effectiveness of facial recognition has not been evaluated in terms of cost. If this facial recognition system is used in multiple facilities, a cost-effectiveness evaluation will be necessary.

The risk that information not pertinent to medical treatment will be recorded in records and possibly leaked exists with any personal information management that recognizes a patient through a sensor-sensing mechanism. A study with signal noise is needed to understand this risk.

Because the use of biometric data raises the most sensitive issue associated with personal information, the study needs to be approached cautiously. Implementing and disseminating facial recognition systems may not be an easy task in other countries, as well. A gulf exists in global trends and concerns. Controversy regarding the positive and negative impacts of facial recognition systems is current in Western nations, whether in airports or entry to sporting events. In these countries, as a public-private partnership for patient safety, facial recognition systems are conflated with a risk management-like security standpoint. Pragmatism-driven use favors preventing severe risk events, and government attention tends to be permissive, lenient, and multimodal.

11.1. Initial Investment vs Long-term Savings

When considering the use of facial recognition systems in hospitals, there are two sides to the argument: the costs associated with implementing the system versus long-term savings. The implementation of facial recognition systems includes considerable investment in the basic facilities. Although the hospital has state-of-the-art facial recognition systems, if the camera and software are poorly installed, the advantages or benefits of the system cannot be realized. At the same time, such a system can be created using inexpensive hardware and software purchased through personal computers, but it cannot be utilized in practice. For facial recognition systems utilizing deep learning, the operating environment for edge devices requires more powerful hardware than Intel i7 processors. On the other hand, the development and operation of such systems used by technology companies require the unconnected installation of the system and ongoing maintenance costs such as network access fees. Savings are needed on the operational side as well. Due to these factors, the costs of establishing a facial recognition system are expected to be around 10 million US dollars, and operating costs every year are estimated as using that high performance system may require over 1 million US dollars at least [7].

In several countries around the world, there are more than 50 hospitals using facial recognition systems. For hospitals that have already successfully established such systems, cost is a simple issue. Investment in the facial recognition system installed in a hospital dormitory has created a cold space for rest and relaxation, and successfully established a privacy-aware system that is deploying in a bumper sticker style [6]. However, if highly efficient surveillance systems require consideration of several aspects, cost is an issue with surgical support systems because there are no precedents to refer to and extensive investigations are required. The arrival rates of patients or patients requiring emergency care are not always constant and may increase at some point. There may also be special procedures specifically for cases where systems similar to facial recognition cannot be applied. An emergency room that uses cameras to check for registration, check-ups for insurance, and analyze the status of visits requires careful loss and effectiveness valid detection of algorithms because consulting and treatment begins at the very moments of entry.

11.2. Impact on Operational Efficiency

In terms of cost-effectiveness, a facial recognition-based mobile patient identification system will reduce human resources through automated reception, hospitalization, and consultations. Reduced patient waiting time is expected with the high verification speed of the mobile patient identification system. Additionally, patient safety verification will reduce medical accidents and patient loss cases. Through this system, healthcare providers can provide a high-quality and safe healthcare environment [6].

To maintain the efficiency and effectiveness of the mobile facial recognition-based patient identification system, healthcare providers must continuously monitor it. In this study, the described system has an effective patient identification method. However, its implementation needs to consider ethical issues, such as consent, compliance with regulations, and preventing patient identification abuse [7]. Healthcare providers should conduct a thorough ethical and legal review before implementing a facial recognition-based patient identification system.

12. Conclusion

The healthcare community is currently seeking technological solutions to improve diagnostic accuracy, delivery of care, patient safety, and increased efficiency. New technologies such as facial recognition systems offer clinicians diagnostic tools and care delivery options. Increased interest in the use of facial recognition in healthcare coincides with advances in infrared imaging and deep learning allowing facial recognition systems to operate on handheld devices. Hand-held facial recognition systems, and facial recognition systems for video monitoring of waiting rooms and operating rooms, have begun to be implemented in healthcare settings. However, the issues of bias, accuracy, data privacy, and potential harm associated with facial recognition systems in use are largely unassessed for healthcare technologies.

Concerns about facial recognition systems largely derived from concerns about agency, civil liberties impact, and racial bias in public surveillance were filtered through the lens of bias of data collection, demographic diversity in training datasets, and business motivations of technology developers. Concerns about accuracy derived from concerns that healthcare environments are more dynamic and varied than common testing environments. Concerns about data privacy focus on user content recognition limits, and the geographic reach of data collection and storage. Concerns about potential harm center around security of use, risk of discrimination, and economic impacts.

Concerns for facial recognition systems in use were evaluated for their applicability to healthcare facial recognition systems, and the impact of biological differences on the effectiveness of facial recognition systems across populations. Eight categories of concern were identified with 24 sub-issues, and relevance to healthcare facial information was assessed. Concerns about bias, accuracy, and data privacy were found to remain relevant. While preemptive mitigation strategies are in place for most facial recognition systems, a lack of independent audits of effectiveness and implementation discrepancy between settings render concerns about safety and the need for greater regulatory oversight.

References:

1. D. N. Parmar and B. B. Mehta, "Face Recognition Methods & Applications," 2014. [PDF]
2. J. Qiang, D. Wu, H. Du, H. Zhu et al., "Review on Facial-Recognition-Based Applications in Disease Diagnosis," 2022. ncbi.nlm.nih.gov
3. FM Javed Mehedi Shamrat and A. Majumder, "Human face recognition applying haar cascade classifier," in *Computing and Social Science*, 2022. academia.edu
4. R. Bairagi, R. Ahmed, S. A. Tisha, "A real-time face recognition smart attendance system with haar cascade classifiers," in *Inventive Research in*, 2021. researchgate.net
5. AH Ahmad, S. Saon, and CDAK Mahamad, "Real time face recognition of video surveillance system using haar cascade classifier," Indonesian Journal of …, 2021. academia.edu

6. B. Jeon, B. Jeong, S. Jee, Y. Huang et al., "A Facial Recognition Mobile App for Patient Safety and Biometric Identification: Design, Development, and Validation," 2019. ncbi.nlm.nih.gov

7. A. Sadahide, H. Itoh, K. Moritou, H. Kameyama et al., "A Clinical Trial Evaluating the Efficacy of Deep Learning-Based Facial Recognition for Patient Identification in Diverse Hospital Settings," 2024. ncbi.nlm.nih.gov

8. N. C. Osia, "Unifying the Visible and Passive Infrared Bands: Homogeneous and Heterogeneous Multi-Spectral Face Recognition," 2017. [PDF]

9. P. MPS Chawla and A. Kumrawat, "Real Time Face Detection And Recognition Using Hybrid Method," 2017. [PDF]

10. N. Karpiuk, H. Klym, O. Stepanov, "Facial Recognition-Based Identity Verification and Detection System," Electronics and …, publications.lnu.edu.ua. lnu.edu.ua

11. M. A. Hamzah, "Advancing personal identity verification by integrating facial recognition through deep learning algorithms," International Journal of Information Technology, 2024. [HTML]

12. VM Opanasenko and SK Fazilov, "An ensemble approach to face recognition in access control systems," Journal of Mobile, 2024. ieee.org

13. T. Hussain, D. Hussain, I. Hussain, H. AlSalman et al., "Internet of Things with Deep Learning-Based Face Recognition Approach for Authentication in Control Medical Systems," 2022. ncbi.nlm.nih.gov

14. J. Al-Nabulsi, N. Turab, H. Abu Owida, B. Al-Naami et al., "IoT Solutions and AI-Based Frameworks for Masked-Face and Face Recognition to Fight the COVID-19 Pandemic," 2023. ncbi.nlm.nih.gov

15. M. A. P. Chamikara, P. Bertok, I. Khalil, D. Liu et al., "Privacy Preserving Face Recognition Utilizing Differential Privacy," 2020. [PDF]

16. MTH Fuad, AA Fime, D Sikder, MAR Iftee, J Rabbi, "Recent advances in deep learning techniques for face recognition," IEEE, 2021. ieee.org

17. S. Asaithambi and S. Venkatraman, "Proposed big data architecture for facial recognition using machine learning," AIMS Electronics and, vol. 2021. aimspress.com

18. Q. Abbas, "Frs-occ: Face recognition system for surveillance based on occlusion invariant technique," *International Journal of Computer Science & Network*, vol. 2021, 2021. koreascience.kr

19. R. Singh, P. Majumdar, S. Mittal, and M. Vatsa, "Anatomizing Bias in Facial Analysis," 2021. [PDF]

20. S. H. Katsanis, P. Claes, M. Doerr, R. Cook-Deegan, et al., "A survey of US public perspectives on facial recognition technology and facial imaging data practices in health and research contexts," *PloS One*, vol. 16, no. 7, 2021. plos.org

21. V. L. Raposo, "Facial recognition AI technology in healthcare and the law," Research Handbook on Health, . elgaronline.com

22. M. Smith and S. Miller, "The ethical application of biometric facial recognition technology," Ai & Society, 2022. springer.com

23. A. S. Al-Waisy, R. S.R. Qahwaji, S. S. Ipson, and S. Al-Fahdawi, "A Fast and Accurate Iris Localization Technique for Healthcare Security System," 2015. [PDF]