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An Intelligent m-Healthcare System for Improving the Service Quality in Domestic Care Industry

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Abstract: Due to declining fertility rate and increasing life expectancy, population aging has become a growing problem in Hong Kong. Domestic elderly service providers and public health institutions have been suffering from a shortage of experienced staff for elderly healthcare, which has led to a drop in both the quality and efficiency of the local elderly service. With the rising popularity of mobile applications and the betterment of machine vision technology, this paper describes the design of an Intelligent m-Healthcare System (ImHS) for relieving the manpower pressure on local elderly service providers by lowering the technical threshold and simplifying staff training process. Face recognition technology is applied to identify the elderly by searching and tracing the elderly medical record through the FaceAPI service. In addition, the proposed ImHS provides the immediate insight into healthcare knowledge for users, which lowers the occurrence of Adverse Drug Event (ADE) and shortens the duration of pill distribution process. By conducting a case study in a local elderly home, the proposed system allowed the nursing staff to better allocate healthcare resources and to improve the operation effectiveness and efficiency.

Keywords: Mobile application, Face recognition, Domestic Care Service, Healthcare resources, Aging population

1. INTRODUCTION

In Hong Kong, population aging has been a growing problem for decades. The causes are believed to be the falling birth rate and the increasing life expectancy. The percentage of the elderly in the whole population is estimated to rise from 16.6 percent in 2016 to 31.1 percent in 2036 (Census and Statistics Department, 2017). Due to the aging population, the demands for healthcare services are significantly increased and brings challenges to healthcare services providers, which includes public hospitals and nursing homes at different scales (Kamruzzaman et al., 2013).

However, the shortage of healthcare resources including capital, staffing and facilities have been proven to affect the quality and efficiency in delivery the required healthcare services (Antwi & Bowblis, 2018; Berrideg et al., 2018). Currently, nursing staff in elderly homes still rely on the manual approach in executing daily routine tasks such as drug distribution and health monitoring processes, which are very time-consuming. In addition, performing such daily tasks require professional knowledge. It is difficult for junior nursing staff to instantly grasp each elderly's routine regarding their health, drug habituation, allergies and history of medication. Once mistakes appear in the execution of the daily tasks, they may cause an Adverse Drug Event (ADE), health deterioration and even death. Therefore, there is a need to improve the accuracy and efficiency in performing the daily routine tasks in elderly homes. In this paper, an intelligent m-healthcare system (ImHS) is proposed. A mobile application is developed to store, record and monitor the elderly historical records. Moreover, face recognition technology is applied can assist the nursing staff to perform the daily routine tasks so as to improve the services through the reduction of the human mistakes.

The rest of paper is organised as follows. The literature related to the healthcare services in the elderly homes and artificial intelligence (AI) technologies is reviewed in Section 2. Section 3 describes the system architecture while Section 4 covers the case study. The results and discussion are presented in Section 5 and the conclusion are given in Section 6.

2. LITECTURE REVIEW

The aging population issue has become a key issue to governments and societies all over the world. Aging is generally associated with weakening functional abilities and health deterioration conditions, which greatly increases the demand for healthcare services, in both long-term and short-term care. In order to relieve pressure on the public hospitals, the governments in different countries such as Taiwan and United Status are shifting healthcare strategies to provide comprehensive long-term care services in the community (Godin et al., 2015; Ministry of Health and Welfare, 2017). However, due to the shortage of knowledgeable nursing staff and healthcare resources, this results in poor quality in delivering healthcare services and ADE in elderly homes.

Nursing staff always reflect a lack of time to serve the elderly due to the high workload. In dealing with shortages of healthcare resources, the healthcare services providers tend to adopt advanced technologies and healthcare systems in the elderly homes in order to reduce operation costs, enhance the resources management and improve the operation efficiency. The emergence of the electronic health record (EHR) is an evolving concept over the last decade for the systematic collection of the health information of the elderly (Xhafa et al., 2015). The use of EHR allows nursing staff to easily access the health records and eliminates mistakes and errors from poor penmanship. Cresswell et al. (2012) integrated the EHR system in the work practices to improve hospital management and communications. Liu et al. (2016) adopted the cloud-based electronic health record system to collect, store and collect health information in order to improve the operation efficiency in delivering the healthcare services. Furthermore, with the rising availability of mobile devices in clinical practices, cloud-based mobile application for the healthcare industry has become more popular in enhancing communication and information resources at the point of care (Moodley et al., 2013). Doukas & Pliakas (2010) proposed a mobile healthcare information system to enable the electronic healthcare data storage, updating and retrieval. Santos et al. (2014) integrated the internet of things and mobile health applications for monitoring and controlling the health condition of the elderly. Considering the need for delivering a high quality of care to the elderly, it is essential to adopt mobile applications with the EHR to improve the operation effectiveness in performing the daily routine activities in elderly homes.

Even though the EHR system has been adopted in elderly homes, risks to the elderly may occur by failure to correctly identify a particular elderly, resulting in incorrect medication and even ADE. To avoid medical malpractice due to the human mistakes, it is important to adopt automatic recognition technologies to identify and verify a particular elderly. Face recognition technology was biometric artificial intelligence for verifying an individual's identity using its facial image (Sumathi & Malini, 2010). It analyses the patterns of the person's facial contours by comparing with the known face in databases. Compared to other recognition technologies such as iris recognition and fingerprint recognition, the face recognition allows the users to capture the face at a distance in order to provide contactless access to the required information. In the healthcare context, Hossain & Muhamma (2015) proposed a speech and face recognition framework to improve the accuracy and efficiency for monitoring the health of the elderly. Jeon et al. (2019) developed a facial recognition mobile application for improving the verification of the patients in hospitals in order to reduce the risks in regard to patient safety. Hence, it is feasible to adopt face recognition technology to reduce medical malpractices in elderly homes.

To summarize, the above studies indicate that elderly homes are facing challenges in delivering healthcare services due to the shortage of healthcare resources. It is believed that through the integration of the mobile applications and face recognition technology, nursing staff as well as caregivers can gain benefits in enhancing the quality of healthcare services and reducing the medical malpractices.

3. METHODOLOGY

The architecture of the proposed ImHS is presented in Fig. 1. Three modules are involved in the ImHS: (i) data collection module, (ii) data management module and (iii) face recognition module.

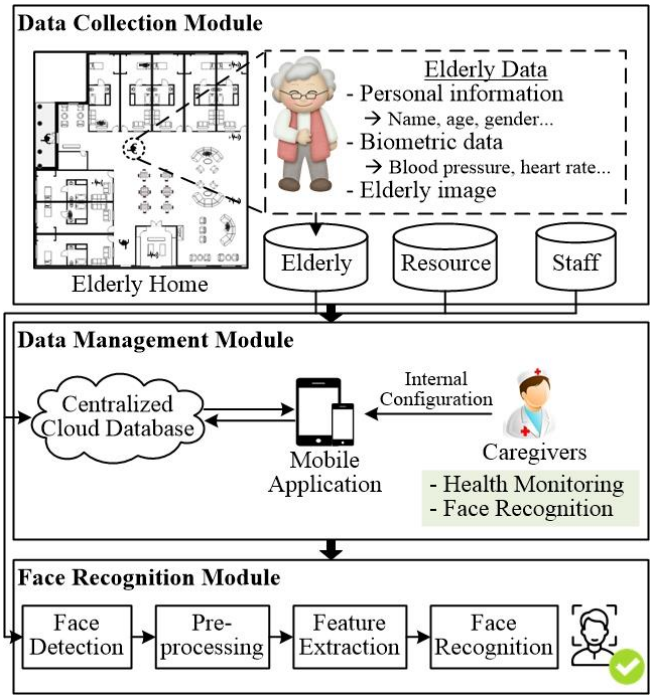

Fig. 1 Architecture of the ImHS

3.1 Data Collection Module

In this module, three type of data, elderly data, resource data and staff data, are collected. Table 1 shows examples of the collected data. First, the elderly data can be collected through review of the personal records of the elderly. Biometric data are also collected through the daily monitoring processes for understanding the healthcare status of the elderly. The images of the elderly and their families are also collected for the further face recognition process. Second, resource data refers to available equipment for serving the elderly while staff data is the nursing staff information such as their education level and experience. In addition to these data, interviews are conducted to understand the problems that the nursing staff encounter in the daily routine and manual documentation processes.

Table 1. Examples of the collected data

Type of Data	Examples
Elderly data	Name, Age, Gender, Contact person, Types of diseases
Resource data	Wheelchairs, Diapers, Meals
Staff data	Name, Age, Gender, Experience, Education level, Type of staff,

3.2 Data Management Module

In the data management module, the collected data are transferred to the centralized cloud database for data storage. Considering the collected data are presented in various format, data pre-processing is required to integrate, combine and consolidate the data into a standard format. Through the connection of the cloud database and the development of a mobile application, users can access the elderly information in mobile devices such as smart phones and tablets. By defining the application programming interface (API), the data can be effectively interacted with various mobile devices for achieving the functionalities of health monitoring and face recognition. The proposed ImHS allows nursing staff to monitor the health situation of the elderly. Moreover, caregivers can check and review the electronic medical records of the elderly in order to reduce the errors and mistakes in the execution of daily routine tasks.

3.3 Face Recognition Module

In the face recognition module, the face image is captured for recognizing the identity of the elderly so as to accurately access the elderly records. A database is constructed to store the known faces for matching the facial features with the captured images. Four steps are involved in the face recognition process: (i) face detection, (ii) pre-processing, (iii) feature extraction and (iv) face recognition. Firstly, a mobile device with the camera is used to automatically locate the face of the elderly in the image with a bounding box. Considering the difference in the image colour, facial orientation and pose, pre-processing is required to convert the image from colour to grayscale, adjust the image size and normalize the face to be consistent with the database. After that, the normalized image is scanned with a fixed-size window from left-to-right and top-to-bottom to extract the facial features, such as the eyes, nose and emotion through the feature extraction step. Fig. 2 shows the flow for face recognition. The selected facial features from the image are then matched with the known faces in the training databases with various scales. By comparing the similarity of the face features, the proposed system can recognize, verify and access the elderly information. Therefore, the caregivers can efficiently deliver accurate healthcare services to the elderly. Especially, it benefits to the junior caregivers with less experience in taking care of the elderly so as to reduce any human mistakes and the occurrence of ADE.

4.CASE STUDY

In order to validate the feasibility of the proposed ImHS, a case study was conducted in an elderly home located in Hong Kong. The case company was founded in 1953, and has a long history and possesses great experience in taking care of the elderly. There are 20 staff, including supervisors, executive directors, registered nurses, caregivers, assistants and social workers to serve more than 70 residents. Fig. 3 shows the staff structure of the case company which aims to provide 24-hour diversified basic healthcare services including personal care, nursing care and resident care services to the elderly. In addition, medication services and physical examinations are regularly provided by registered doctors. Currently, the nursing staff-to-elderly ratio is 1:5 which means that the manpower in the case company is insufficient. In order to reduce the workloads of full-time nursing staff, the case company recruits part-time healthcare assistants for assisting in the daily routine tasks. However, the part-time healthcare assistants may not have sufficient professional knowledge in delivering the required healthcare services. In such situations, it increases the chance of making mistakes which results in high complaint rates and poor satisfaction levels. In addition, the case company relies on a manual approach to store and document the health records of the elderly residents in a spreadsheet, which is time-consuming. In the fact that the health records may pass through different nursing staff and the family of the elderly, misunderstandings and confusion may easily occur. Therefore, the ImHS is implemented in the case company to provide an electronic health platform through the use of the mobile application with face recognition ability for reducing the human errors and mistakes in daily routine processes. Considering the privacy issue or misuse of data, training will be provided to the part-time healthcare assistants so as to get familiar with the proposed system.

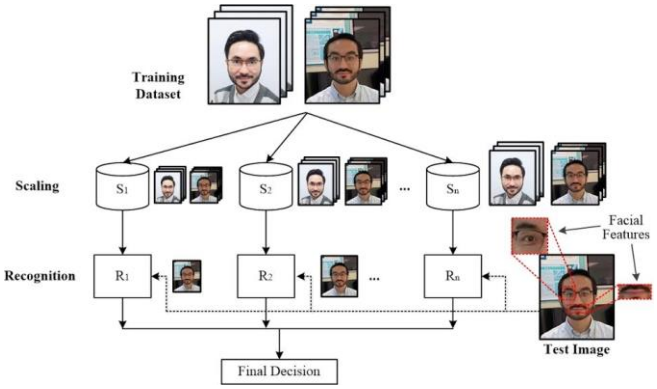

Fig. 2 Sample flow for face recognition

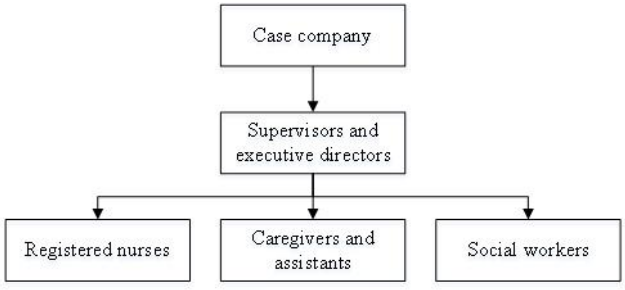

Fig. 3 Staff structure of the case company

4.1 Design of the user interface of the mobile application

In this step, a mobile application is developed to replace the traditional elderly health record. Based on the information provided from the traditional record, the important information, including the elderly basic information, health monitoring information, treatment methods as well as the

drug dosage should be included in the mobile application. In addition, the user interfaces for capturing the facial feature and images.

4.2 Data Collection and Management

With the designed user interfaces, the facial image and medical records in paper format can be collected and inputted to the ImHS. The basic personal information such as name, age, contact information and emergency contact information are required as input to the corresponding text fields. A photo of the elderly can be taken as the profile picture. Then, the past medication records are also inputted to the system, including the problems, family disease history, allergies, and treatment methods. Generally, three types of information can be checked from the proposed ImHS: personal data, medical record and monitor medication. Fig. 4 shows the user interface of the ImHS. The caregivers equipped with mobile devices can review and trace the medicine intake time in the function for monitoring medication during the delivery of healthcare services. In addition, the caregivers can edit the remarks in the health records to show the current health status. For example, if there are any abnormalities that occurred during the daily checking process, the caregivers can add remarks in the ImHS so as to inform the nursing staff with professional medical knowledge to take care of them. In addition, the ImHS allows caregivers to accurately check the medicine intake records. Fig. 4 and 6 show the user interfaces of monitoring medication records in the ImHS.

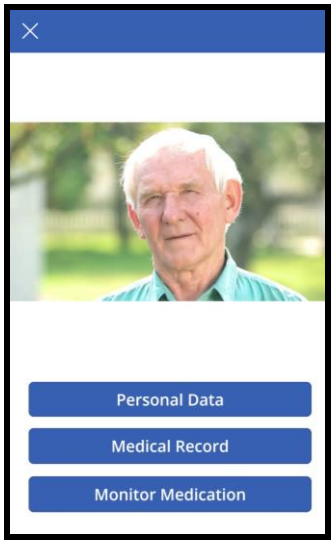

Fig. 4 User interface of the ImHS

4.3 Data Analysis using Face Recognition

In order to eliminating handwriting errors and mismatching of the hard copies of medication records, the facial recognition technology is applied to improve the performance of the caregivers, particular those with less experience. FaceAPI offered by Microsoft Azure is applied to process the captured image and compare it with the known face in the private repository for achieving facial recognition. Fig. 7 shows a set of facial images as training data in the private repository. To connect the FaceAPI with the ImHS, several features must be defined, including the Personal Group ID, Personal Group Name, Personal ID, Image URL, Face List, Persist Face ID and Face ID. Table 2 shows the details of these features. By simply taking a photo, the caregivers can call the FaceAPI to verify the identity of the elderly. The process flow for verification is shown in Fig. 6. To search for medication records with facial recognition, a valid Personal Group ID is required. Users simply take a photo and can request a face ID by calling the Face API service. If there are any matched faces in the personal group, a valid face ID will be returned to show the result. In addition, a confidence score defined by caregivers (i.e. lower than 80% of the faces in the testing data set) is provided to present the confidence value for successfully matching the captured image with the known face in the database. In such a situation, a result with a high confidence value implies that there is a higher chance that the compared two faces belong to the same person.

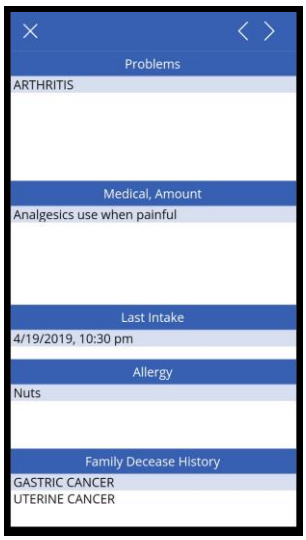

Fig. 5 Review of medication records

Fig. 6 Intake medicine records

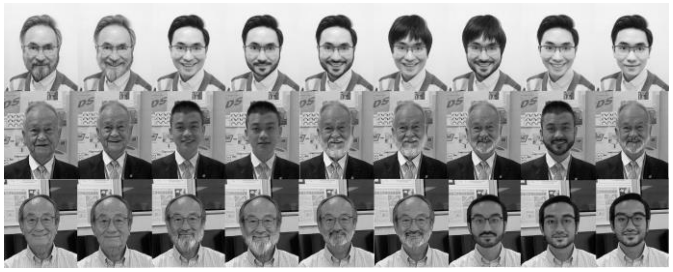

Fig. 7 A set of facial images

5. RESULTS AND DISCUSSION

The proposed ImHS enables the caregivers to systematically collect the elderly health information in digital format for tracing their health situation so as to facilitate the daily routine processes in elderly homes. The prototype of the ImHS was implemented in the case home for three months and was found that the efficiency and effectiveness in delivering of healthcare services was improved, and the satisfaction level was enhanced.

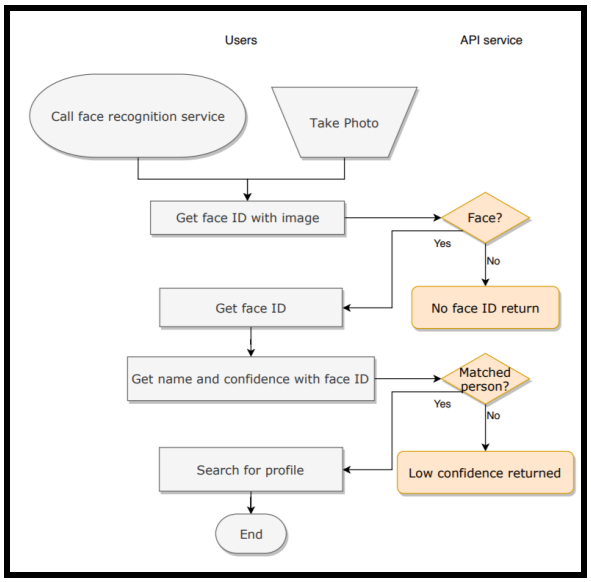

Fig. 8 Process flow of face recoginition in the FaceAPI

Table 2. Details of the features involved in the FaceAPI

Personal Group ID	A unique ID to identify the corresponding organization. It is used to locate specific group. The group contains the personal IDs of the organisation's elderly.
Personal Group Name	The name of the organisation.
Personal ID	A unique ID to identify the corresponding person. It is used to locate identify the persons in a personal group.
Image URL	A directory of an image. It is used to locate the image for the API services.
Face List	A collection contains face IDs and the corresponding personal IDs.
Persist Face ID	An ID identifying a face. Persist Face IDs is subjected to a face list.

5.1 Improvement in the efficiency of daily routine processes

Compared with the traditional paper-based documentation method, the ImHS provides a systematic approach for caregivers to store and review information. Table 3 shows a comparison of the efficiency of the daily routine processes before and after the use of the proposed system. Instead of tedious daily checking processes from collecting data, and, marking the data into spreadsheets to manually input in the computer for documentation, the caregivers can directly input the biometric data and any remarks into the ImHS through the mobile device. Therefore, the time for documenting health information is reduced by 78%. In addition, by reviewing the historical health records in digital format, the caregivers no longer need to review such records from separate files, which also helps to shorten the time for the execution of the daily routine processes.

Table 3. Improvement in the efficiency of daily routine process

	Manual Approach	With ImHS	Improvement (%)
Time for documenting health information	9 mins	2 mins	78%
Time for reviewing historical health records	16 mins	3 mins	81%
Total	25 mins	5 mins	80%

5.2 Reduction in the number of complaints regarding human mistakes

Table 4 shows the complaint rate and satisfaction level in the case company before and after implementing the ImHS. By adopting the face recognition technology, the junior caregivers, especially part-time caregivers, can easily identify the needs of elderly through reviewing the health record from the ImHS. It significantly reduces the chance of ADE and medical incidents due to the human mistakes. Therefore, the number of complaints regarding human mistakes per month is reduced from 8 to 3, which is a 63% reduction. In addition, a survey was distributed to the elderly to investigate their satisfaction level after the implementation of the ImHS. It was found that the service satisfaction level of the case company (ranging from 0 to 10) is increased by 36%.

Table 4. Complaint rate and satisfaction level before and after implementing the ImHS

	Manual Approach	With ImHS	Improvement (%)
Complaint due to human mistakes (per month)	8	3	63%
Satisfaction level	6.1	8.3	36%

5.3 Sensitivity analysis of face recognition

To test the accuracy of facial recognition, sensitivity analysis was conducted to determine how the number of known faces in the database affected the confidence score. In this case, three datasets of known faces with different number of known faces were inputted to the privacy repository for verifying twenty images. The number of known faces for training in the dataset A, B and C are 200, 300 and 400, respectively. Table 5 shows the confidence score, success rate and average processing time of these three datasets. From Table 5, it was found that the both confidence score and the average processing time are increased with the number of known faces in the privacy repository. However, based on the increment of confidence score and average processing time, dataset B is more suitable since it only requires 35s to process the data with an acceptable confidence score. When compared with the success rate for recognizing faces, it was found that datasets B and C have the same success rate, i.e. 89%.

Table 5. Confidence score, success rate and average processing time of face recognition

Dataset	A	B	C
Confidence score	0.77	0.87	0.92
Success rate for recognizing faces	82%	89%	89%
Average processing time	15s	35s	98s

6. CONCLUSION

At present, Hong Kong is affected by increasing population aging which has brought serious challenges to the local healthcare services providers in the aspects of manpower, work efficiency and medical safety. The execution of daily routine tasks, including direct care and indirect care services, are professional tasks that require care and concentration. However, due to limited healthcare resources and high turnover rate in elderly homes, it is difficult for caregivers to provide the fast-response and accurate healthcare services. In addition, these homes still rely on paper-based health records for storing information which causes inconvenience in administration and health monitoring. Therefore, this paper proposes an intelligent m-healthcare system (ImHS) to tackle the mentioned problems. It combines several cutting-edge technologies - machine vision, artificial intelligence and biometrics - and puts them into practical use. A case study was implemented in a local nursing home for the elderly. From the results, it is found that the proposed system improves the accuracy and efficiency in the execution of the daily routine checking process. With the use of the mobile devices, the occurrence of medical incidents and ADE is reduced so that the satisfaction level is enhanced. Therefore, the proposed ImHS provides an intelligent solution for the domestic care industry. Through the integration of machine vision and AI techniques, it can reduce the mistakes form ADE and improve the operation performance in the elderly homes. In future work, other functions, such as real-time data monitoring and automatic care operation, can be integrated in the ImHS to provide customized healthcare services. Also, future work can be focused on data security, availability, and integrity of the system.

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