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An IoMT-based Geriatric Care Management System for Achieving Smart Health in Nursing Homes

Abstract

Purpose – The purpose of this paper is to develop an Internet of medical things (IoMT)-based geriatric care management system (I-GCMS), integrating IoMT and case-based reasoning (CBR) in order to deal with the global concerns of the increasing demand for elderly care service in nursing homes.

Design/methodology/approach – The I-GCMS is developed under the IoMT environment to collect real-time biometric data for total health monitoring. When the health of an elderly deteriorates, the CBR is used to revise and generate the customized care plan, and hence support and improve the geriatric care management (GCM) service in nursing homes.

Findings – A case study is conducted in a nursing home in Taiwan to evaluate the performance of the I-GCMS. Under the IoMT environment, the time saving in executing total health monitoring helps improve the daily operation effectiveness and efficiency. In addition, the proposed system helps leverage a proactive approach in modifying the content of a care plan in response to the change of health status of elderly.

Originality/value – Considering the needs for demanding and accurate healthcare services, this is the first time IoMT and CBR technologies have been integrated in the field of GCM. This paper illustrates how to seamlessly connect various sensors to capture real-time biometric data to the I-GCMS platform for responsively supporting decision making in the care plan modification processes. With the aid of I-GCMS, the efficiency in executing the daily routine processes and the quality of healthcare services can be improved.

Keywords Geriatric care management, Internet of medical things, Case-based reasoning, Nursing home

Introduction

Facing the unavoidable phenomenon of the aging population, the need for long-term care (LTC) has been emphasized for serving the elderly with chronic diseases or disabilities who have the difficulties in their daily life so as to relieve the pressure faced by hospitals (He & Chou, 2017; Beard & Bloom, 2015). In order to deliver quality, affordable and accessible healthcare services to the elderly, a long-term care project (LTCP) was launched in 2007 by the Taiwan government with the aim of establishing a comprehensive care plan in the community through the adoption of smart health in the area of geriatric care management (GCM) (Ministry of Health and Welfare, 2016). This concept of LTCP is widely followed in other countries such as China and the US for developing a complete chain of healthcare services, from preventative care to community-based healthcare support and finally to hospice care (Feng et al., 2012). As important LTC providers, nursing homes play an important role in providing GCM, which refers to a series of steps of assessing, planning, coordinating, monitoring and providing the healthcare services for the elderly (Wideman, 2012). It not only provides basic healthcare services such as nursing care, personal care and residential care for fulfilling the needs of the elderly, but also emphasizes on how to maintain and promote quality of life (Zimmerman et al., 2014).

Currently, three problems are identified in the current GCM workflow, as shown in Figure 1, which are (i) collection of biometric data separately and repetitively, (ii) no data linkage between health monitoring and the care plan modification processes, and, (iii) long timeframe for the complex evaluation in care plan modification. At the time of admission, a customized care plan with the goals of meeting the needs of an elderly, is formulated through a comprehensive review on the information related to historical health records of an individual and science of care. During the time in nursing homes, the health of the elderly inevitably deteriorates, and thus the monitoring of their health status is important during their stay in nursing homes. Caregivers are required to check and record the biometric data, such as vital signs including heart rate, body temperature and breathing rate, on manual paper-based daily worksheets several times per day. Such biometric data are then stored separately for recording and reference only. Once the regular review of care plan is executed, such data will be extracted and integrated from the separate database to analyze the health status of the elderly for meeting their changing needs. Without a systematic approach in GCM, relevant data cannot be instantly captured, integrated and managed for monitoring and analysis. As a result, caregivers may overlook any abnormalities appearing of the biometric data resulting in a delay in providing instant treatment in emergency cases. Health deterioration may occur and even cause harmful effect to the elderly. In addition, since any care plan modification requires the deep expert knowledge, the current practice needs a long timeframe to complete the review of the care plan and to make appropriate amendments.

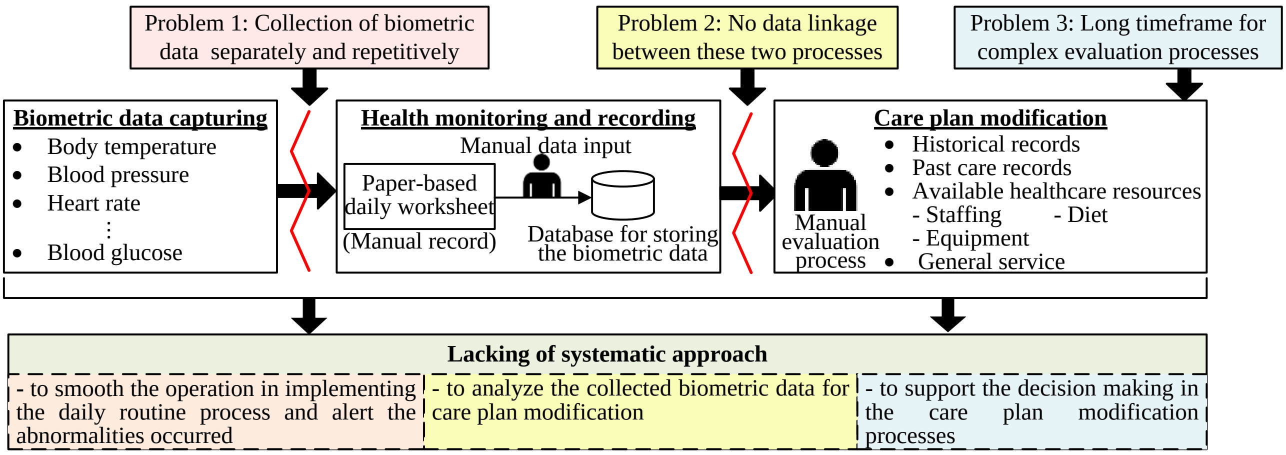

Figure 1. Existing problems in the geriatric care management (GCM)

Although Wong et al (2017) has introduced the adoption of healthcare sensors for collecting the real-time data, the infrastructure of IoMT, including how healthcare sensors are connected for collecting the desirable data, how the health data processes and transfers from sensors to cloud and how the data can be visualized by the users for providing the personalized-based services, is neglected. In addition, it is found that most research related to healthcare focused on the area of disease diagnosis, disease prevention and drug reaction detection, attention rarely is paid to the field of GCM in nursing homes, as well as the decision support system for analyzing the relevant data and facilitating care plan formulation. Therefore, in order to fill this research gap, an internet of medical things-based geriatric care management system (I-GCMS) is proposed in this paper. The system integrates IoMT and case-based reasoning (CBR) to (i) monitor the real-time biometric data of the elderly, and, (ii) support decision making for caregivers in care plan modification. The data, including barometric data and operation data taken in nursing homes, can be captured by the means of IoMT, and thus the CBR can be used for revising health care plans effectively and efficiently. By doing so, the proposed I-GCMS helps caregivers deliver a reliable and high quality of care (QoC) to the elderly in nursing homes while health deterioration can be controlled.

The rest of the paper is organized as follows. Section 2 reviews the literature related to smart health in nursing homes, IoMT and CBR. Section 3 describes the architecture of I-GCMS while a case study is presented in Section 4 for validating the feasibility of I-GCMS. Section 5 discusses the results, findings and system performance. The conclusions are drawn in Section 6.

2. Literature Review

2.1 Overview of smart health and geriatric care management in nursing home

With the continuous influence of rising life expectancy, declining birth rate and infant mortality, the phenomenon of the global aging population has become one of greatest challenges in the healthcare industry (Veiga et al., 2018; Al-Shaqi et al., 2016). LTC becomes increasingly important in providing a variety of ongoing healthcare and social services for people with physical or mental disabilities (Lehning & Austin, 2010). In order to cope with the associated challenge, LTC service providers seek to deploy the concept of smart health, which is the idea of integration of IoMT and artificial intelligence (AI), to support the delivery of LTC services in the home and community (Holzinger et al., 2015). Smart health offers the advantages of facilitating the information sharing of medical resources, accelerating the timeline of geriatric care and providing decision making in health and disease diagnosis, analysis and prediction (Shen et al., 2018; Chang et al., 2017). Iqbal et al. (2017) adopted smart health concepts to improve the reliability, precision, accuracy and work efficiency in hospitals. Mshali et al. (2018) designed an adaptive context-aware monitoring system for the daily activities of the elderly and isolated persons, adapted to the daily behaviour of the monitored person so as to detect abnormal situations in their homes. Despite the adoption of smart health offering significant benefits to hospitals and home care providers, the adoption of smart health in nursing homes is limited due to a lack of access to capital by nursing homes' providers, the relatively low education level of nursing staff and a lack of proper implementation planning (Kruse et al., 2015). As important LTC organizations in the community, nursing homes provide geriatric care including personal care, such as in feeding and bathing, nursing care, as well as skilled and therapeutic care, to the elderly with chronic diseases and disabilities (Verleye et al., 2014). The adoption of smart health in the area of GCM is worthy of consideration in nursing homes so as to deliver accurate and fast response healthcare services and improve the QoC. Without the adoption of smart health, caregivers in nursing homes still rely on traditional manual approaches to check and record the biometric data of the elderly, and review their care plans. Concerning the need for providing high QoC for the elderly with chronic diseases and disabilities, there is room to extend this concept for improving the effectiveness, efficiency, reliability and accuracy in executing the GCM in nursing homes.

2.2 Internet of medical things in healthcare industry

The applications of IoMT, also known as healthcare IoT, have rapidly grown in recent years. A set of medical devices and products under the IoMT environment are linked to healthcare systems through wireless sensor networks to collect and exchange medical data (Tu et al., 2018; Mishra et al., 2016; Gao et al., 2015). The adoption of IoMT in the healthcare industry, especially for hospitals and home-care providers, has opened a new window of research in providing remote patient monitoring, to facilitate disease diagnoses and to improve the personalization of healthcare services (Shin & Hwang, 2017; Islam et al., 2015). Al-Majeed et al. (2015) developed an IoT system, “CogSense”, to monitor physiological conditions using sensors so that caregivers can provide active and real-time care to patients. Xu et al. (2016) proposed to link hospital beds with various sensors and analytics consoles for measuring patients’ vital sign using IoMT technology. Sood & Mahajan (2017) developed a healthcare system with the use of IoMT and fuzzy c-mean clustering to monitor and identify possible infected victims of the Chikungunya virus in the early phase so as to control the outbreak of this disease. Thus, it is promising to deploy IoMT in nursing homes for continuous monitoring of the biometric data of the elderly in order to react to abnormalities appearing in their health status. Although IoMT is able to monitor the health status of the elderly, it cannot trigger and support the decision making for modifying care plans when the health of the elderly deteriorates.

2.3 Artificial intelligence techniques in geriatric care management

In recent years, AI techniques such as genetic algorithms (GA) and fuzzy logic have been widely adopted to improve the quality of healthcare services, planning and allocation of healthcare resources and to facilitate diagnosis of diseases (Lupo 2016; Liu 2013). GA is useful for handling optimization problems, while fuzzy logic is used to deal with linguistic concepts during diagnosis and prognosis. For instance, Kuo et al. (2016) suggested integrating information and mobile communication technology with a GA to enhance utilization of elderly care centers through better work scheduling and more efficient delivery of care services. Bekker et al. (2019) proposed the task-scheduling method, involving the use of a GA and integer linear program for assigning care tasks to available care workers in order to support staff allocation decisions. Medjahed et al. (2009) utilized fuzzy logic to monitor daily activities of elderly people living in a nursing home. Hussain et al. (2016) proposed a fuzzy logic-based home healthcare system for the follow-up and monitoring of patients with chronic heart disease. However, considering the responsiveness and manpower required to re-assess the massive amount of health information relating to the elderly in GCM processes, there is a need to provide caregivers with decision-making approaches which make good use of the knowledge that can be gained from relevant past records. Case-based reasoning (CBR) is a promising AI technique, which has a self-learning capability, providing valuable knowledge to support decision-making (Kolodner

1993). It supposes that problems can be solved by using similar past solutions, particularly when occurrence of these problems is high (Yan et al. 2017). By utilizing the knowledge and previous experience stored in the CBR case library, users can generate solutions to cope with a new problem (Prentzas & Hatzilygeroudis, 2016). Thus, researchers are paying increasing attention in applying CBR in the healthcare industry for diseases diagnosis, medical decision support and treatment planning (Gu et al., 2017; Marling et al, 2014). Wang et al. (2007) developed a knowledge-based treatment planning system using the CBR and rule-based reasoning for enabling nursing staff to construct the treatment plan effectively and efficiently. Petrovic et al. (2016) adopted the CBR to formulate the parameters of a radiotherapy treatment plan in dealing with patients with brain cancer. Therefore, applying CBR in nursing homes is a feasible solution for caregivers so as to formulate more efficient care plans in reviewing huge amounts of health information.

With the above studies, it is shown that there is a crucial need for adopting smart health in nursing homes so as to deliver accurate and fast responses in healthcare services and hence improve the overall satisfaction of the elderly. However, considering the different functions and responsibilities among various healthcare parties, current studies that are related to the context of healthcare that focus on short-term and urgent treatment in hospitals may not be suitable for nursing homes since around-the-clock GCM is more emphasized in nursing homes. Therefore, this paper develops an Internet of medical things-based geriatric care management system (I-GCMS) for facilitating the adoption of smart health in nursing homes so as to improve the efficiency and reliability of daily routines and care plan modification processes.

3. Design of I-GCMS

In order to achieve smart health in nursing homes, an I-GCMS is proposed to monitor the biometric data of the elderly in real-time and support decision making in care plan modifications. Figure 2 shows the architecture of I-GCMS which includes three modules: (i) IoMT data capturing module, (ii) IoMT monitoring module and (iii) nursing care plan revision module.

3.1 IoMT Data Capturing Module

In the front-end part of I-GCMS, three types of wireless sensors are needed to capture the real-time biometric data, and the product specifications are shown in Table 1. Firstly, the elderly in nursing homes are fitted with wearable devices, i.e. WearPai WP107, allowing caregivers to monitor their blood pressure (mmHg), heart rate (per min), oxygen saturation level (%) and number of steps (per day). Secondly, Nokia Thermo is provided for caregivers for measuring the body temperature of the elderly (ºC). Thirdly, an iHealth Smart Glucometer is used to collect the blood glucose level (mmol/L). To select the appropriateness of sensors for collecting data in nursing homes, three criteria are considered: cost, feasibility and the use of wireless communication technologies for data transmission. For the Nokia Thermo and iHealth Smart Glucometer, these sensors are shared by the elderly in the same ward to use. Therefore, the cost for purchasing these sensors is reasonable. In addition, since these three sensors are able to an extract data from external cloud / application programming interface

(API), real-time data in JavaScript Object Notation (JSON) format can be easily converted and integrated to the customized cloud platform for the application. Considering the application in nursing homes, such sensors using Bluetooth or WIFI as the wireless communication technology are appropriate for the use due to low power consumption, high level of quality of service (QoS) and high ease of use. Such sensors are suitable as sensor nodes for capturing real-time biometric data in the nursing home environment. The collected data are then transferred to the back-end part of I-GCMS for further data management and analysis purposes.

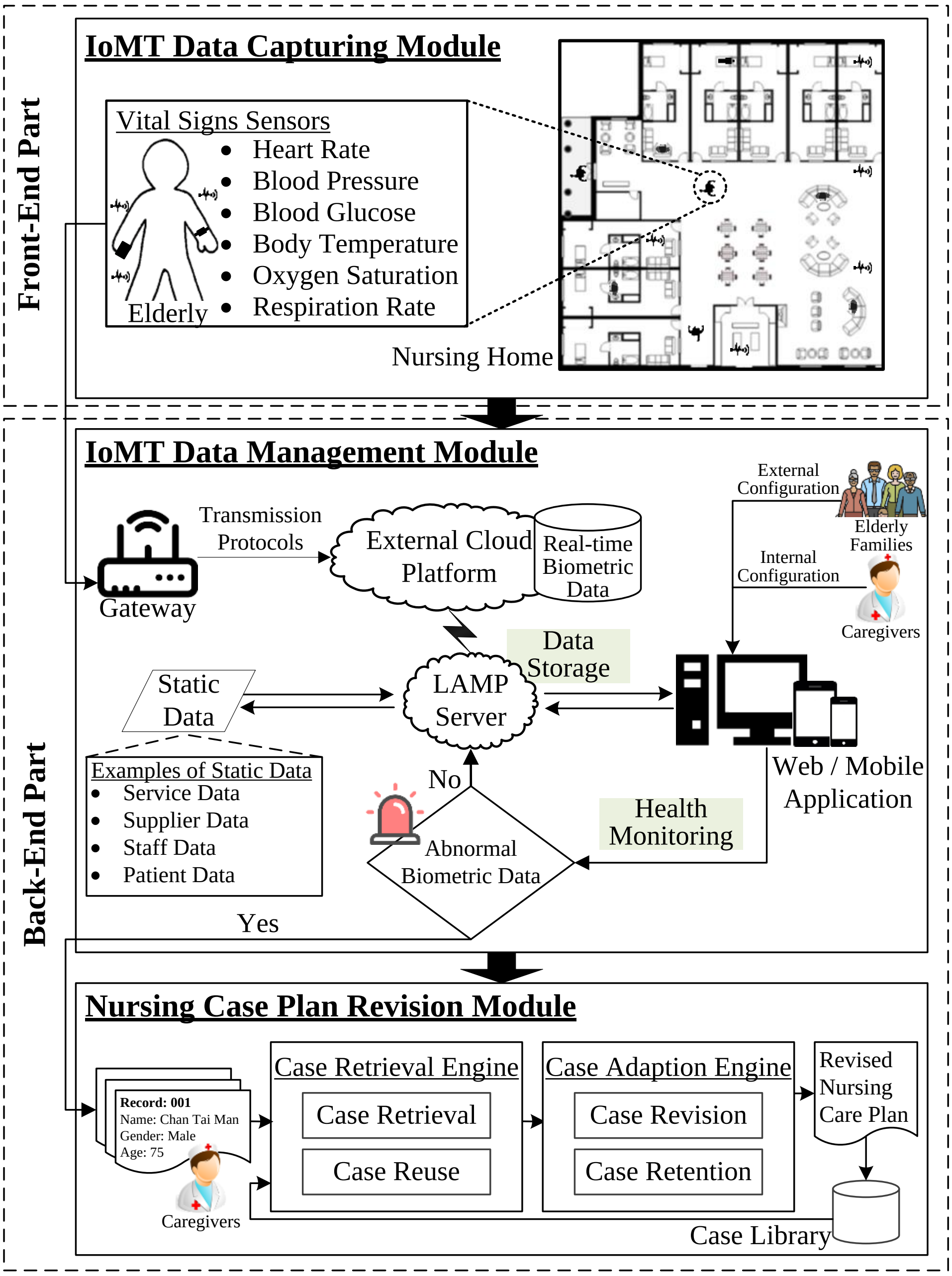

Figure 2. System architecture of the I-GCMS

To ensure data security, message queuing telemetry transport (MATT) is adopted for transiting data at various layers of the I-GCMS. Through the messaging protocol, MATT enables communication between constrained IoT devices. The rapid response, low battery and bandwidth usage features of the MATT protocol facilitate data transmission in a more secure and efficient way.

Moreover, the application programming interface (API) is used to enable transmission of data from an external cloud platform to the LAMP server. In addition, user configuration ensures that only authorized users (i.e., managers and nursing staff in care homes, and the families of the elderly) are allowed to log in to the I-GCMS. Regular testing and use of a firewall are important for reducing system vulnerabilities and the chances of insecure interfaces occurring in the I-GCMS.

Table 1. Product specification of three types of sensors used

Sensors	Type of information	Details
Wearable Device	Brand	WearPai
	Model Number	Wearpai WP107
	Sensor (s)	3 axis motion sensor, heart rate sensor, heart pressure sensor, blood oxygen sensor
	Measuring Range	60 – 220 bpm for heart rate 90 – 255 mmHg for systolic blood pressure 50 – 255 mmHg for diastolic blood pressure
	Accuracy	±2.35%
	Communication Protocol	Bluetooth 4.0
Thermometer	Brand	Nokia
	Model Number	SCT01
	Sensor (s)	Thermopile
	Measuring Range	35ºC – 43.2ºC (95ºF – 109.8ºF)
	Accuracy	±0.2 ºC on 35ºC – 42.7ºC (±0.4 ºF on 95ºF – 107.6ºF) ±0.3 ºC (±0.5 ºF) outside this range
	Communication Protocol	Wi-Fi b/g/n 2.4 Ghz / Bluetooth Smart Ready
Glucometer	Brand	iHealth
	Model Number	BG5
	Sensor (s)	Amperometric technology using glucose oxidase
	Measuring Range	20 mg/dL ~600 mg/dL (1.1 mmol/L~33.3mmol/L)
	Accuracy	±10%
	Communication Protocol	Bluetooth 3.0

3.2 IoMT Data Management Module

In the back-end part of I-GCMS, four layers are involved in the IoMT framework: (i) IoMT sensors layer, (ii) gateway and network layer (iii) management service layer, and, (iv) application layer. Details of the IoMT framework of I-GCMS is shown as Figure 3. As mentioned in section 3.1, in the IoMT sensors layer, three types of sensors are installed and equipped in nursing homes for collecting relevant biometric data. In the gateway and network layer, in order to gather and synchronize such data in the proposed system, the sensors are connected using smartphones, which act as the gateway, through the wireless communication technology of Wi-Fi b/g/n 2.4GHz or Bluetooth Smart Ready. By getting the credentials in the sensing devices and registering the AppIDs for the sensors, the biometric data can be transmitted and stored in external cloud services under a wireless local area network (WLAN). In the management service layer, the data stored in the external cloud services are transferred to the customized LAMP (Linux, Apache, MySQL, and PHP/Python) server. The LAMP server allows the users to develop front-end and back-end applications so that the received biometric data can be stored, analyzed and displayed through developing a web application. In the application layer, with the use of web development programming language, such as HTML and JavaScript, users can access biometric data in a number of devices. The API is used as a mechanism for the interacting of the data between multiple external cloud services and the LAMP server. Simple object access protocol (SOAP) and representational state transfer (REST) are the two main protocols for developing the API. By defining the specifications of the API, such as Hypertext Transfer Protocol (HTTP), request messages and uniform resource locator (URL), the data from the external cloud services can be effectively transferred to the specific server location for developing customized applications. The proposed I-GCMS allows caregivers to monitor the health status of the elderly so that real-time alerts can be generated when abnormalities appear. In addition, these biometric data can be used for analyzing the needs for any care plan modification process in the nursing care plan revision module so as to provide the corresponding updated healthcare services. On the other hand, the elderly patient's families are able to login into the I-GCMS to check the health status so as to ensure proper care is provided by the nursing homes.

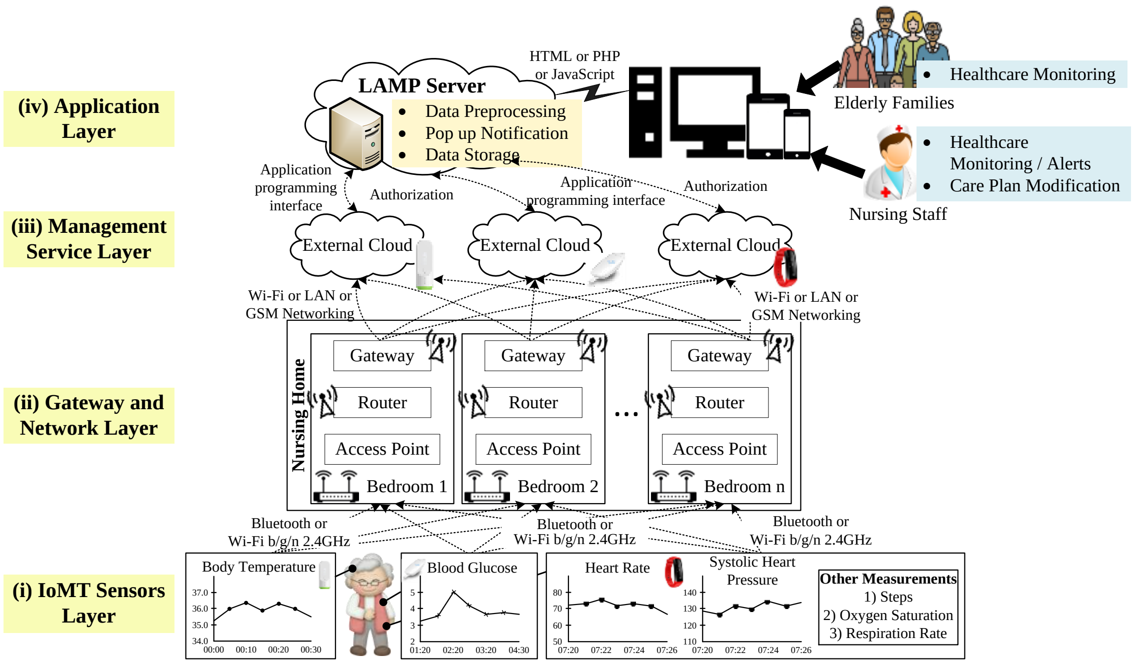

Figure 3. IoMT Framework of I-GCMS

Apart from collecting real-time biometric data, static data, such as the care plan information, personal information of the elderly and staff information, are also stored in the cloud database in the proposed I-GCMS for improving the decision making processes in nursing homes. The I-GCMS provides a built-in dashboard so that caregivers can perform care plan modification, and real-time data monitoring and visualization. Pop up alerts through SMS are delivered so that caregivers can be aware of any continuous abnormal signals appearing. The normal range of biometric data is shown in Table 2. Once an alert occurs, instant action, such as sending the elderly to hospital, can be taken for preventing serious health deterioration. With the ability of data storage, caregivers can view the historical health data of the elderly so as to analyze their needs. In addition, caregivers can peruse the clear instructions on the current care plan in serving the elderly through the user interface of I-GCMS. In a specific period of time, the biometric data stored in the cloud database are also transmitted to the nursing care plan revision module for re-assessing the needs of the elderly based on their level of health deterioration. By doing so, accurate and fast responsive healthcare services can be delivered to the elderly.

Table 2. Normal range of biometric data collected by various sensors

Biometric Parameters	Units	Normal Range	Remarks
Systolic Blood Pressure	mmHg	90 – 120	Expressed in millimeters of mercury for a healthy person
Diastolic Blood Pressure	mmHg	60 – 80	Expressed in millimeters of mercury for a healthy person
Heart Rate	bpm	60 – 100	Expressed in beats per minute
Oxygen Saturation	%	95 – 100	Expressed in %
Body temperature	ºC	36.5 – 37.2	Expressed in degree Celsius for a healthy person
Blood Glucose Level	mmol/L	3.9 – 5.5	Expressed in Millimoles per liter for a healthy person at fasting

3.3 Nursing Care Plan Revision Module

The purpose of this module is to revise the current care plan based on the change of health status of the elderly. In order to reduce the time and complexity in care plan modification processes, CBR is applied in which adapt knowledge is stored in past cases in the case library, so that appropriate healthcare services can be effectively provided by caregivers. Typically, each case C stored in the case library is divided into two main parts: input problem and output solution, as shown in Figure 4, i.e. C = {HR, FB, BI, EC, HS, S, E, D} where HR is health record, FB is functional ability, BI is biometric information, EC is expect cost, HS is healthcare service, S is staff, E is equipment and D is diet. The input problem part of C contains 4 tuples, HR, FB, BI and EC, while tuples, i.e. HS, S, E, and D, are involved in the output solution part. Table 3 shows the detail description of the 8 tuples involved in C.

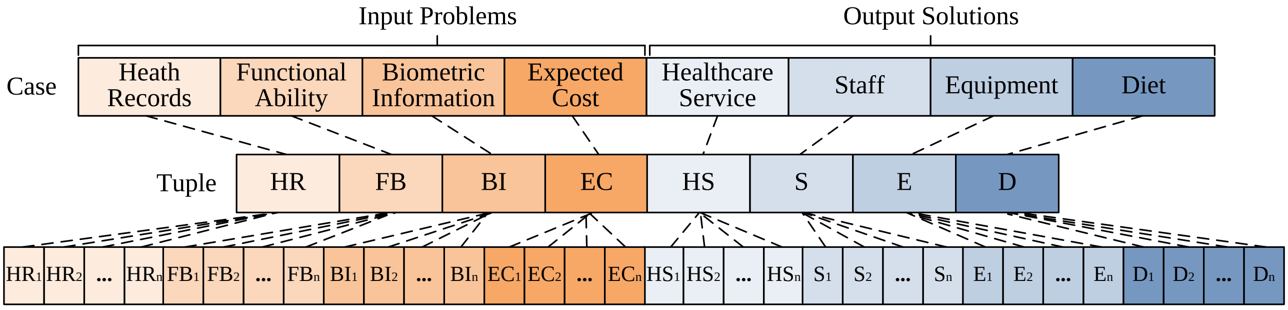

Figure 4. Input problems and output solutions in the case

To formulate an updated care plan, two engines are involved in this module: the case retrieval engine and case adaptation engine. In the case retrieval engine, caregivers are required to define the key attributes that can help cluster the care plan stored in the case library into meaningful groups using the inductive indexing method. Inductive algorithms such as ID3 and CART are used for discriminating and generating a tree-type structure of past cases into various groups. The most important attribute is allocated to the highest indexing level. By retrieving a small group of potential cases from a large set of categories, this can reduce the computational load in further processing. With the increase of indexing level, the importance of attributes decrease. According to Freedman and Spillman (2014), the mobility of the elderly is the most significant factor that affects the care provided by nursing homes. In this situation, the elderly can be classified into three main categories: bedridden, moving with assisting equipment and ambulant. To serve the elderly in different categories, specific healthcare services are required. Therefore, mobility attributes should be placed in the highest level of the indexing tree. By doing so, a group of potential care plans that meet all the requirements are selected when the retrieval processes follows the path of the indexing tree.

Table 3. The detail description of seven tuple in the case

Input Problems	**Tuple**	**Description**
1. Health Records	HR = {HR_1, HR_2, … , HR_n}	A set of health records for identifying types of diseases that the elderly has
2. Functional Ability	FB = {FB_1, FB_2, … , FB_n}	A set of personal data that shows the functional ability
3. Biometric Information	BI = {BI_1, BI_2, … , BI_n}	A set of biometric data collected through various sensors
4. Expected Cost	EC = {EC_1, EC_2, … , EC_n}	A set of the expected cost that the elderly and their family can afford based on healthcare services provided by the nursing home
Output Solutions	**Tuple**	**Description**
1. Healthcare Service	HS = {HS_1, HS_2, … , HS_n}	A set of healthcare services such as personal care that nursing homes can offer to the elderly based on the their health situations and requirements
2. Staff	S = {S_1, S_2, … , S_n}	The type of staff for serving the elderly
3. Equipment	E = {E_1, E_2, … , E_n}	A set of equipment that the elderly need in assisting their daily living
4. Diet	D = {D_1, D_2, … , D_n}	A set of diets that nursing homes can offer

To further improve the appropriateness of the care plan, the nearest neighbor method is adopted for computing the similarity value between the new input case and individual past cases retrieved in the last level of the indexing tree using Eq. (1) and (2). Specific weighting ranging from 0 to 1 is given to the attributes considered. Typically, higher weighting implies that the attributes are more important in the formulation of the care plan.

$$\mathrm{sim}\left(f_i^{new}, f_i^{old}\right) = \frac{\min\left(\left|f_i^{new}\right|, \left|f_i^{old}\right|\right)}{\max\left(\left|f_i^{new}\right|, \left|f_i^{old}\right|\right)} \quad (1)$$

$$\text{Total similarity value}(\text{case}_{\text{new}}, \text{case}_{\text{old}}) = \frac{\sum_{i=1}^{n} \omega_i \cdot \mathrm{sim}(f_i^{new}, f_i^{old})}{\sum_{i=1}^{n} \omega_i} \quad (2)$$

where ω_i is the weighting of individual attribute, sim is the function for calculating the similarity value of attributes, f_i^{new} and f_i^{old} are the value of attributes *i* in the new input case and past cases. The total similarity values range from 0 to 1, in which 0 indicates that the attribute in the new input case is totally different to the attribute in the past case. In contrast, a value of 1 in the total similarity value represents the attribute in the new input case being the same as the attribute in the past case. By ranking the similarity value of past care records in descending order, the care plan with the highest similarity value to the new input case is retrieved as a reference and then transferred to the case adaptation engine.

In the case adaptation engine, modification of the retrieved care plan is needed for ensuring the fitness of the output solution. Based on the knowledge and experience of the caregivers, editing of new services based on actual needs and removing outdated service methods can help to improve the quality of healthcare service and maintain service satisfaction. After the modification, the revised solution is treated as a new care plan for serving the elderly in nursing homes. In order to achieve continuous improvement in nursing homes, the new care plans with new healthcare information are transferred to the case library for storage purpose. Useful and valuable information can be retained and used as important assets for solving new problems in the future.

4. Case Study

A case study was conducted in a nursing home in Taichung, Taiwan to validate the performance of the proposed I-GCMS. The nursing home was founded in 1987 and has around 80 staff. Through providing professional and comprehensive healthcare services, the nursing home aims at building a safe and comfortable living environment for more than 200 elderly residents who have chronic diseases and require rehabilitative medical care. At the admission stage, an elderly is required to submit all relevant documents such as daily health records and inpatients records to enable the nursing home to formulate a customized care plan. This health information is then stored in the local database of the nursing home through a manual input process. Figure 5 shows the existing flow and the problems in daily routine processes. Three problems are identified in such processes in the case company as shown in Figure 6. i.e. (i) Inefficiency in the daily checking process due to the manual and repeated tasks involved, (ii) Lack of a real-time alert system for monitoring any abnormalities appearing, and (iii) Long time required for evaluating the health information in regular care plan review processes,

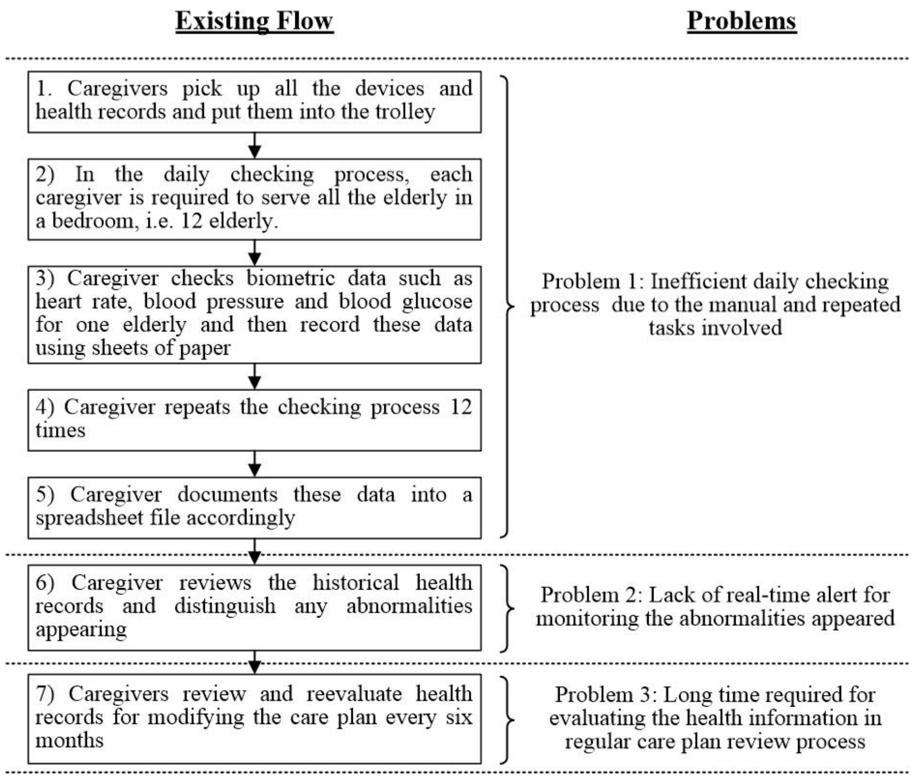

Figure 5. Existing flow and problems for daily routine processes

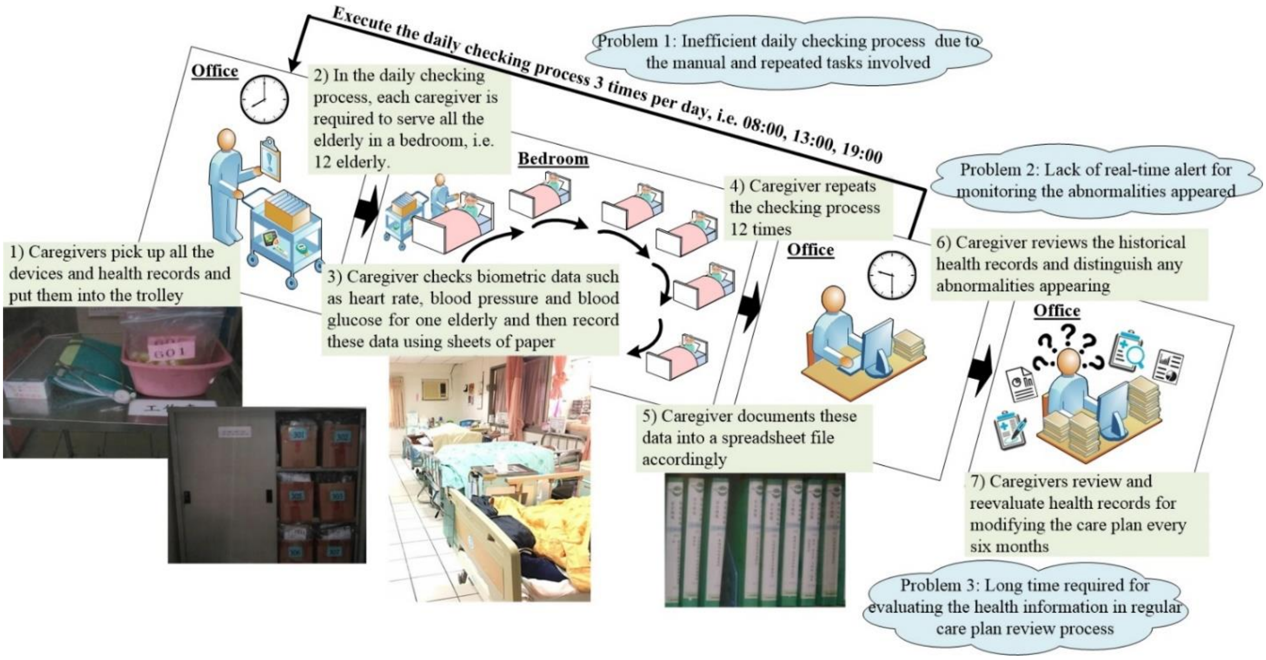

Figure 6. Workflows and problems for daily routine processes in the case nursing home

Concerning the need for accurate and fast responsiveness in delivering daily routine processes in the context of GCM, the proposed system is implemented in the nursing home to achieve smart health for delivering high-quality healthcare services to the elderly, thereby improving customer satisfaction. The implementation procedures of the I-GCMS are shown in Figure 7, which involves four steps.

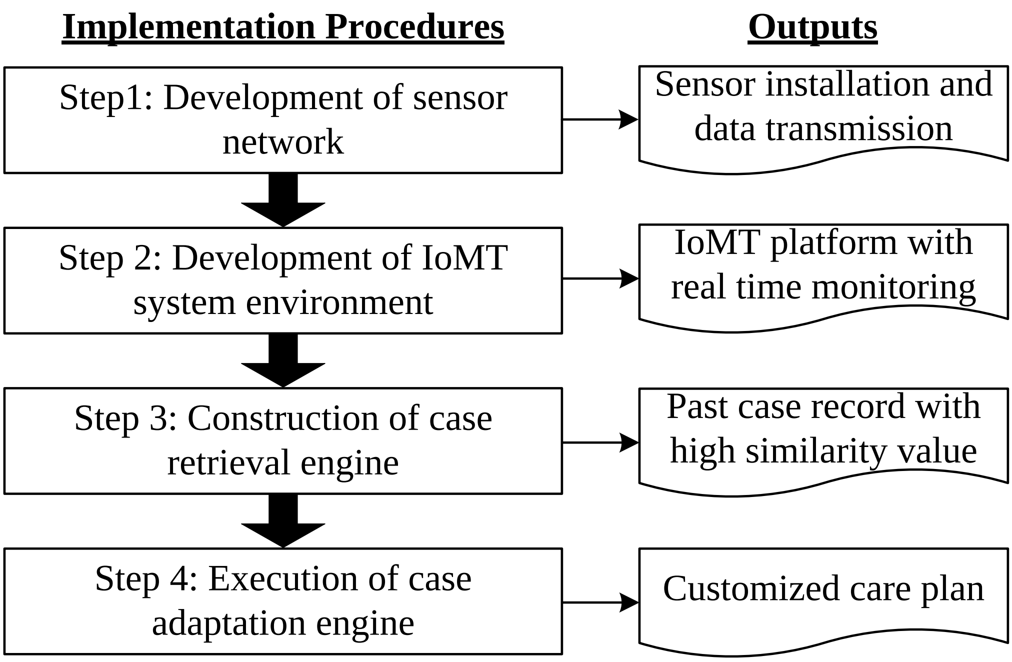

Figure 7. Implementation procedures of the I-GCMS

4.1 Development of Sensor Network

In order to achieve smart health in the case nursing home, three types of sensors, i.e. WP107, Nokia Thermo and iHealth Smart Glucometer, are used for collecting the biometric data of the elderly through the creation of the sensor network. The elderly living in the nursing home are required to wear the WP107, while Nokia Thermo and iHealth Samrt Glucometer are provided to the caregivers who carry out daily routine checking to the elderly. Nokia Thermo is selected as an example to demonstrate the construction of a sensor network, and the implementation procedures are shown in Figure 8. Since Nokia Thermo is capable of connecting the Nokia app through Wi-Fi b/g/n 2.4GHz, the data can be transmitted to a smartphone with the Nokia app for temporary data storage purpose. Then, users can register Nokia Health to the account so as to obtain the client ID and secert. The client ID is used for getting the authorization code through sending a GET request to the Nokia API providers. After that, through making a POST request with the use of authorization code to the access token and secert can be obtained for accessing the data in the external cloud services. From the API documetation provided by the Nokia Health developer, measure type 71 corresponds to the measured body temperature data. Figure 9 shows the body temperature data from Nokia Thermo stored in an external cloud service in the JSON format. By following similar procedures in the API connections, the biometric data collected by WP107 and iHealth Smart Glucometer are also gathered and loaded in the LAMP server. Considering three types of sensors used for collecting the biometric data in which data may be present in various formats, these data are parsed into a single strcuture format, i.e. integer data. In order to gather the data from different external cloud services, the data is finally transferred to the LAMP server for developing the function of the proposed I-GCMS.

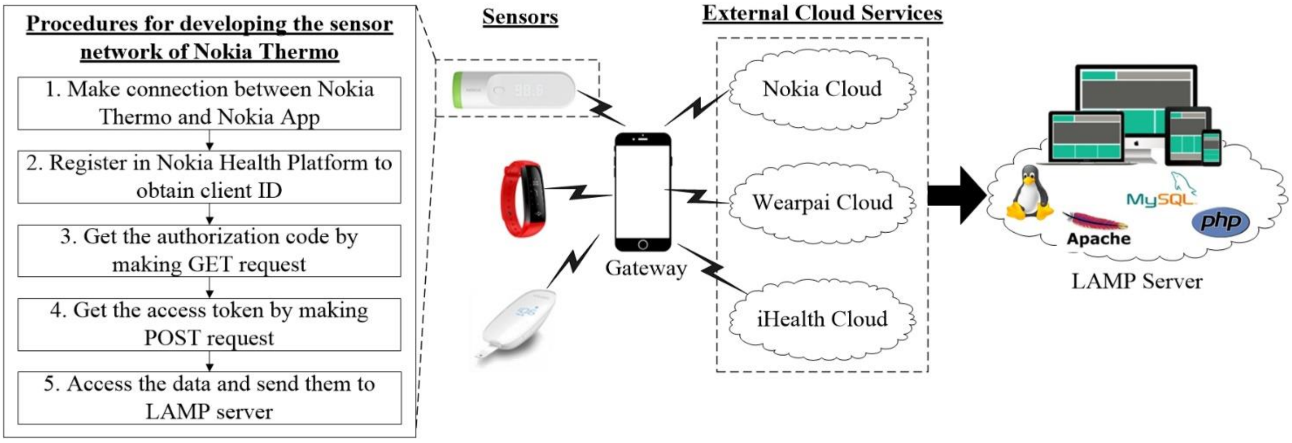

Figure 8. Procedure for developing the sensor network of Nokia Thermo

4.2 Development of IoMT system

In this phase, Ubuntu Server 16.04 with a full LAMP stack is used for developing the I-GCMS. Ubuntu is the most popular Linux-based operating system, and is capable of supporting multiple programming languages, such as Python and C++, in developing customized applications. With the use of API, the interaction between the external cloud services and the LAMP server can be created so as to achieve the function of real-time data transmission. In addition, through the configuration of MySQL provided by Ubuntu packages, dynamic biometric data and static data can be stored in the proposed I-GCMS. Figure 10 illustrates the user interface of the I-GCMS for monitoring the biometric data of the elderly in a ward. By selecting a particular elderly, caregivers can also view the detailed information of that elderly in a specific time interval. Seven types of biometric data: heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), oxygen saturation (OS), body temperature (BT), blood glucose level (BG) and step can be monitored under a real-time environment. In order to detect any continuous abnormality that may appear, caregivers are required to define the safety range of each biometric data input according to the information shown in Table 2. Once the biometric data is out of the safety range, an alert box will pop up to remind the caregivers to take a higher level of care, such as change in observation frequency and transferring that elderly to a hospitals for preventing the continuous health deterioration. Apart from the real time monitoring of biometric data, the caregivers are able to view the historical health records and details of the care plan. During the regular review of care plans, such data are extracted and transferred to the nursing care plan revision module for assessing any care plan modification according to the health deterioration of the elderly. Therefore, the functionalities of health monitoring and care plan modification can be performed by authorized users in the proposed I-GCMS.

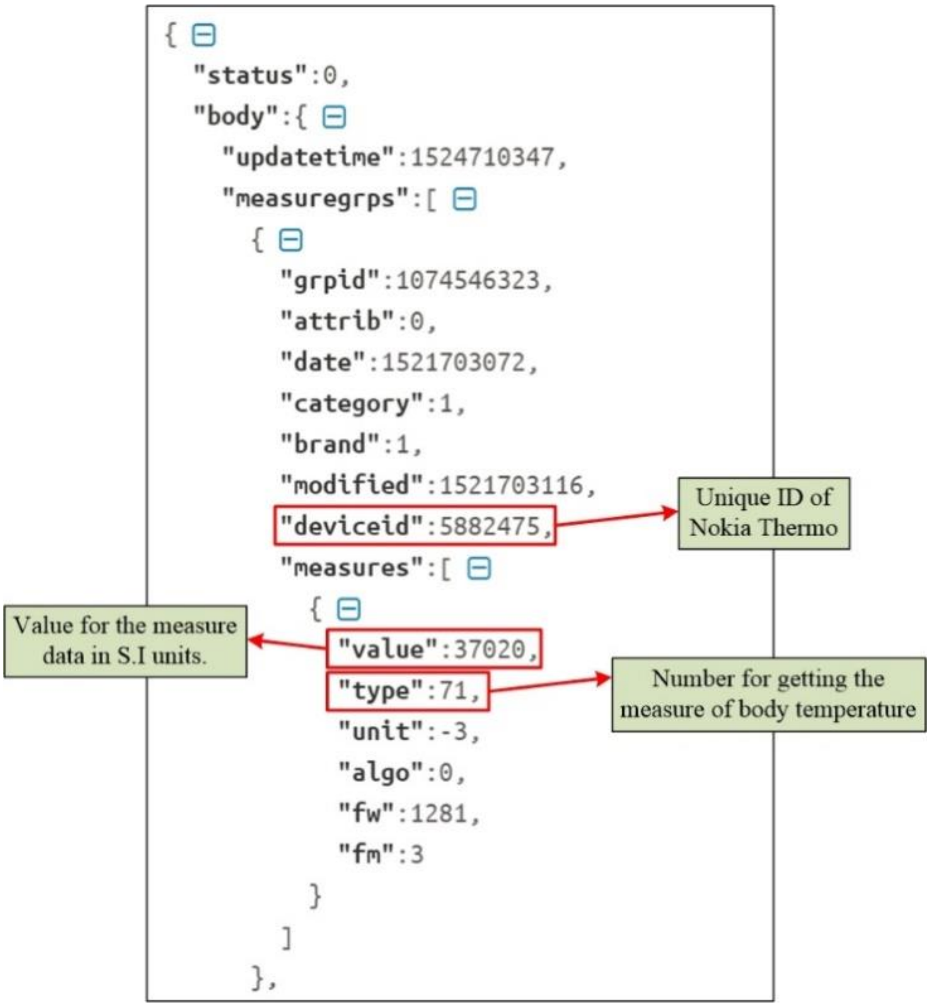

Figure 9. Example of data of body temperature in JSON format

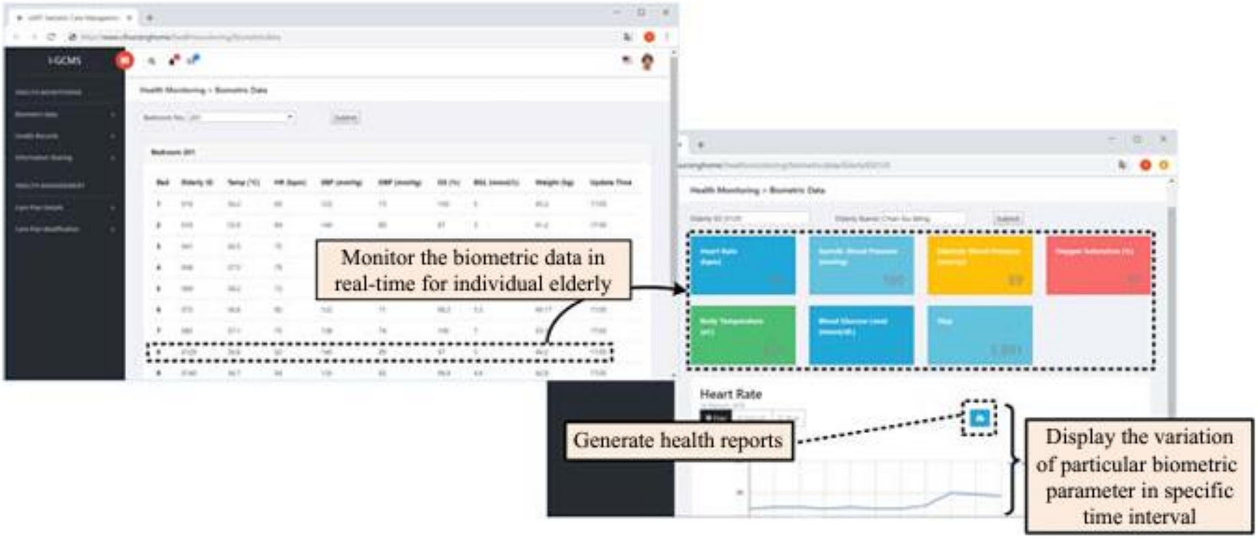

Figure 10. User interface of health monitoring in the I-GCMS

4.4 Construction of case retrieval engine

In the proposed system, all the biometric data can be gathered in the centralized cloud databases under the IoMT environment. The CBR is then employed to re-evaluate the need for care plan modification by considering the average values of the biometric information. Python, one of the common programming languages, is used to construct the proposed I-GCMS. In order to implement the case retrieval engine process, past care records in Excel format are loaded to the MySQL database in the LAMP server for constructing the CBR library. After that, the inductive indexing approach and the nearest neighbor method are employed to retrieve the most relevant past care plans in this engine, and the mechanism is shown in Figure 11.

Firstly, through construction of a decision tree with different levels, past care plans in the CBR library can be clustered according to the main attributes that may affect the healthcare services. Thus, five levels are defined in the decision tree: (i) Mobility in Level 1, (ii) Self-care ability in Level 2, (iii) Neuropsychiatric condition in Level 3, (iv) Communication method in Level 4 and (iv) Age in Level 5. The detailed structure of the decision tree in the I-GCMS is shown in Figure 12. By matching such attributes along the search path of the decision tree, a group of past care plans can be identified and extracted. These past care plans are then ranked based on their similarity to the care plan required for modification using the nearest neighbor method; the details are shown in Figure 13. The average value of the biometric data collected in the data capturing module, expected cost and diseases suffered by the elderly, are defined as important attributes for calculating the similarity value. In addition, through discussion with the senior caregivers who have sufficient experience and knowledge in generating care plans, a predefined weighting is given to the corresponding attributes to present their importance. With such information, the total similarity value of individual past care plans to the care plan needing for modification is computed using Eq. (1) and (2).

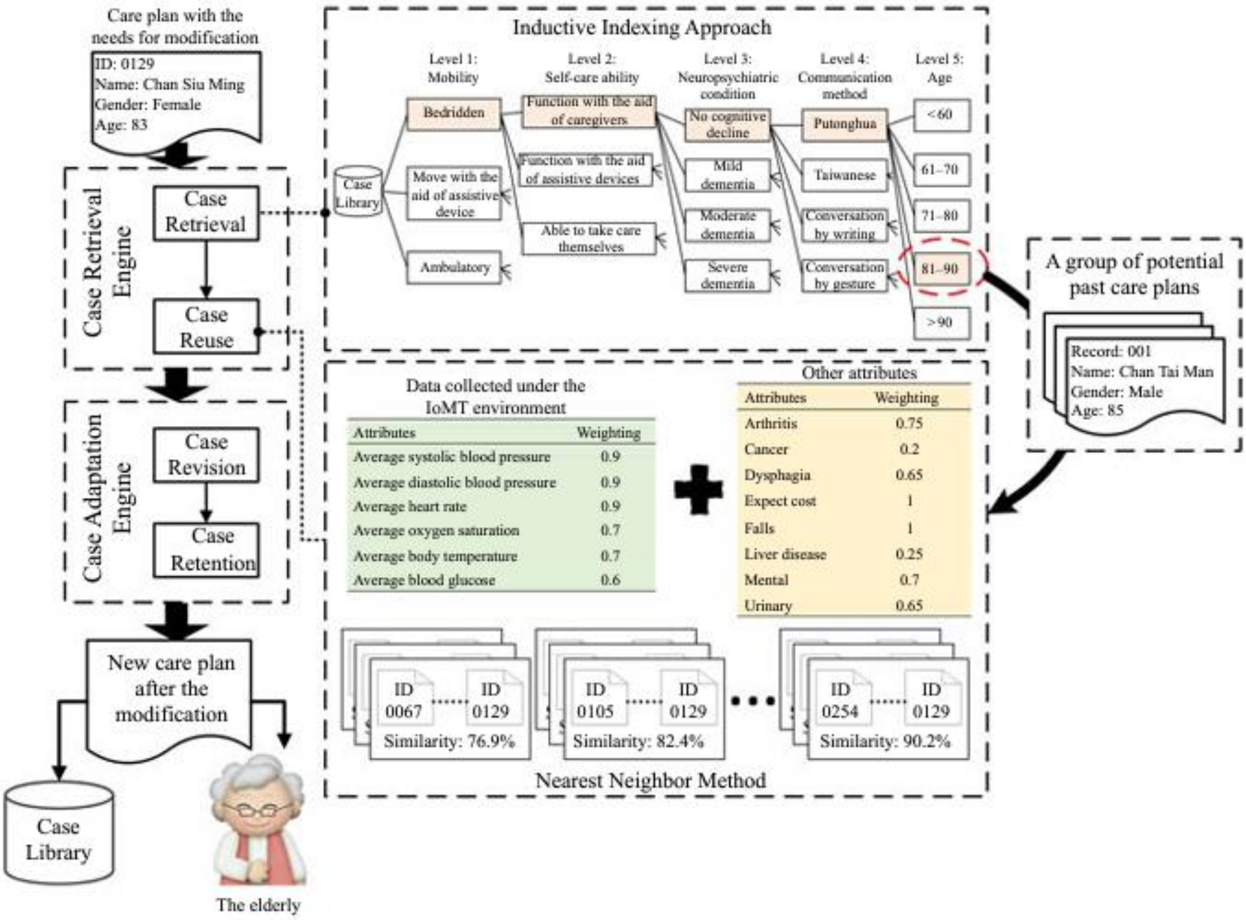

Figure 11. The mechanism of case retrieval engine

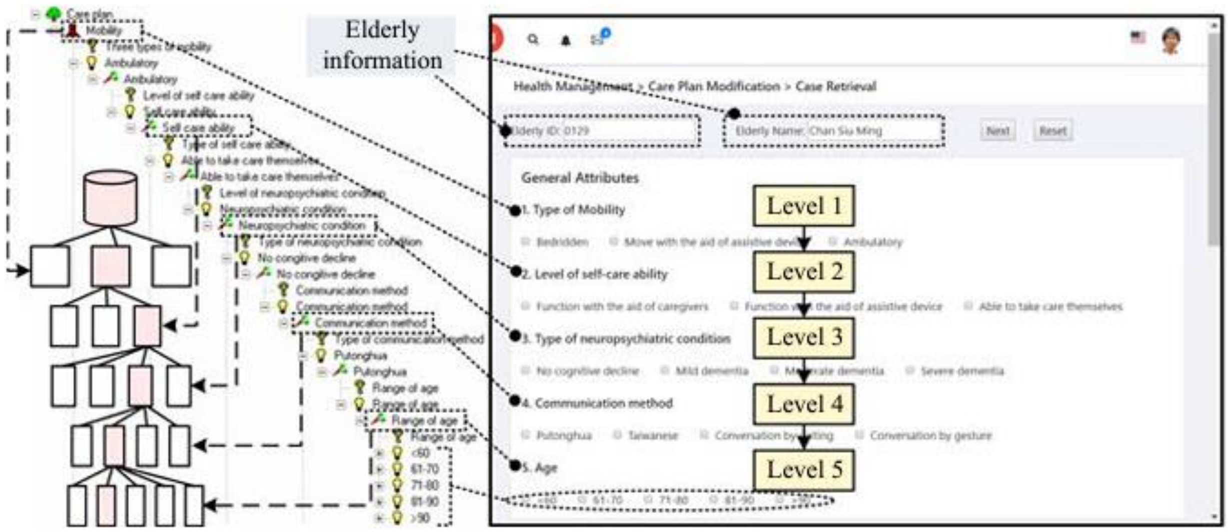

Figure 12. Detail structure of decision tree in the I-GCMS

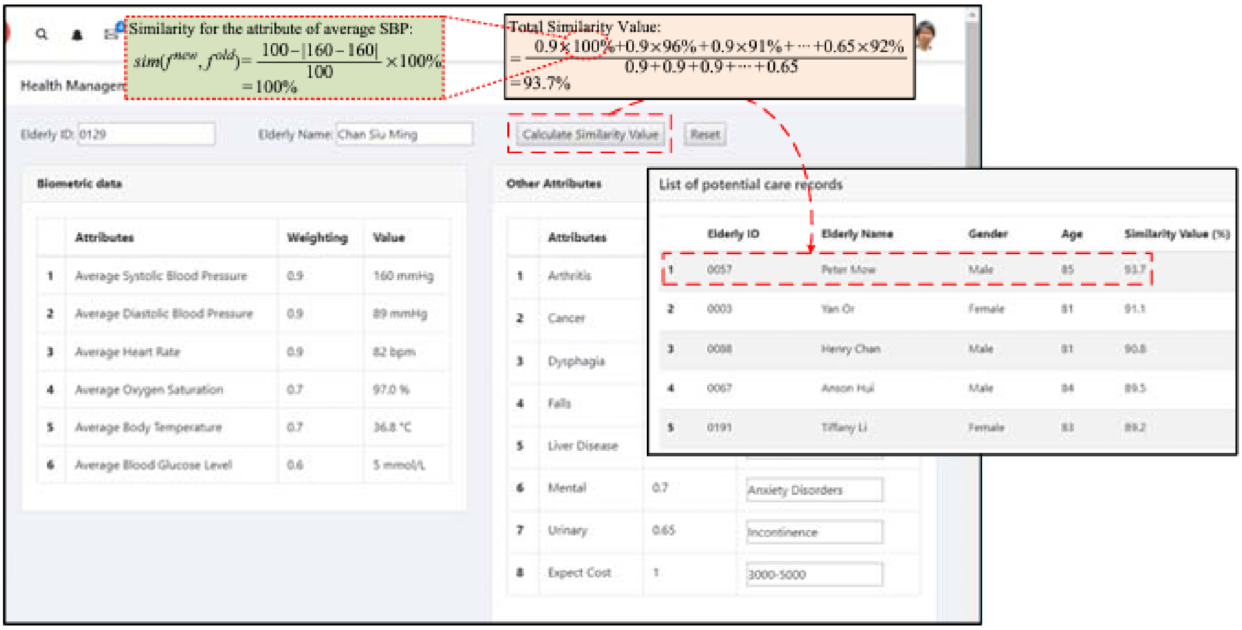

Figure 13. User interface for ranking the total similarity value of a group of retrieved care plans

An elderly (Elderly ID 0129) was selected to illustrate the mechanism of CBR in I-GCMS. It was found that the elderly has chronic diseases resulting from high blood pressure and was required to take medicine for controlling the blood pressure in normal level. However, in this two weeks, the average SBP and average DBP increased to 160mmHg and 89mmHg respectively. For other biometric data, the elderly had an average HR of 82 bpm, 97% average OS, 36.8°C average BT, 5mmol/L average BG. To deal with the increasing blood pressure, a comprehensive review was executed for generating a new customized care plan. As shown in Figure 14, it was found that a past care plan for serving another elderly ID 0057 had the highest similarity value (93.7%) to the elderly ID 0129 so that caregivers can retrieve and treat the care plan as a reference for generating a new solution.

4.5 Execution of case adaptation engine

Considering the specific healthcare services requested by the elderly and their families, the content of the retrieved care plan may not fully satisfy their needs. Therefore, the retrieved care plan is then passed to the case adaptation engine for further improving its appropriateness. Caregivers with professional health knowledge can make modifications to the retrieved care plan by adding and removing the types of healthcare services, or by simplifying the checking process to fit the needs of the elderly based on the change of their health status. Figure 14 shows the user interface of the care plan modification in the I-GCMS. Under a smart health environment, the new care plan can be formulated effectively for preventing further health deterioration occurring while the overall satisfaction level can be enhanced. Since the blood pressure of elderly 0129 was slightly increased in in two weeks, it was suggested to provide a diet with low sodium for controlling the blood pressure. In addition, a 30 minutes tailor-made exercise program five times per week was provided so as to help lower the blood pressure. In order to achieve continuous improvement in QoC in the case nursing home, the new care plan is retained and stored in the case library for handling new problems in the future.

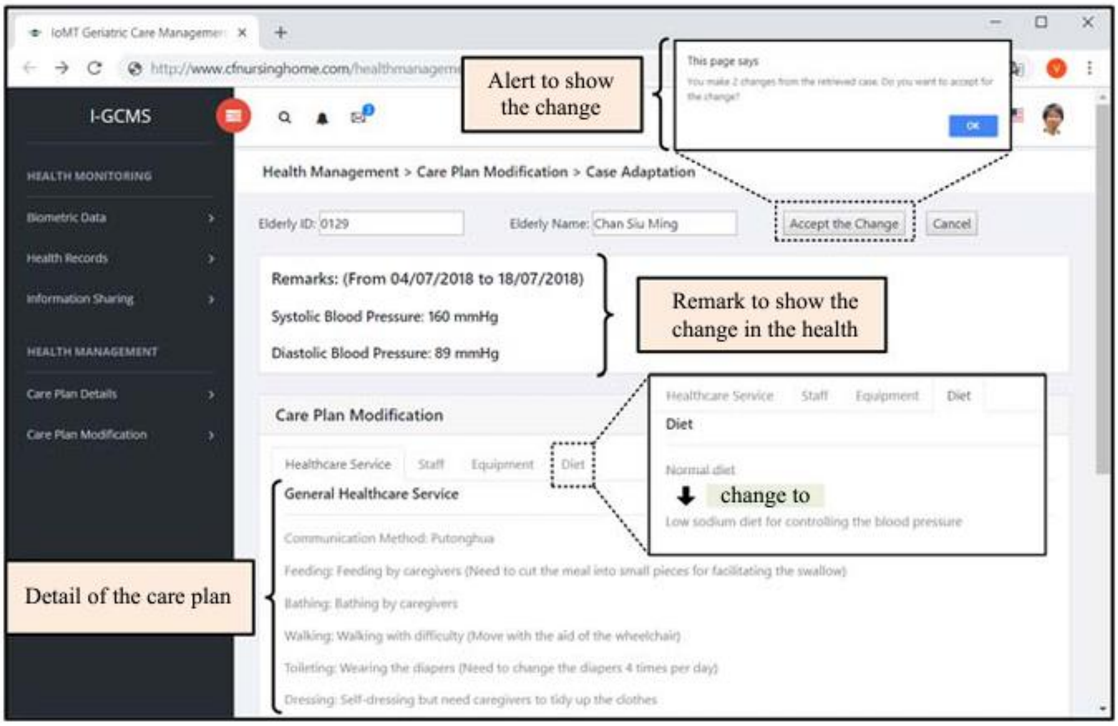

Figure 14. User interface of care plan modification in the I-GCMS

5. Results and Discussion

To verify the significance and contribution of the proposed I-GCMS, a prototype was developed and a trial run of the prototype was conducted in the case nursing home for enhancing the performance in health monitoring and care planning modification. In this paper, the proposed system provides benefits to (i) caregivers for increasing the operational efficiency in the daily routine processes and (ii) the families of the elderly for increasing the visibility in tracking real time health information.

5.1 Advantage of I-GCMS

After the implementation of I-GCMS, it was found that the efficiency for executing the daily routine processes was improved while the healthcare service satisfaction was enhanced in the case nursing home.

(i) Improvement in the efficiency of daily routine processes through the data integration

Table 4 shows the performance improvement in the execution of daily routine processes in the aspects of the health information collection and care plan modification. Under the IoMT environment, the proposed system allows caregivers to collect the biometric data in real-time, and this information can be effectively synchronized in the cloud platform. The caregivers no longer need to spend a great deal of time to manually input this information into the spreadsheet. Therefore, compared with the manual approach, the time for executing the daily checking processes with the help of I-GCMS is significantly reduced by 84.6%. Particularly, no time is spent on manually documenting the biometric data after the implementation of I-GCMS. Besides, the time for reviewing the relevant health records and formulating the details of care plan are reduced from 22 minutes to 1 minute and from 15 minutes to 4 minutes, respectively. This is because the adoption of CBR in the I-GCMS takes the past care plan as a reference so that caregivers can effectively create solutions with the elements of the types of healthcare services, staff, equipment and diet. Therefore, the time for modifying the care plan is greatly reduced by 86.4%.

Table 4. Improvement in the execution of daily routine processes

	Manual Approach	With I-GCMS	Improvement (%)
Time for executing the daily checking process			
- Collect the biometric data	5 min	2 min	
- Document the biometric data	8 min	0 min	
Total	13 min	2 min	84.6%
Time for modifying the care plan			
- Review the relevant health records	22 min	1 min	
- Formulate the details of care plan (including the types of healthcare services, staff, equipment and diet)	15 min	4 min	
Total	37 min	5 min	86.4%

(ii) Improvement in the healthcare services satisfaction

Without the adoption of I-GCMS, the case nursing home relies on the manual health monitoring approach in which caregivers are required to collect biometric data three times per day. In such a situation, it is inefficient and labor-intensive in checking around 200 residents in the nursing home at the same time. Instead of the traditional approach, the IoMT application in the nursing home provides advantages for caregivers to capture and monitor relevant data in real-time. With a pop-up alert system, caregivers can notice any abnormality appearing in the health status of the elderly so that instant action can be taken for preventing further health deterioration. Therefore, complaints due to any delay in delivering appropriate healthcare services can be reduced. Apart from the health monitoring function, the data analytics ability in the I-GCMS helps the caregivers to facilitate decision making in the care plan modification process, with high reliability and validity. Further, the use of I-GCMS also aids information sharing between the case nursing home and the families of the elderly. The families always expect high transparency and continuous involvement in the care process. Through the I-GCMS platform, they can easily obtain real-time health information and details of the care plan. Consequently, with the good relationship and communication with the families of the elderly, the caregivers can better understand the expectations and goals, decrease any dissonance among two parties and ultimately maintain a high quality of healthcare services to the elderly.

5.2 Discussion on the proposed approach

In the proposed I-GCMS, CBR is adopted in the nursing care plan revision module for generating a customized care plan based on any health deterioration of the elderly. In order to validate the appropriateness of the care plan, a test was conducted and two indicators, i.e. accuracy and acceptability, were used to measure the performance of the proposed system. Accuracy was used to measure the difference of 4 tuples in the output solutions part of the case, i.e. HS, S, E and D, compared with the content of the care plan generated by domain experts with professional knowledge and experience. Acceptability refers to the percentage of the care plan accepted by the elderly and their families. Three criteria, i.e. cost, convenience in use and solution feasibility, are used to measure the acceptability of care plan formulated using CBR approach. A total of 20 cases were selected in the test and the accuracy and acceptability achieved by CBR is shown in Table 5. It was found that the proposed I-GCMS resulted in an average accuracy of 92.3% which 16 cases had the accuracy value of higher than 90%. According to the three criteria, the acceptability of the care plan generated by the CBR approach was 87.8%. Apart from the above two indicators, a cross validation process was implemented by a group of senior caregivers and nursing officers for further validating appropriateness of the care plans. Once the care plans with poor quality were rejected in this case, a process for re-evaluating the needs for the elderly and their corresponding historical health records is required to regenerate the customized care plan.

Table 5. Accuracy and acceptability of 20 cases using CBR methods

	Elderly ID	**Accuracy (%)**	**Acceptability (%)**		**Elderly ID**	**Accuracy (%)**	**Acceptability (%)**
1	0008	96.2	84.2	**11**	0129	85.4	84.2
2	0015	92.8	80.6	**12**	0132	94.8	75.6
3	0036	90.1	90.2	**13**	0133	90.5	85.6
4	0059	91.5	88.9	**14**	0163	91.6	95.5
5	0070	93.7	95.4	**15**	0169	93.9	93.5
6	0076	88.5	89.2	**16**	0185	92.3	80.4
7	0083	98.3	90	**17**	0181	94.6	76.1
8	0101	95.4	92.1	**18**	0207	89.6	84.4
9	0116	92.1	94.3	**19**	0212	92.6	97.3
10	0122	93.7	88.3	**20**	0215	88.4	89.7
				Average Value		**92.3%**	**87.8%**

5.3 Managerial implications

The rapidly aging population poses challenges to all parties in the healthcare industry. Short-term and urgent treatment are emphasized in hospitals while LTC is the focus in nursing homes. Delivering high quality and proactive healthcare services in nursing homes are essential reducing avoidable incidents occurring. However, limited budgets, shortage of skilled nursing staff, increasing healthcare costs coupled with growing healthcare needs are the critical constraints for nursing homes in handling the GCM, as well as long-term health management and monitoring. Therefore, nursing homes are willing to adopt the smart health concept for developing affordable and easy-to-use healthcare solutions in dealing with the growing needs of healthcare services by the elderly and their families.

Under the smart health environment, the integration of the IoMT and AI techniques allows valuable data such as biometric data, healthcare resources data, historical data of the elderly, across the health monitoring operations and care plan modification processes to be seamless, so users can manipulate such data intelligently, as shown in Figure 15. This can improve the operational efficiency, transparency and traceability among the different stakeholders. The standard user interfaces of I-GCMS allows the nursing staff to effective capture, monitor and be alerted on the health status of the elderly in real-time, so as to improve the operation efficiency in GCM. With integration, the formalized operation procedures can be adopted for nursing staff to follow in providing the necessary healthcare services. In addition, the interactive interfaces between the nursing staff and the families of the elderly not only facilitates their communication in terms of involvement of care planning, but also improve the quality of healthcare solutions for serving the elderly. From a management perspective, with limited resources, the deployment of the IoMT system not only offers benefits for the managers in organizing and sharing the health data among internal and external parties, but also aids the formulation of effective healthcare management solutions through big data analytics. Valuable healthcare knowledge can be retained for achieving operational excellence in nursing homes. Therefore, it benefits the managers in nursing homes to better allocate and manage resources, such as equipment and staffing, to achieve positive outcomes for the elderly. Ultimately, patient-centered healthcare services can be delivered to the elderly in nursing homes in a timely manner thereby maintaining their health and maximizing their quality of life.

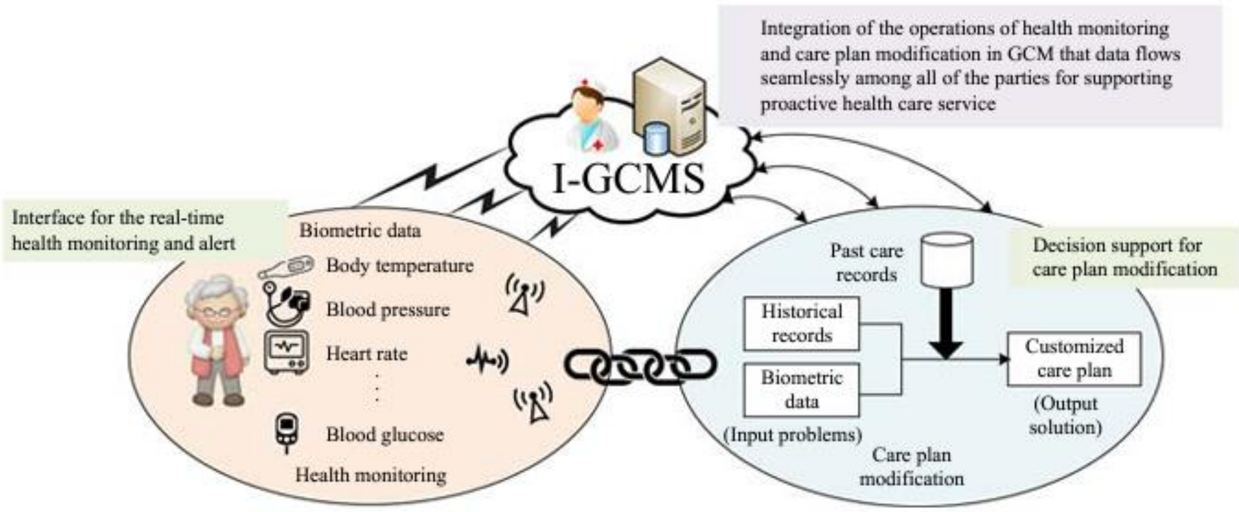

Figure 15. Managerial implication of I-GCMS

6. Conclusions

With the growing demand for healthcare services, the adoption of smart health has been recognized as one of key factors in reducing healthcare expenditure, improving the health outcomes of patients and enhancing LTC services. However, due to the limited resources and the low adoption of smart health in nursing homes, caregivers still rely on manual approaches for executing daily routine operations in GCM. In handling such highly repeatable and complex processes, caregivers may overlook any abnormal signals appearing in the biometric data, resulting in continuous health deterioration and even fatalities. In order to narrow the research gap in the field of GCM in nursing homes, in this study, an Internet of medical things-based geriatric care management system (I-GCMS), which integrates the IoMT and CBR techniques, is developed to deliver highly accurate and fast responsive healthcare services to the elderly. Under the IoMT environment, three types of sensors, i.e. WP107, Nokia Thermo and iHealth Smart Glucometer, are connected to the customized LAMP server through the interactive interface with the external cloud services for real-time health monitoring. Instead of manual reviewing of care plans, the care plan can be re-evaluated and re-modified with consideration of the change of health status through the use of CBR. Thus, solutions can be effectively made by adopting knowledge from past care records, thereby reducing the time for revising the care plan. Under a smart health environment, data between the processes of total health monitoring and care plan modification can seamless flow in the I-GCMS, which significant improves the operational efficiency. On the other hand, this study also enhances the communication and involvement of the families of the elderly in the care planning process through information sharing in the I-GCMS. With better understanding of healthcare needs, decision makers, i.e. managers in nursing homes, can decide an appropriate strategies for better allocation of resources so as to achieve continuous quality improvement in a cost-effective manner. However, this study has three key limitations: (i) the willingness of the elderly to wear IoT devices; (ii) system blackout; and (iii) reliance on the knowledge of domain experts in the case of the adaptation engine of the CBR. Some elderly people may not be willing to wear the IoT devices. In this case, these people would be grouped together, and normal health monitoring approaches would be adopted to take care of them. In order to minimize the effects of a system blackout in the nursing home, backup power would be provided in the interim to maintain the functions of the proposed system. The emergency plan would be executed, and normal daily checking and care planning procedures followed to provide basic healthcare services for the elderly until system recovery is instated. Furthermore, future research should be undertaken, focusing on a more systematic approach such as text mining to improve the efficiency of knowledge acquisition for modification and retrieval of past records.

Acknowledgements

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References

Al- Majeed, S. S., Al-Mejibli, I. S., & Karam, J. (2015, May). Home telehealth by internet of things (IoT). In *Electrical and computer engineering (CCECE), 2015 IEEE 28th Canadian conference on* (*pp.* 609-613). IEEE.

Al-Shaqi, R., Mourshed, M., & Rezgui, Y. (2016). Progress in ambient assisted systems for independent living by the elderly. *SpringerPlus*, *5*(1), 624.

Beard, H. P. J. R., & Bloom, D. E. (2015). Towards a comprehensive public health response to population ageing. *Lancet (London, England)*, *385*(9968), 658.

Bekker, R., Moeke, D., Dieleman, N., Buitink, M., den Uijl, J., Otsen, F., Koreman, K., Passial, R., & Couwenberg, M. (2019). Demand-Driven Task-Scheduling in a Nursing Home Setting: A Genetic Algorithm Approach. *Available at SSRN 3367017*.

Chang, D. S., Liu, S. M., & Chen, Y. C. (2017). Applying DEMATEL to assess TRIZ's inventive principles for resolving contradictions in the long-term care cloud system. *Industrial Management & Data Systems*, *117*(6), 1244-1262.

Cordón, O. (2011). A historical review of evolutionary learning methods for Mamdani-type fuzzy rule-based systems: Designing interpretable genetic fuzzy systems. *International Journal of Approximate Reasoning*, *52*(6), 894-913.

Feng, Z., Liu, C., Guan, X., & Mor, V. (2012). China's rapidly aging population creates policy challenges in shaping a viable long-term care system. *Health Affairs*, *31*(12), 2764-2773.

Gao, Y., Li, H., & Luo, Y. (2015). An empirical study of wearable technology acceptance in healthcare. *Industrial Management & Data Systems*, *115*(9), 1704-1723.

Gu, D., Liang, C., & Zhao, H. (2017). A case-based reasoning system based on weighted heterogeneous value distance metric for breast cancer diagnosis. *Artificial intelligence in medicine*, *77*, 31-47.

Havig, A. K., Skogstad, A., Kjekshus, L. E., & Romøren, T. I. (2011). Leadership, staffing and quality of care in nursing homes. *BMC Health Services Research*, *11*(1), 327.

He, A., & Chou, K. (2017). Long-term care service needs and planning for the future: A study of middle-aged and older adults in Hong Kong. *Ageing and Society,* 1-33. doi:10.1017/S0144686X17000824

Holzinger, A., Röcker, C., & Ziefle, M. (2015). From smart health to smart hospitals. In *Smart health* (pp. 1-20). Springer, Cham.

Hussain, A., Wenbi, R., Xiaosong, Z., Hongyang, W., & da Silva, A. L. (2016). Personal home healthcare system for the cardiac patient of smart city using fuzzy logic. *Journal of Advances in Information Technology Vol*, *7*(1).

Iqbal, S., Tong, Z., & Razzaq, S. (2017). Novel Healthcare Solution for Smart Hospitals: A Qualitative Review. *Biomedical Letters*, *3*(2), 99-106.

Islam, S. R., Kwak, D., Kabir, M. H., Hossain, M., & Kwak, K. S. (2015). The internet of things for health care: a comprehensive survey. *IEEE Access*, *3*, 678-708.

Kolodner J. (1993). *Case-based reasoning*. Morgan Kaufmann, San Mateo

Kruse, C. S., Mileski, M., Alaytsev, V., Carol, E., & Williams, A. (2015). Adoption factors associated with electronic health record among long-term care facilities: a systematic review. *BMJ open*, *5*(1), e006615.

Kuo, M. H., Wang, S. L., & Chen, W. T. (2016). Using information and mobile technology improved elderly home care services. *Health Policy and Technology*, *5*(2), 131-142.

Lehning, A. J., & Austin, M. J. (2010). Long-term care in the United States: Policy themes and promising practices. *Journal of Gerontological Social Work*, *53*(1), 43-63.

Liu, R., Xie, X., Augusto, V., & Rodriguez, C. (2013). Heuristic algorithms for a vehicle routing problem with simultaneous delivery and pickup and time windows in home health care. European Journal of Operational Research, 230(3), 475-486.

Lupo, T. (2016). A fuzzy framework to evaluate service quality in the healthcare industry: An empirical case of public hospital service evaluation in Sicily. *Applied Soft Computing*, *40*, 468-478.

Mariani, E., Chattat, R., Vernooij-Dassen, M., Koopmans, R., & Engels, Y. (2017). Care Plan Improvement in Nursing Homes: An Integrative Review. *Journal of Alzheimer's Disease*, *55*(4), 1621-1638.

Marling, C., Montani, S., Bichindaritz, I., & Funk, P. (2014). Synergistic case-based reasoning in medical domains. *Expert systems with applications*, *41*(2), 249-259.

Medjahed, H., Istrate, D., Boudy, J., & Dorizzi, B. (2009). Human activities of daily living recognition using fuzzy logic for elderly home monitoring. In *2009 IEEE International Conference on Fuzzy Systems* (pp. 2001-2006). IEEE.

Ministry of Health and Welfare. (2016). Taiwan health and welfare report. Retrived from http://www.mohw.gov.tw/fp-137-521-2.html

Mishra, D., Gunasekaran, A., Childe, S. J., Papadopoulos, T., Dubey, R., & Wamba, S. (2016). Vision, applications and future challenges of Internet of Things: A bibliometric study of the recent literature. *Industrial Management & Data Systems*, *116*(7), 1331-1355.

Mshali, H., Lemlouma, T., & Magoni, D. (2018). Adaptive monitoring system for e-health smart homes. Pervasive and Mobile Computing, 43, 1-19.

Petrovic, S., Khussainova, G., & Jagannathan, R. (2016). Knowledge-light adaptation approaches in case-based reasoning for radiotherapy treatment planning. *Artificial intelligence in medicine*, *68*, 17-28.

Prentzas, J., & Hatzilygeroudis, I. (2016). Assessment of life insurance applications: an approach integrating neuro-symbolic rule-based with case-based reasoning. *Expert Systems*, 33(2), 145-160.

Shen, X. L., Li, Y. J., & Sun, Y. (2018). Wearable health information systems intermittent discontinuance: A revised expectation-disconfirmation model. Industrial Management & Data Systems, 118(3), 506-523.

Shin, D., & Hwang, Y. (2017). Integrated acceptance and sustainability evaluation of Internet of Medical Things: A dual-level analysis. *Internet Research*, *27*(5), 1227-1254.

Sood, S. K., & Mahajan, I. (2017). Wearable IoT sensor based healthcare system for identifying and controlling chikungunya virus. *Computers in Industry*, *91*, 33-44.

Tu, M., Lim, M. K., & Yang, M. F. (2018). IoT-based production logistics and supply chain system–Part 1: Modeling IoT-based manufacturing supply chain. *Industrial Management & Data Systems*, *118*(1), 65-95.

United Nations (2017) World population ageing 2017 - Highlights. United Nations, New York

Veiga, N., Couto, P., Fernandes, A., Oliveira, A., Gomes, D., Santos, D., Amaral, O., Pereira, C., Pereira, P., & Coelho, I. (2018). The influence of population aging in Public Health. *International Research Journal of Public Health*, *2*.

Verleye, K., Gemmel, P., & Rangarajan, D. (2014). Managing engagement behaviors in a network of customers and stakeholders: Evidence from the nursing home sector. *Journal of Service Research*, *17*(1), 68-84.

Wang, W. M., Cheung, C. F., Lee, W. B., & Kwok, S. K. (2007). Knowledge-based treatment planning for adolescent early intervention of mental healthcare: a hybrid case-based reasoning approach. *Expert Systems*, *24*(4), 232-251.

Wideman, M. (2012). Geriatric care management: role, need, and benefits. *Home Healthcare Now*, *30*(9), 553-559.

Wong, B., Ho, G. T., & Tsui, E. (2017). Development of an intelligent e-healthcare system for the domestic care industry. *Industrial Management & Data Systems*, *117*(7), 1426-1445.

Xu, X., He, W., Yin, P., Xu, X., Wang, Y., & Zhang, H. (2016). Business network information ecological chain: A new tool for building ecological business environment in IoT era. *Internet Research*, *26*(2), 446-459.

Yan, A., Yu, H., & Wang, D. (2017). Case-based reasoning classifier based on learning pseudo metric retrieval. *Expert Systems with Applications*, *89*, 91-98.

Zimmerman, S., Shier, V., & Saliba, D. (2014). Transforming nursing home culture: evidence for practice and policy. *The Gerontologist*, 54 (Suppl 1), S1-S5