Home Healthcare Matching Service System Using IoT

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Abstract. Home healthcare services enable patients to live in an environment and amongst people they are familiar with while receiving the healthcare they need. However, to provide such an arrangement, readings from healthcare devices need to be read and analyzed on a regular basis to determine healthcare services needed by patients. Then the services that are needed are matched with a limited number of healthcare professionals capable of providing the services needed. In this paper, we present a system we developed to that is capable of meeting the above requirements, but in a manner that enables patients to feel they are in charge of their healthcare while meeting licensing requirements, legal requirements, and travel schedule restrictions of professional healthcare personnel.

Keywords: Home healthcare · Personnel matching

1 Introduction

Home healthcare involves licensed healthcare professionals providing medical treatment or rehabilitation care to patients in their homes [4]. Such arrangements enable patients to live a quality life, in an environment in which they are familiar and comfortable with [2], and amongst friends and family members. It also reduces the burden of on overcrowded healthcare facilities. However, when patients are residing in their homes as opposed to healthcare facilities, healthcare professionals cannot personally monitor the health status of patients as closely as those residing in healthcare facilities normally do. The emergence of IoT technologies enables us to overcome this gap.

IoT enabled healthcare devices is a new category of devices that can transfer readings directly into information systems via communication devices without direct involvement of health professionals. This key factor makes home health care economically viable, the eliminating the need for frequent periodic visits by healthcare professionals to homes of patients just to record the readings of healthcare devices.

Many offsite systems are already available to receive and process the data received from healthcare devices. However, these systems are typically operation at one of the two following extremes. At one extreme, systems provide graphical analysis of the health data received and may suggest patients to seek healthcare if the results of the

readings indicate such need. However, patients need to seek proper healthcare services on their own without detailed guidance. At the other extreme, the devices transfers the health data to healthcare institutions directly, if necessary healthcare personnel will contact patients and provide them with instructions on actions that are to follow. The problem with the first extreme is that these systems leave patients on their own to seek proper healthcare services based on the analysis of healthcare data. This may be challenging for many home care patients, especially those suffering from reduced mental capacity. The latter extreme completely bypasses the patient and gives healthcare providers control of the process. Many systems also lack the ability to aggregate the health readings from multiple devices and provide a comprehensive analysis.

To overcome these limitations, we developed a cloud based home healthcare service that directs patients to receive healthcare services from proper medical personnel licensed to perform the service while letting patients remain in control of the healthcare process.

2   Cloud-Based Home Healthcare Service

In this section we describe the cloud based home healthcare service that we developed. We will provide a general description of its operation, and then technical details of each phrase in the operation. Finally, we will provide a detailed use case to further illustrate the operation of the system.

2.1   General Description of Operations

To participate in the cloud based home healthcare service (the cloud), each patient will need to download an app onto his or her smart mobile phone to act as a window of communication with the patient (Fig. 1). Each patient will have supported IoT healthcare devices that connect to the app on the smart mobile phone via Bluetooth Low Energy (BLE). The smart mobile phone should have at least a 3G or higher mobile connection to ensure normal operations. The mobile app relays the data received to the cloud based healthcare service. In addition, the mobile app receives information from the cloud that requires the attention of the patient. Such information include alerts of malfunctioning devices, health situations that warrant attention, and responses to requests for home healthcare services. The patent can also use the mobile app the submit request for home healthcare services.

A patent participating in the cloud based home care service will need to pair each of his or her IoT enabled healthcare devices, such as wearable diabetic glucose patches, heartrate sensors, and pacemaker monitors via the Bluetooth Low Energy (BLE) to the mobile app. The cloud will receive period data readings from these pair devices and issue alerts to the mobile app if updated data readings discontinues for a certain amount of time. The mobile app will then notify the patient of such irregularity. The cloud will also provide updated concise health reports to the patient via the mobile app. If the results of a health report warrant the need for attention from healthcare professionals, the mobile app will notify the patient of the type of healthcare service recommended

and offer assistance in scheduling a visit from a healthcare professional with the appropriate license to address the health issue. If the patient accepts the recommendation, the patient will need to enter times he or she is available to receive home healthcare service. The mobile app will relay the request along with the time availability back to the cloud. After receiving the request, the cloud will then attempt to schedule a healthcare professional to visit the patient at the time requested. The cloud will take into consideration factors such as the work hour preferences, licensed specializations of healthcare professionals, travel routes from previous scheduled visit, language requirements of patients, and legal restrictions when scheduling the new visit. The mobile app will notify the patient as to whether his or her request for healthcare service is successful. If the scheduling request is successful, a notification will be sent to the patient to notify him or her that the appointment with the healthcare professional. In cases where the scheduling request have failed, a notification is sent to the patient indicating the failure to schedule an appointment with the healthcare professional.
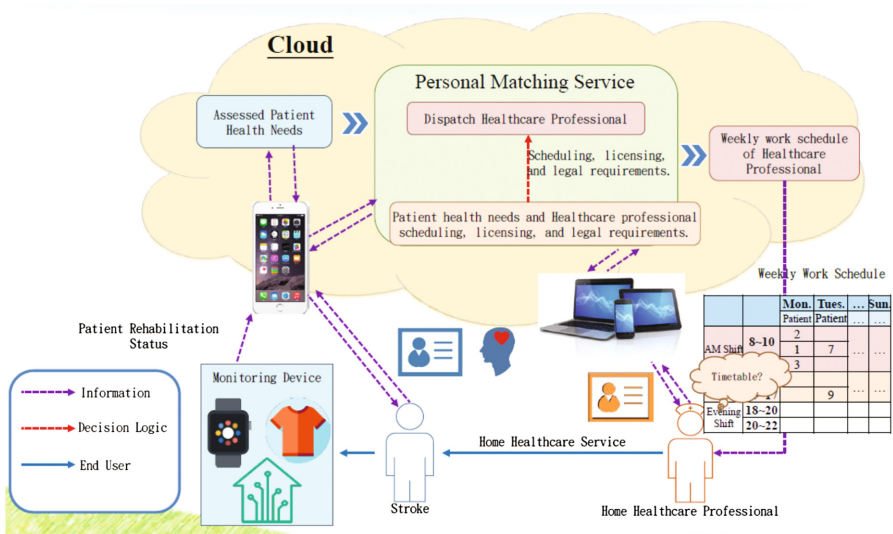

Fig. 1. Operational overview of home healthcare matching service

The matching of health needs of patents and healthcare professionals is achieved by applying the Analytic Hierarchy Process (AHP) [6] and Taguchi Loss Function [5] to select personnel capable of meeting the licensing requirements. Then we apply Genetic Algorithm (GA) [1] to the shortlisted personnel to generate a list of qualified healthcare professionals that are available to perform the necessary services while meeting the legal requirements that determine the maximum hours for each day and the arrangement of workdays. Then the Variable Neighborhood Search (VNS) [3] is applied to analyze the travel routes of qualified healthcare professionals to ensure that the

healthcare professional selected to perform the service is capable of traveling to the home of the patient in need from their previous assignment within the time preferences of the patient. In addition, it also ensures the healthcare professional is capable of traveling [7] to the next scheduled assignment on time (that was previously determined and scheduled).

2.2   Mobile App

The mobile app runs on an Android 6.0 based mobile phone. Notification services on the mobile phone are used by the mobile app to alert patients their attention to the app is needed. The mobile phone supports Bluetooth 4.0 so that the Bluetooth Low Energy (BLE) protocol is used to communicate with the IoT healthcare devices. Communication with the cloud is conducted via mobile networks. To ensure smooth performance, a 3G or 4G mobile data connection on the patent's mobile phone is needed to ensure smooth communications with the cloud.

2.3   The Cloud

The cloud is the key component of the Home Healthcare Service. It is responsible discovering service "needs" based on heath device readings from the mobile app and then using logic derived from the Outcome and Assessment Information Set (OASIS) [8] developed and maintained by the Centers for Medicare & Medicaid Services of the United States Department of Health and Human Services. If the patient accepts the "needs" that are recommended, the cloud will attempt to schedule a qualified healthcare professional to visit the patient at time preferences designated by the patient.

The cloud not only needs to ensure the healthcare professional is licensed to perform the qualified tasks, but also the timetable generated for the healthcare professional meets licensing requirements and legal labor requirements as shown below in Tables 1 and 2 respectively.

Table 1.   Licensing requirements

#	Licensed tasks
1	General health and wound treatment
2	Insertion and removal of urinary catheter, tracheostomy, and nasogastric tube
3	Operation of urinary catheter, tracheostomy, and nasogastric tube
4	Bladder and intestine irrigation. Bladder training. Collection of urine and stool specimen
5	Rehabilitation care. Sanitary education. Nutrition care
6	Personal care for severely handicapped persons. (Such as dressing, bathing, etc.)
7	Lite housekeeping and meal delivery service

Table 2. Legal Requirements

#	Description of legal requirement
1	Minimum work hours (per month)
2	No more than 8 working hours per day
3	Consists of 2 or more consecutive workdays
4	Consists of 6 or less consecutive workdays

The matching of health needs of patents and healthcare professionals is achieved by first applying the Analytic Hierarchy Process (AHP) to the healthcare requirements and as patient preferences to determine the weight of variables used to select personnel capable of meeting the licensing requirements and satisfying patient preferences. If these requirements and patient preferences include quantitative variables, we apply the Taguchi Loss Function to analyze the quantitative variables. A list of personnel with an acceptable matching score meets licensing requirements. Figure 2 displays a graphic presentation of this process.
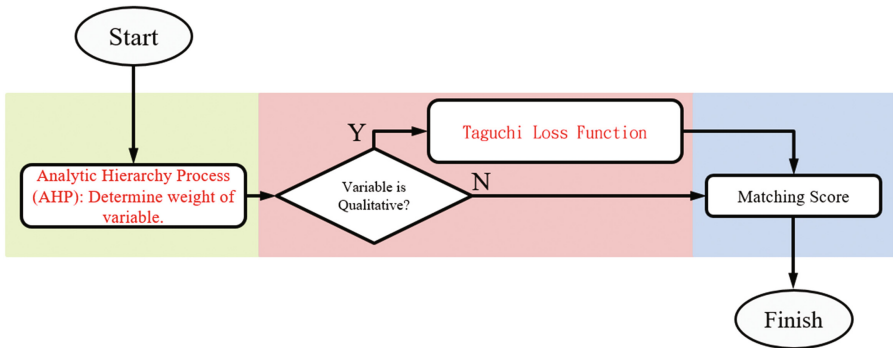
Fig. 2. Process to generate the matching score

Then we apply Genetic Algorithm (GA) (see Fig. 3) to the shortlisted personnel to generate a list of qualified healthcare professionals that are available to perform the necessary services while meeting the legal requirements that determine the maximum hours for each day and the arrangement of workdays.

Next, the Variable Neighborhood Search (VNS) is applied to analyze the travel routes of qualified healthcare professionals to ensure that the healthcare professional selected to perform the service is capable of traveling to the home of the patient in need from their previous assignment within the time preferences of the patient. In addition, it also ensures the healthcare professional is capable of traveling to the next scheduled assignment on time (that was previously determined and scheduled).
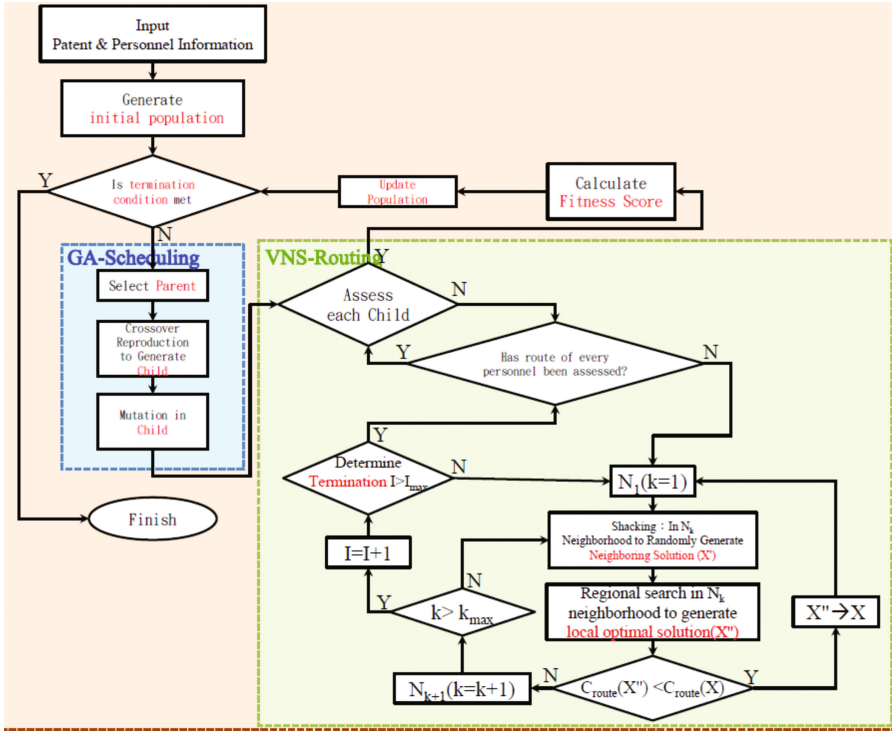
Fig. 3. Applying GA-scheduling and VNS routing to generate personnel match

3   Results and Discussion

In this paper, we demonstrate our service as deployed meets the labor regulations that apply to healthcare personnel. Furthermore, it also schedules healthcare personnel to service locations that can be traveled to in the time allocated. This is critical for actual deployment.

One area in which our service can be improved is the selection of least-cost option when multiple personnel meets all the requirements. Healthcare personnel are usually licensed to perform multiple tasks, however, some are licensed in more categories than others. When assigning personnel to a patient, it would be useful assign the personnel with the least additional licensed categories whenever possible, so that personnel with more additional licensed categories can be saved for future home patient requests, thus reducing the probability not being able to satisfy homecare patent requests in the upcoming days.

4   Conclusion

The Home Healthcare Matching Service demonstrates the feasibility of utilizing IoT healthcare devices in the home to monitor and provide homecare service suggestions that enable patients to be in control. It also successfully addresses another difficult question, which is delivering the actual service to the home of patents. Not only are there logistical limitations, mainly traveling to the homes as scheduled, but also licensing regulations that limit the tasks that each personnel can perform as well as labor regulations on the workhours and days personnel are able to work. These overcoming logistics limitations and complying with regulations is critical deploying such service to home healthcare patients.

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