Development of Service Systems to Support Diabetes Patient Self-management Using a Personalized Service Framework

Marut Buranarach, Nattanun Thatphithakkul, Asanee Kawtrakul
National Electronics and Computer Technology Center (NECTEC), Thailand Science Park
Pathumthani, Thailand 12120
e-mail: {marut.bur, nattanun.tha}@nectec.or.th

Suwaree Wongrochananan, Nittayawan Kulnawan, Wiroj Jiamjarasrangsi
Faculty of Medicine, Chulalongkorn University, King Chulalongkorn Memorial Hospital
Bangkok, Thailand 10330
e-mail: wjiamja@gmail.com

Abstract—Patient self-management is an important component in improving quality of chronic disease healthcare. The promising benefits of the Interactive Behavior Change Technology (IBCT) on diabetes patient self-management are increasingly recognized. In this paper, we describe a service framework and two service systems designed to support self-care activities among type-2 diabetes patients: an automated telephone disease management (ATDM) service and a patient self-management support portal. In chronic disease healthcare, enhancing patients’ self-management can lead to enhancing user-co-creation and participation in the service system. The services to support patients’ self-management must also focus on user customization, i.e. personalization, of the services. We describe a personalized service framework that coordinates the related data, knowledge, interactions and personalized services in facilitating patients’ self-care. Finally, we discuss potentials of the proposed service systems to provide supplements and add-values to conventional healthcare service.

Keywords: Personalization, Interactive Behavior Change Technology, Healthcare Service Innovation, Value Co-creation

I. INTRODUCTION

Diabetes is a worldwide burden; its prevalence is expected to rise to 366 million by 2030 [1]. Diabetes is a chronic disease which requires special attention both from healthcare providers and patients. Its treatment procedure is typically complicated and requires a lot of interactions between medical personnel and patients. However, due to the limited number of medical personnel and the increasing number of patients, the time and attention that the medical personnel can spend with each patient becomes less and less. From a last year statistics, the average time that a Thai diabetes patient has met with doctor was less than 24 hours, which was clearly insufficient. Further, most diabetes patients are elderly people and working people who cannot conveniently travel to meet with their doctors regularly.

In alleviating the problems, we propose uses of specialized technology to support self-management activities for diabetes patients. Supplement to conventional healthcare, the services are designed to imitate virtual home visits to the patients using telephone and internet. They offer added services that are important for the patients especially while they are waiting for next visits to their doctors. The services aim to achieve four major goals. First is to assess patient's self-care. Second is to provide personalized recommendation. Third is to encourage and remind patient's self-care activities, such as exercises. Fourth is to screen and monitor for some patient's critical conditions, such as medication overdose, disease complications, which require immediate intervention.

In this paper, we describe a service framework and service systems designed to support self-care activities among type-2 diabetes patients. The service framework consists of four layers: data, knowledge, interaction and personalized service models. We describe development of two service systems that coordinated the related data, knowledge and interaction in providing personalized services for the patients. The first service system involves an automated telephone disease management service. The second service system involves a patient self-management support portal. Finally, we discuss potentials of the proposed service systems to provide supplements and add-values to conventional healthcare service.

II. BACKGROUND

A. Chronic Care Model

The Chronic Care Model (CCM) is a guide to higher-quality chronic illness management in patient care [2]. The model recommends that improving six interrelated components -- self-management support, clinical information system, delivery system redesign, decision support, healthcare organization, and community resources -- can result in a more effective system in chronic care management. These components aim at producing more informed and knowledgeable patients and healthcare providers. This can result in more productive interactions between them and thus can potentially improve the quality of care and outcomes.

Self-management support is the component which focuses on encouraging patients to be knowledgeable about their illness and to be able to sufficiently look after themselves. Some key elements to this achievement include knowledge, motivation, self-efficacy, goal-setting, action planning and problem-solving.
B. Self-management Support for Diabetes Patients

Diabetes patients’ daily lives are generally known to have a great impact on the patients’ health. It is advocated that diabetes must be principally managed by the patient on a day-to-day basis such as dietary habits (e.g., size and timing of meals, carbohydrate and saturated fat intake), increase in exercise (e.g. walking), intake of medications (correct dosage and timing as well as consistency over time), and monitoring of blood sugar levels, blood pressure, blood lipids, feet, and eyes. Unfortunately, self-management support occurs inconsistently during outpatient visits [3].

Effective diabetes self-management support requires a complex series of assessments and instructions. As a result, patients often require additional support and communication outside of the traditional clinician visit [3]. Further, the information provided for patients received should take into account each patient’s distinctive life circumstances. Thus, providing services aimed at achieving health-related behavior change is challenging and often requires the time, knowledge and skills.

C. Interactive Behavior Change Technology

The Interactive Behavior Change Technology (IBCT) can be used to address and support diabetes self-management [4]. Some support technologies include the Internet, CD-ROMs and DVDs, and telephone-based systems such as interactive voice responder (IVR), also known as automated telephone disease management, personal digital assistants (PDAs) or other handheld devices. In general, IBCT assists both patients and health care providers in monitoring changes in self-care needs. It also supports patients’ efforts to make behavior changes by promoting health and effective self-care. In addition, it can enhance communication between patients and potential supporters for their disease management.

IBCT increases patients’ access to the types of services available from their health care team. The 5A’s model [5] addresses the roles of IBCT in behavior change interventions. The 5A’s model includes assess – obtain data on behaviors and preferences, advise – recommend changes tied to patient lab results and values, agree – set goals collaboratively with patient, assist – identify barriers and develop action plan, and arrange – provide follow-up support and resources. The benefits of IBCT can be assessed based on the 5A’s model. For example, IVR can be useful to assess and arrange due to high availability of phone access comparing to a web site. However, a web site can be more useful to assess, advise, agree and assist due to its higher interactivity.

IBCTs include the use of hardware and software to promote and sustain behavior changes [5]. Examples include the use of PDAs, patient-centered Web sites, automated telephone calls, DVDs, and touch-screen kiosks. In general, these tools 1) assist patients and their clinicians in monitoring changes in health and self-care needs, 2) support patients' efforts to make behavior changes by promoting health and effective self-care, and 3) enhance communication between patients and potential supporters for their disease management.

Other technologies such as physician-targeted clinical decision aids, electronic medical records, and disease registries can also support higher-quality diabetes care. However, these tools are usually considered separately from IBCT because they provide information solely to the clinician and represent a more passive data processing approach rather than a proactive effort to change behaviors.

D. Service and Service System

The service paradigm focuses on customization, customer relationships, service focusing, marketing to individual customers and improved information processing [6]. Service is co-creation of value between the customer and the provider. Quality is a measure of value from a customer stakeholder perspective, and productivity is a measure of value from a provider stakeholder perspective [7]. Thus, one of the challenges is to increase value co-creation outcomes of customer and provider interactions. Digital Connections Scaling (DCS) studies how the digital means may increase in the value outcomes [7]. The model proposes that digitization reduces the time and the transaction cost of service co-creation, improves service quality and productivity, and ultimately enhances the utility of service to the customer and the profit of service to the provider.

A service system made up of its entities: customer, service provider, and service experience [8]. The unified services theory [9] emphasizes that, in the service model, the customer provides significant inputs into the production process. The customer-input involvement distinguishes the service model from the non-service model, where customer mostly involves in consuming the output. Thus, a service system is distinguished from other types of systems by the fact that the customer may be actively involved in all nine classes [10]: customer, goals, input, output, process, human enabler (as a resource in the process), physical enabler (providing a resource to the process), informatic enabler (applying knowledge to the process) and environment.

One major goal of developing science of service systems is to provide a foundation for creating and promoting service innovation [11, 12]. Service innovations have the potential to impact service productivity, service quality, and rates of growth and return for service systems [13]. In this paper, we advocate that digitization, user co-creation and personalization must be combined into service systems in order to promote service innovation and usefulness. In chronic disease healthcare, enhancing patients’ self-management can lead to enhancing user-co-creation and participation in the service system. In addition, the services provided to the patients must be scalable to support a wide range of patients who differ in their illness, profiles and preferences. Thus, the proposed services to support patients’ self-management must also focus on user customization, i.e. user personalization, of the services.

III. FRAMEWORK

A. A Personalized Service Framework

Although there are many diabetes self-management websites, few sites offered interactive assessments, social
support or problem-solving assistance [14]. It was suggested that the helpfulness and interactivity of these resources should be improved. One example of interactive diabetes patient portal was developed that linked to an existing electronic medical record system [15]. The portal also provided patients with personal log and calculator for diabetes control, scheduling system and reminder, communications with the provider and other patients, and educational materials, and self-management resources.

Our service model consists of five major personalized services: self-regulation, self-monitoring and assessment, social support, virtual home visit and reminder. Self-regulation [16] is used as a dynamic motivational system of setting goals and developing strategies to achieve these goals. In self-monitoring and assessment, personal log, graphs and calculators are provided to estimate the patient’s diabetes control. The social support function gives the patients opportunities to communicate with other patients with similar concerns or interests. Virtual home visits and reminders are system-initiated contact sessions, e.g. phone-based questionnaires and SMS alerts.

Self-regulation is used as a dynamic motivational system of setting goals, developing and enacting strategies to achieve these goals, appraising progress, and revising goals, developing and enacting strategies accordingly. Thus, this service provides interactive tools for setting reasonable and realistic goals, barriers and strategies as well as provides related knowledge for some selected strategies to encourage the user behavior change.

Self-monitoring and assessment of blood sugar levels, blood pressure, blood lipids, feet, and eyes are very necessary for further assessment and recommendation related to the patients’ diets.

Our conceptual framework of the personalized service approach is shown in a layered architecture in Figure 1. The layered architecture composes of data, knowledge, interaction and process support, collaboration and personalization. Each layer is briefly described in the following sub-sections.

### B. Data Model

The data model layer focuses on storing the patient profile, clinical and activity data. Patient clinical data such as hospital-based and lab test data can be obtained from the patient clinical data records. Patient daily activity data are recorded to allow monitoring, assessing and recommending based on the patient’s behavior. The patients can enter their activity measurement obtained from some measuring devices such as a step counter device, i.e. pedometer, minutes and calories measured by exercising machines as well as creating their meal records. Food and nutrition databases are necessary for further assessment and recommendation related to the patients’ diets.

### C. Knowledge Model

The knowledge model layer focuses on acquiring and modeling knowledge required for patient’s self-management. Such knowledge includes food and nutrition needs for the patients with different age, gender and their illness condition as well as their diet preference. Medical guidelines such as the clinical practice guideline (CPG) provides the knowledge related to recommended follow-up examinations, life style modifications and medications (correct dosage and timing) etc. The clinical guideline knowledge captured into machine-processing form, such as ontology, will allow such knowledge to be applied to the data. In addition, diabetes patients often need friends to share and discuss their experiences. Community resources are important for the patients to motivate their behavior change. Educators can discuss with the patients to provide suggestions, and answer questions both in synchronous and asynchronous modes. Analytical processing of user activity data, e.g. user behavior analysis, can be applied to improve recommendation results. Further, recommendations that are provided based on the user’s selected goals, barriers and strategies can help to encourage the user behavior change.

### D. Interaction Model

IBCT usually relies on the following modalities: Website, E-mail, CD-ROM, PDA and IVR. Each has different advantages and disadvantages according to IBCT 5A’s dimension [5]. Thus, combining these modalities can complement each other in assisting the patient self-management care. Interaction with the patients via IVR focuses on dialogue management. Dialogue management must take into account the patient profile, clinical and activity data, and medical knowledge. In generating new questions, the patient’s previous answers and profiles should be taken into accounts. This will allow dynamic and personalized question generations that imitate human conversations. Interactive website should also be accessible by mobile devices which will allow the patient to conveniently input their daily activity data. Mobile sensors, such as pedometers, calorie burned meters, may be attached to the patient, e.g. to track the patient daily calories burned.

### E. Personalized Service Model

In our project, we adopt a personalized service approach which focuses on providing the patient’s self-management process support, collaboration and personalization. A conceptual framework of the personalized service approach is shown in a layered architecture in Figure 1. The layered architecture composes of data, knowledge, interaction and personalized service models. Each layer is briefly described in the following sub-sections.

![Figure 1. Layered architecture of a personalized service framework for patient self-management support](image-url)
important for diabetes patient. Personal logs, graphs and calculators should be provided for the patient to estimate his or her diabetes control.

Social support has been found to be a relevant factor in diabetes self-management. The social support function gives the patients opportunities to communicate with other patients with similar concerns or interests. The patients can utilize asynchronous communications, e.g. bulletin board, personal/group mailboxes, to report their motivational behavior, calorie counting and physical activity. In addition, synchronous communications such as instant messaging or live chat systems can be utilized for more interactive conversations.

In contrast to patient-initiated login sessions, virtual home visits and reminders are system-initiated contact sessions. The virtual home visits are basically phone-based questionnaires supported by an IVR system. The system weekly contacts the patients based on the patients’ chosen schedules. Each week the system will call and ask the questions related to the patients’ past week diets, activities and medication intakes, e.g. dosages, timing and consistency. One of the main purposes is to screen for some events which would require some urgent attentions. For example, when the patient felt depressed or had not taken medications properly for some times, the system will notify the educators to promptly contact and talk to the patient.

The reminders, i.e. using SMS and/or e-mails, may be activated for several purposes. First is to remind and encourage the patient to logon to the system at some specified periods. Second is to remind and encourage the patient to perform tasks according to the action plan, e.g. records his or her weight, exercises, etc.

In the following sections, we describe development of two service systems that exemplified the framework adoption. Section 4 describes an automated telephone disease management service. Section 5 describes a personalized patient self-management support portal.

IV. AUTOMATED TELEPHONE DISEASE MANAGEMENT SERVICE

Telephone care programs are available strategies for bringing diabetes management services into patients’ homes and improving their glycemic control [17, 18]. Automated telephone disease management (ATDM) systems can augment telephone care by providing frequent monitoring and health education to large patient panels while allowing clinicians to focus attention on individuals who need it most. ATDM systems use specialized technology to deliver messages and collect information from patients using either their telephone’s touch-tone keypad or voice-recognition software. Findings from multiple studies indicate that chronically ill patients will participate in ATDM and that the information they report during ATDM assessments is at least as reliable as information obtained via structured clinical interviews or medical record reviews [19-21]. In some cases, patients are more inclined to report health problems during an automated assessment than directly to a clinician [22].

In this section, we describe design and interactions of an ATDM service prototype that supports diabetes patient self-care activities.

A. Design of Service System

The system architecture of an ATDM service prototype is shown in Figure 2. The six core components of the service are briefly described as follows.

1) Automated Call Management Module

This module involves setting up and configuring an IVR system. It initiates and manages outgoing call sessions made to each patient. The status of each call is logged whether a phone conversation session has been terminated successfully or hung up prematurely. The information will help the call sessions to be reattempted in gathering the required information. The module also manages user authentication mechanism using phone number-password verification.

2) Call Scheduling Module

This module manages the patient-defined call schedules. The patient can interactively specify the timeslots that he or she intends to receive the phone calls each week as shown in Figure 3. The patient can define timeslots for three types of phone calls: questionnaire (Q/A), system recommendation (SG) and self-learning knowledge resources (KM). The module also helps to identify whether the timeslots are available for the patient to select, i.e. all phone lines are occupied (red) or some phone lines are occupied (yellow). The patient can define alternate timeslots that will be used when the call attempts failed during the intent timeslots.

3) Dialog Management Module

This module manages the system dialogs and interactions between the patient and the service. The service utilizes Vaja1, a Thai text-to-speech software, in synthesizing audio clips from a dialog corpus. The interaction model is created based on the patient’s clinical data, profiles, and medical knowledge.

4) Data and Content Management Module

This module allows the educator to manage knowledge resources and recommendations that will be provided to the patients. It also manages the patient profile and clinical data.

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1 http://www.hlt.nectec.or.th/speech/
Further, the computer-generated audio clips can be overwritten with human-recorded voices to enhance naturalness of some dialogs.

5) Patient Monitoring and Report Generation Modules

The patient monitoring module allows the educator to remotely monitor the patients. After the patient has finished answering a questionnaire, the data is reported to the responsible medical personnel. The reports are shown in different colors according to the patient health status. For example, in Figure 4, the report for a patient is shown in red alert because there was a patient critical condition, such as medication overdose, disease complication, etc. In this case, the educator will immediately contact the patient. The patient report generation module allows the information collected from the patient to be used as hospital-based records.

<table>
<thead>
<tr>
<th>Service Dialog</th>
<th>Patient Dialog</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Welcome to the diabetes patient self-management support project.&quot;</td>
<td></td>
</tr>
<tr>
<td>&quot;Please enter your password.&quot;</td>
<td>[password]</td>
</tr>
<tr>
<td>&quot;Please answer the following questions. Your answer will help us to better support your diabetes control.&quot;</td>
<td></td>
</tr>
<tr>
<td>&quot;If you are ready for conversation, please press &quot;1&quot;. If not, please press &quot;2&quot;.&quot;</td>
<td>1</td>
</tr>
<tr>
<td>&quot;In the past 2 weeks, did you feel any chest pain or breathing difficulty? No symptom, press &quot;1&quot;. Yes in small degree, press &quot;2&quot;. Yes in high degree, press &quot;3&quot;.&quot;</td>
<td>3</td>
</tr>
<tr>
<td>&quot;When experience this symptom, you should rest and see your doctor as soon as possible.&quot;</td>
<td></td>
</tr>
<tr>
<td>&quot;In the past 7 days, did you often feel thirsty or frequent urination for more than 2 consecutive days? No, press &quot;1&quot;. Yes, press &quot;2&quot;.&quot;</td>
<td>1</td>
</tr>
<tr>
<td>&quot;In the past 7 days, did your feet look darker or have any injury? Don't know, press &quot;1&quot;. No, press &quot;2&quot;. Yes, press &quot;3&quot;.&quot;</td>
<td>1</td>
</tr>
<tr>
<td>&quot;Thank you for answering the questionnaire. Your answers will be forwarded to your medical personnel. You may be contacted if your conditions require special advices or consultations.&quot;</td>
<td></td>
</tr>
<tr>
<td>[The educator is notified on his or her computer screen. The report for this patient is shown in red because there was an indication of a possible risk of heart attack. The educator promptly contacts the patient.]</td>
<td></td>
</tr>
</tbody>
</table>

V. PERSONALIZED PATIENT SELF-MANAGEMENT SUPPORT PORTAL

The self-regulation theory [16] is incorporated into the design of a personalized patient self-management support portal. The main mechanisms of self-regulation models are goal selection/setting, active goal pursuit, and goal attainment and maintenance [23]. They are applied as guideline to deliver tailored skills, encourage the patient to set personal goal, find individual’s barriers, plan to action, go on the plan, and maintain self-behavior. All these are stimulated by himself or herself (internal stimuli) and essential intervention of the portal (external stimuli) for increasing patients’ self-efficacy, which can subsequently influence the patient to behave on diabetic self-management regularly. Therefore, the portal intervention has features and options to support the user process. For example, once logging into the website, the patient meets a tailored welcome message, which include personal and summarized health data. Subsequently, the patient is provided with a set of goals, barriers, and strategies to reach achievement. The patient can then create action plan that can help him or her to accomplish the goals. In order to maintain improved
behavior, reminder mechanisms, such as SMS and email, are activated for encouragement. In addition, health information can be exchanged between health care providers and patients through the portal. The ultimate aim of the portal is to influence the patient to change his or her behaviors on diabetes self-management.

In this section, we describe design and interactions of a prototype of personalized patient self-management support portal that supports diabetes patient self-care activities.

A. Design of Service System

Designed functions of the portal can be grouped into five main services: providing self-regulation and management, self-monitoring and evaluation, social support, virtual home visit and reminder. In addition, the portal provides supported knowledge and tools related to the patient self-management. Some main functions of the portal prototype are summarized in Figure 5. The five support services are briefly described as follows.

1) Self-regulation and management

The patient can log on to the system and set his or her targets and plans. The patient can set targets such as food control, weight control, exercises, foot care, etc. After setting the targets, the system shows list of possible barriers that may prevent the patient to achieve the targets as shown in Figure 6. After the patient specifies his or her barriers, the system shows recommended strategies that the patient can adopt to overcome the barriers. Further, each recommended strategy is associated with the related knowledge resources. The patient can create daily action plan on his or her calendar as shown in Figure 7. This calendar is linked with the reminder service that can send email or SMS to notify and encourage the patient to follow his or her plan.

2) Self-monitoring and evaluation

The patient can create his or her health records such as weight, blood sugar level, blood pressure and lipid level. The patient can also record the daily activities, such as daily diets and exercise minutes. The system will provide supported calculation tools, e.g. food energy and exercise calories, and recommendations that help to support the patient self-care activities. The system can show personal and summarized health data to help the patient to monitor and assess his or her diabetes control performance. In addition, the patient can record and see reports of some major activities and milestones, e.g. changing targets, achieving the targets, visiting doctors, etc.

3) Social Support

Patient can communicate with other patients with similar concerns or interests. The patient can post his or her message on the discussion board or to other patients’ private mailboxes. The portal allows the patient to search for other patients in the system, e.g. based on patient profiles and performance records. In addition, patients with good performance records are automatically promoted as “heroes”, who would be more visible to other patients.

4) Reminder and Virtual Home Visit

SMS and e-mail are automatically activated to encourage and remind the patient to follow his or her action plan. In addition, the educator can monitor and review each patient’s record to assess the patient performance. The educator can communicate with each patient by e-mail, SMS or make phone calls to give personalized recommendation and advice for each patient.
B. Interactions in Service System

This section exemplifies interactions between the service provider and the consumer in this service system. Table 2 illustrates interactions between a diabetes patient and the service.

**TABLE II. EXAMPLE INTERACTIONS BETWEEN A DIABETES PATIENT AND THE SELF-MANAGEMENT SUPPORT PORTAL SERVICE.**

<table>
<thead>
<tr>
<th>Service Dialog</th>
<th>Patient Dialog</th>
</tr>
</thead>
</table>
| **“Hello. Your current assessment are:****
| - BMI: overweight**
| - Blood Sugar: increased”**
| Let me guide you to complete your tasks.** | **“Ok”** |
| **“You have not yet specified your target.**
| Do you want to define one?”** | **“Yes”** |
| **“Please choose your target.”** | **[Exercise at least 30mins/day, 5 days/week.]** |
| **“Please identify your barriers.”** | **[I have no time to go to fitness club. I work in office and rarely move away from my desk.]** |
| **“Please define your action plan for the coming week.”** | **[25-29 Oct 10 – bike to work. 25-29 Oct 10 – walk up the stairs instead of using elevator. 26 Oct 10 – record my weight.]** |
| **“Please record your personal data and past week activities.”** | **“Ok”** |
| **“Do you want to record your blood sugar level?”** | **“Yes” – [20 Oct 10 – FBS 160 mg/dl]** |
| **“Do you want to record your weight?”** | **“Yes” – [24 Oct 10 – Weight 80 Kg]** |
| **“Do you want to record your meal records?”** | **“Yes”**
| **[24 Oct 10 – breakfast – apple 1 item, bread 2 slices, orange juice 1 glass]**
| **[24 Oct 10 – lunch – pork fried rice 1 dish]**
| **[24 Oct 10 – dinner – chicken salad 2 dishes]** |
| **“Do you want to record your exercise activities?”** | **“Yes”**
| **[24 Oct 10 – walking – 30 minutes]**
| **[24 Oct 10 – gardening – 60 minutes]** |
| **“Thank you for sharing your information today. Here are your summary reports:**
| - Blood Sugar Report**
| - BMI Report**
| - Calories Balance Report**
| You may click “Ok” to use other parts of our website.” | **“Ok”**
| **[The patient can view his or her diabetes control performance and explore the related knowledge resources customized for the patient.]** |

VI. DISCUSSIONS

In this paper, we propose a personalized service framework designed for enhancing self-management support among patients with type-2 diabetes. We describe two service systems that adopted the framework. The service systems aimed at supplementing conventional healthcare service by offering added channels to healthcare service access. Nowadays, nearly anyone has a telephone, either home phone or mobile phone. The automated telephone disease management service is expected to be conveniently accessible to a large number of patients. Although many diabetes patients are elderly people who do not currently use Internet, the patient self-management support portal has many advantages, such as low operation cost and providing anywhere and anytime access for the patients. Further, increasingly more elderly people are using Internet while more young people have diabetes. Thus, this service has a potential to become more accessible for the patients in the near future.

The design of the two service systems relied on a personalized service framework that incorporated the related data, knowledge and interaction to support the provided services. The service framework aims at promoting user co-creation and service scalability by means of digitization and personalization. Our future works will focus on evaluation of the services and their utility and creating added-value services, e.g. recommending patient activities and diets based on the patient’s past activities and preference, etc. In addition, we aim to simplify the patient’s data input process, e.g. by incorporating automated acquisition of user data from mobile sensors and devices in preventing user’s errors from manual recording.

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