Recommendation Framework for Detecting Sedentary Behavior in Smart Home Environment

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***Abstract*—Sedentary behavior is lifestyle with no or irregular physical activity that is associated with poor health and increased risk of diseases. Effective techniques are necessary to avoid sedentary behavior and promote healthy habits. Existing physical activity recommendation systems provide recommendation based on user request. However, it is rather more natural to provide the recommendations on automatic detection of user situation. In this paper, we extended our previous work of recommendation service for chronic disease patients in multimodal sensors home environment. In this work, we enhance the framework to continuously monitor the sedentary situation of elderly in smart home environment and generate the alert/recommendation, whenever a sedentary behavior is detected. The recommendations are checked and verified by the care giver and take appropriate action in response to the system recommendation.**

I. Introduction

PHYSICAL activity improves a number of health issues, such as cardio-respiratory, muscular fitness, bone health, and reduced risk of diabetes [1] , general in all age groups, but specifically in elderly people. A physically inactive person, defined as sedentary, is the one that has either no physical activity or with irregular pattern or insufficient amount [2]. Research community defines the concept of inactivity or sedentary lifestyle from different perspectives, such as the activities with METs value less than 1.5 [3] or time spent in sitting or lying down, except sleeping [4] or lack of moderate to vigorous physical activity [3, 5]. Lack of physical activities adds to many preventable causes of death [6].

An individual that regularly follows physical activity guideline's recommendations, proposed by ACSM [7], CDC [8], UK [9], Canada [10] and AHA [1], but mostly live sedentary for long time, has high potentials of health risk. For example, people that sit more than 4 hours per day have 40 percent higher risk than those that sit fewer than 4 hours per day.

Proper interventions are required to reduce sedentary behaviors of elderly while they are in their home. Australian guidelines for sedentary behaviors recommend to minimize the amount of prolonged sitting and add more and more breaks to interrupt prolonged sitting. Elderly who frequently interrupt their sedentary time usually have better metabolic profile than those who stayed sedentary [11]. To avoid hazards and risky sedentary situations, smart homes environments with ubiquitous environment should be established with an automatic recommendation system.

To promote healthy lifestyle, research community needs to investigate factors required to influence elderly sedentary behaviors. To achieve this goal, we extended our previous work of recommendation service for chronic disease patients in multimodal sensors home environment to examine elderly daily physical activity routines and provides personalized well-being and health-care recommendation services [12]. These recommendations are generated by the Smart Clinical Decision Support System (CDSS). This paper is focused on how Smart CDSS can be used to induce elderly healthy habits and promote them to avoid sedentary situations. In this work, we enhance the framework to continuously monitor the sedentary situation of elderly in order to generate physical activity recommendations.

II. Recommendation Framework

In Figure 1, we have extended the business process flow of our previous work for generating recommendations for the chronic disease elderly patients in smart home environment [13]. This figure depicts different activity pools for all stakeholders that participate in different activities in the realization of the system. It contains five main pools, patient activities pool, physician setup pool, caregiver environment pool, home healthcare pool, and recommendation pool.

The system provides recommendations to the elderly patients based on their performed medication and non-medication activities. Therefore, the patient is considered as main subject and role of the system. The patient activities pool shows the business flow of patient about taking medication and share the status of the patient. The physician setup pool describes the two main activities that are performed by the physicians in the system. Firstly, the physicians transform their knowledge into the knowledge base of CDSS to generate recommendations and

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alerts to patients and nurses, and secondly the physicians monitor, validate and verify the recommendation by the system to the elderly patients.

The third important subject of the system is caregivers (nurses) that care the patients in smart home environment. The caregiver environment pool shows all the activities that are performed by caregivers. The caregivers find the patient's prescription, check the patient status and amalgamate with status provided by the system and update the new status accordingly. The caregivers share the new status with physicians for verification. According to the prescription approval from physician, the caregivers update the prescription, then complete the medication delivery and post it.

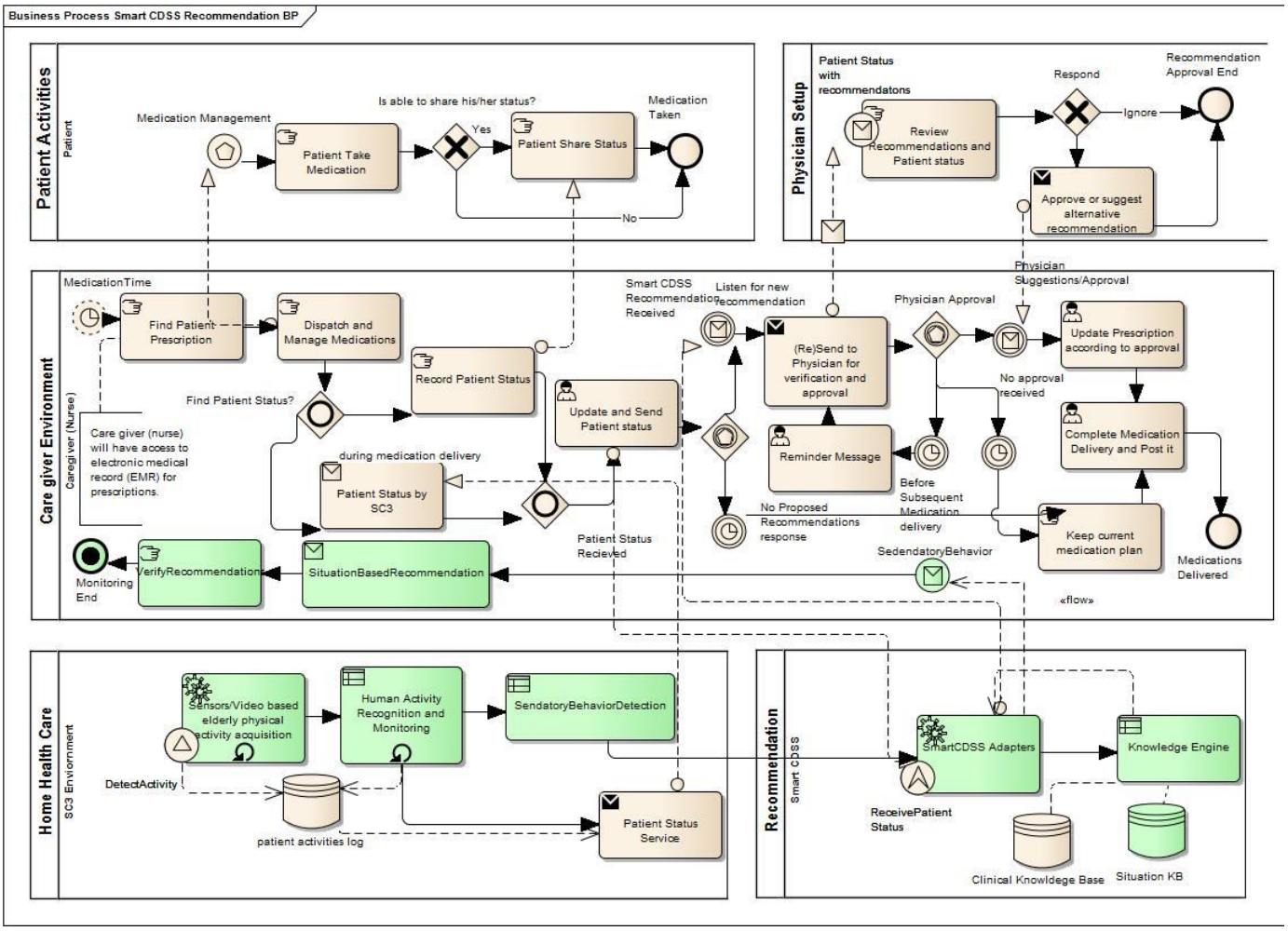

Fig. 1: Extension of Smart CDSS Framework for Detection of Sedentary Situations and Physical Activity Recommendation for Elderly

The home healthcare pool depicts the activities that are performed in the smart home environment based on multi-model sensors. The multi-model sensors acquire the information about patient's performed activities and it monitors and recognize the human behavior. Whenever some sedentary behavior of the patient is recognized then system generate alerts and recommendations to the patient, caregivers and physicians. Therefore the home healthcare pool performs three main activities like elderly patient's physical activity recognition, human activity recognition and monitoring and sedentary behavior detection.

In recommendation pool, the system generates the recommendation using Smart CDSS adapter. The reasoning environment of Smart CDSS fetches the appropriate recommendation rules by the knowledge engine from the clinical knowledge base, the selection of rules based on situation of the corresponding rules, stored in situation knowledge base.

III. CASE STUDY- PROLONGED SITTING

To evaluate the proposed framework, we considered elderly people with sedentary lifestyle that spend long time in sitting situations due to their personal laziness. The objective of the case study is to minimize the elderly sedentary behavior with appropriate recommendations. The case study is realized in the following steps.

A. Specifying Sedentary Situations

Sedentary behavior can be defined as the non-exercise situations including: behaviors with approximate METs value 1.0-1.5 or METs approximately 1.6-2.9 [14]. First we extracted a list of sitting sedentary behaviors from online sources, whose partial list is shown in Table 1.

The criterion column of Table 1 describes conditions that must hold before situation happens.

B. Monitoring Sedentary Situations

The process of measuring the sedentary sitting situations is one of the essential steps of an activity-based recommendation system. In recent years, advancements in microelectronic technologies have enabled systems to first recognize and then measure the time spent by an individual either in sedentary situation or any other healthy physical activity [13]. To exploit advancement of sensor-based technology, specifically the accelerometer and video sensors, the smart CDSS first acquires the elderly physical activities and then recognized. These recognized activities are accumulated in the patient activity log from, where they are monitored, using sedentary behavior detection mechanism implemented in Smart CDSS.

TABLE 1. A PARTIAL LIST OF SEDENTARY SITTING SITUATIONS

SID	Situation Type	Criteria
S1	Sitting	1 hour continuous sitting in chair for non-obese adults
S2	Sitting	15 minutes sitting in a workplace
S3	Sitting	20 minutes sitting for obese and overweight diabetic adults
S4	Sitting	7 hours/day sitting for mid-aged women with no physical activity

C. Knowledge Acquisition for Recommendations

The sedentary situation in elderly can be avoided by providing them appropriate recommendations. We have prepared well established recommendations from online credible sources, whose partial list is shown in Table 2.

TABLE 2. A PARTIAL LIST OF RECOMMENDATIONS FOR THE SET OF SPECIFIED SEDENTARY SITTING SITUATIONS

RID	Criterion	Recommendations
R1S1	1 hour sitting	Take a five-minute walk for every hour you spend in your chair
R2S2	15 minutes sitting	Take a break! Get out of your chair or couch every 15 minutes and merely stand up and then sit back down Or take stretching for 20-30 seconds.
R3S3	20 minutes sitting	Take a 2-min bouts of light-intensity activity every 20 min to increase the chance of diabetes prevention

D. Situation Knowledge Base Creation

To generate physical activity recommendation to the elderly people, we have created situation knowledge base from the identified list of situations (Table 1) and associated recommendations (Table 2). The rules are created from user personal profile information, health condition and sedentary behavior information. A partial list of the rules used for situation-based recommendations generation is shown in Table 3.

TABLE 3. A PARTIAL LIST OF RULES FOR RECOMMENDATIONS AND FACTS GENERATION

RulID	Conditions	Recommendation
Rul1	If (current_act = sitting, amt_sitting >= 1h, health_cond = non-obese)	R1S1
Rul2	If (current_act = sitting, amt_sitting >= 20m, health_cond = obese OR overweight, disease = diabetes)	R3S3
Rul3	If (current_act = sitting, amt_sitting >= 50m, health_cond = normal, disease = none)	R5S7

E. Knowledge Engine – Recommendations Generation

The knowledge Engine of the Smart CDSS generates recommendations and facts, as any of the specified sedentary situation occurs and passed to the Smart CDSS execution Engine. The execution engine performs rule-based reasoning over the identified situations, user profile and situation-based rules. These recommendations are provided to the nurse where he/she verifies the correctness of the recommendations and invokes the appropriate action. He/she decides whether only counseling is required or some medication should be provided. Further, the nurse educate the elderly using the facts that are provided in addition to recommendation.

IV. CONCLUSION AND FUTURE WORK

In recent years, sedentary behaviors of people increased rapidly due to the changing dynamics of workplaces where people spend more time in sitting and finds less time to move. To avoid these prolonged sitting situations and minimize its side effects, an extension to our previous work is introduced and implemented as part of Smart CDSS. A list of unhealthy sitting situations are identified and the corresponding recommendations are produced.

In future, we plan to extend the study to more sedentary behavior, such as lying down etc. and evaluate the results in realistic scenarios.

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