Sedentary Behavior-Based User Life-Log Monitoring for Wellness Services

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Abstract. Ubiquitous computing and smart gadgets have revolutionized the self-quantification in tracking and logging activities for improving daily life and inducing healthy behavior. Life-log monitoring is the process of monitoring the daily life routines of user in an efficient manner in terms of time and amount of activities. The effective utilization of life-log monitoring is to correctly identify and intimate user unhealthy activities in a timely manner. For monitoring life-log, the knowledge of sedentary behavior first need to be formulated by the domain expert in the form of unhealthy situations, these situations are used as the monitoring unit. In this study we proposed a method for automatically monitoring users' unhealthy situations in the domain of sedentary behavior with prolonged activities. The proposed method simultaneously filters out multiple sedentary activities of users simultaneously while ignoring the activities having no situations. The results depict that the monitoring method intimates the stakeholder with delay less than the monitoring interval cycle.

Keywords: Life-log · Automatic monitoring · Sedentary behavior · Unhealthy situation · Wellness

1 Introduction

Health is a reflection of lifestyle and active lifestyle has great impact on wellness. The choice of energetic lifestyle may lead to a fuller, healthy and long lifetime. The element of human well-being may be specified as: safety; availability of livelihood (e.g. food, shelter, energy); freedom; social interaction and physical health [1]. Active routine is an important ingredient in addition to diet, hydration, leisure and finance. A lifestyle with a small or no regular physical activity is a sedentary. A sedentary person is the one who has irregular or insufficient amount of physical activity in daily life routine [2].

1.1 Consequences of Sedentary Behavior

A sedentary person is more vulnerable to health issues like muscular weakness, bone health, blood pressure, obesity and risk of diabetes [3]. Involvement in moderate-vigorous level physical activity is an economical measure to improve health and reduce

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disability [4]. Disability increases the risk of hospitalization and institutionalization and is a major concern of economy [5].

Those, who follow physical activity guideline's recommendations, proposed by ACSM [6] and AHA [3], still have high potentials of health risk due to prolonged sedentary living time. Consider a person who sits more than 4 h per day has 40 percent higher health risk than those who sit less than that [7]. Those having regular interrupts in sedentary activities have a better metabolic profile than those who remain inactive for long periods [8]. Living an active life requires intimation and basic knowledge with connections to healthcare experts.

1.2 Life-Log Monitoring and Wellness Applications

Over the past few years, the focus of software applications is trending towards health and wellness applications. The trend is considered as a prompt and useful resource for analyzing users' data to recommend healthy lifestyle [11]. Thousands of desktop as well as mobile applications are available for logging user activities and enabling users in visualizing the cumulative impact of activities on daily or weekly basis. Routine life activities are quantified through different sensors to manage personalized healthcare and wellness [9]. *Microsoft Health, Apple Healthkit, Samsung S Health*, and *Google Fit* are a few among the numerous applications which collect and analyze users' data to generate healthy lifestyle recommendations [11].

Life-log monitoring is a challenging task; it determines a person's health and wellness state which is more than simply collecting and storing the person's activity data. Therefore, automatic mechanisms are required to process personal data and transform it into information. The monitoring technique can be leveraged by healthcare and wellness systems to extend, adapt and evolve the knowledge provided by domain experts [9]. Generally, life-log monitoring services are used to generate alerts or recommendations to stakeholders in a human-understandable format. These services can provide support for customization of recommendation on the basis of user preferences and demands.

2 Mining Minds: At a Glance

Technology revolution and the modern age of information facilitate the community in terms of on-spot context based health informatics [14]. The information technology is reshaping the world by using cloud computing infrastructure for managing big data from internet of things to support personalize recommendations. Our ongoing project, Mining Minds MM [9, 11, 12] is an innovative platform that constitutes of state-of-art information technologies to motivate users for healthy lifestyle after monitoring their life-log. The innovative platform is necessary to cope with the challenges in healthcare and wellness domains that is more converging towards a user centric model [13].

Mining minds platform's services collectively collect and analyze human's daily life data, generated from multiple sensors and give context based personalized wellness recommendations [12]. Considering the requirements, MM platform consists of five layers, respectively, Data Curation Layer (DCL), Information Curation Layer (ICL),

Service Curation Layer (SCL), Knowledge Curation Layer (KCL) and Supporting Layer (SL). The SCL is responsible for generating personalized recommendation. The hybrid-CBR technique is used to generate personalized recommendations according to the user context and preferences by manipulating recognized activities, user context and user profile information [14].

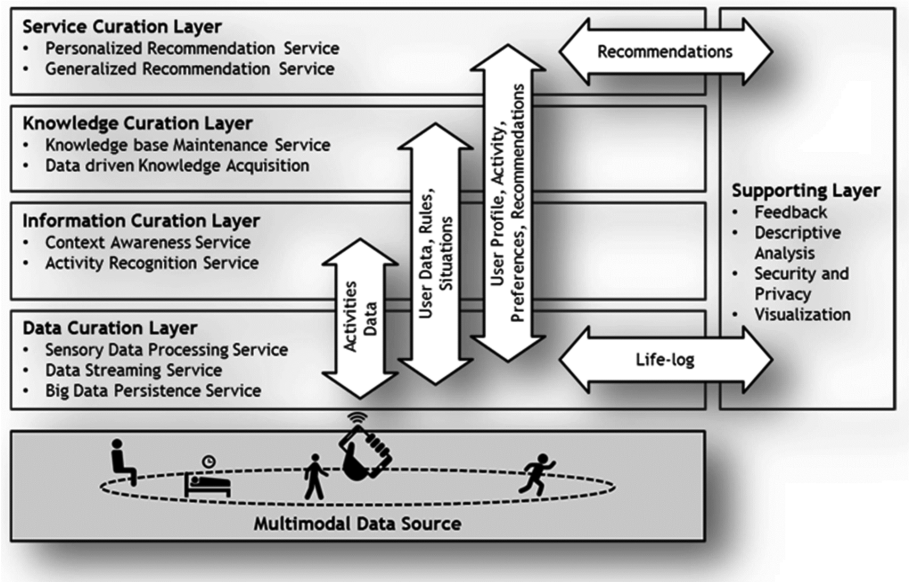

Fig. 1. Mining minds platform

The goal of KCL is to manage and create knowledge for wellness and healthcare. It provides a rule editor environment to expert for expressing his wellness knowledge and healthcare experience in the form of executable guidelines. These guidelines provide the situation for identifying the unhealthy patterns with respect to context and remedies for clutched unhealthy patterns in term of actions [15].

The SL is in charge of the user interface, visualization, and descriptive analytics. The supporting layer creates a unique interface which has the adaptive and personalized approach towards building and managing the user interfaces. The analytics gives users and experts different insights into the habits, activities and different classification of the application [14, 15].

ICL is responsible to infer and recognized the activity of a user by manipulating the data generated by multiple sensors. The data is converted into concepts or categories like physical activities and location. It is the core of MM services which identify the context and activity, e.g. sitting in office, with the help of sensory data. These recognized contexts and activities are essential for identification of user lifestyle pattern [15].

DCL provides the foundation of the MM platform architecture. Data from multimodal data sources is gathered, persisted and processed at DCL. It consists of different modules for data streaming and communication, data representation and mapping and big data. The big

data addresses the 3Vs (volume, velocity and variety) aspects of raw sensory data acquired using multiple sensors [14]. DCL is curating the user data in a temporal manner to build the life-log. Life-log records all those activities which are recognized by the ICL along their temporal credentials. It supports to analyze and identify the lifestyle pattern to highlight the unhealthy activities and abnormal behavior of the user.

Life-log evaluation is an essential concept to highlight the existence of a situation in the running activities of user which is unhealthy for the user. The expert provides this situation using the rule authoring capabilities of KCL e.g. sitting more than one hour. If there is no situation provided by the expert, it means that activity does not require any monitoring and it will not have any unhealthy impact on user life. To filter out all those unhealthy activities and monitor them, we proposed an architecture for life-log monitoring on which the activation of wellness service from SCL and descriptive analytics of unhealthy activities of SL are dependent.

3 Intimation-Based Life-Log Monitor Architecture

Nowadays, most of the wellness applications are capable of recognizing the user time to time activities, log them into one's life-log and present them in an interactive graphical representation [11]. Besides, presenting the user's activities logs, a few applications also present the impact of co-related activities [10]. As a proactive approach for adaption of healthy lifestyle, life-log can be used to highlight the unhealthy behaviors at the time of occurrence. Intimating the to-be unhealthy activities to the health stakeholders adds more comprehension and perfection towards the user wellness.

Health consciousness and proactivity lead us to drive an intimation-based Life-log Monitor (LLM). The derived architecture, shown in Fig. 1, is designed for the LLM constitutes of three major components. These components manage the unhealthy situation information provided by experts and monitor the life-log on the basis of these situations which are the driving force for the monitoring. The provided instructions are guidelines used to monitor the life-log at run time to filter out all those conditions which are needed to be

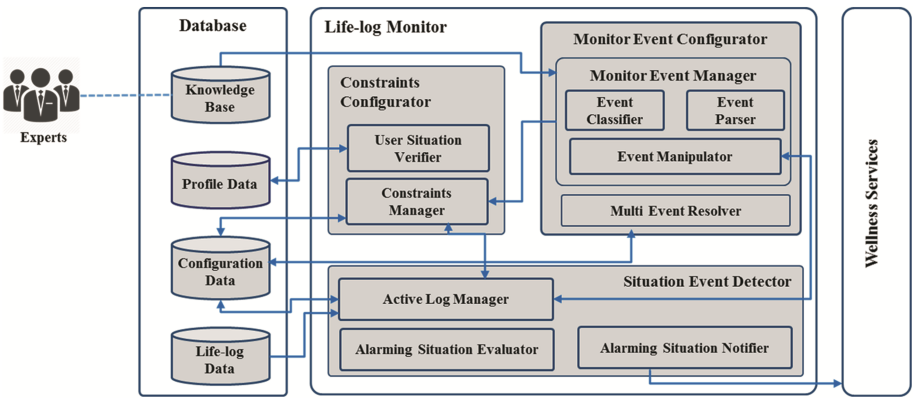

Fig. 2. Architecture of intimation-based life-log monitor

identified and triggers the wellness services. The three main components are Monitor Event Configurator, Constraints Configurator and Situation Event Detector as shown in Fig. 2.

3.1 Monitor Event Configurator

This component is responsible for managing the monitoring situations shared by experts in a common configuration format. The monitoring situation is a guideline to examine the activity of a user at the occurrence time. It constitutes of activity, duration of activity and additional constraints. Monitor Event Configurator (MEC) identifies the situation components and keeps it as configuration data. Beside, storing the information related to situation, MEC has to find out the suitable monitoring situation for situation event detection. MEC has a sub component, Multi Event Resolver (MER), which acts as a conflict resolver in case there are more than one situations related to a single activity.

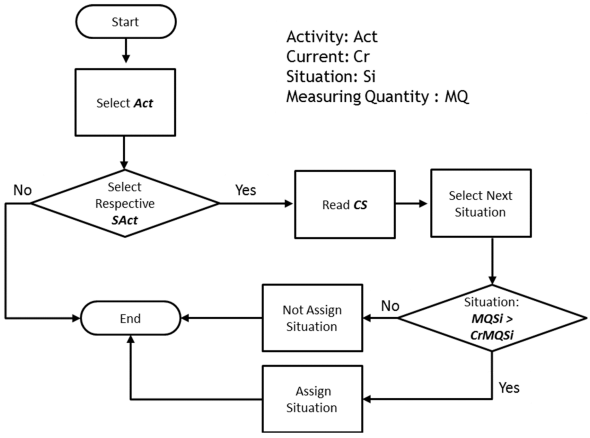

Fig. 3. Flow chart of Conflict resolver in multiple Situations

An activity may have multiple sedentary situations. The choice of appropriate situation for an activity is quite significant. Think there are two situations related to sitting activity. Ace is one hour and the other is three hours. In both cases the wellness actions are different, which are proposed by the expert and notified by wellness services. In this example, if a user starts sitting activity, the appropriate target for intimation is first one hour and then three hours. Figure 3 shows the operation of MER that is getting out the suitable situation on the basis of current activity status of the user.

3.2 Constraint Configurator

This component is responsible for managing the constraints related to a particular monitor-able situation and verifying before monitoring that the user's profile data is matching the constraints. The constraints related to situations are managed by a

constraint manager in the form of key - value pairs. The key-value pair provides dynamicity in handling multiple constraints related to a situation.

To monitor a situation against an activity User Constraint Verifier (UCV) search the user profile. As there are multiple constraints may associate with a single situation, therefore UCV has to cater for all the constraints to verify that the user fulfills the situation constraints. If it is not able to find the information with the given constraints, the monitoring of that activity of the user does not start.

3.3 Situation Event Detector

Situation Event Detector (SED) is the key component of the LLM and is responsible for identifying the situation when activity is transformed into sedentary one according to the monitor-able situation. These situations are identified from the rules generated by the expert. This module consists of three sub components, as shown in Fig. 2, which are Active Log Manager (ALM), Alarming Situation Evaluator (ASE) and Alarming Situation Notifier (ASN).

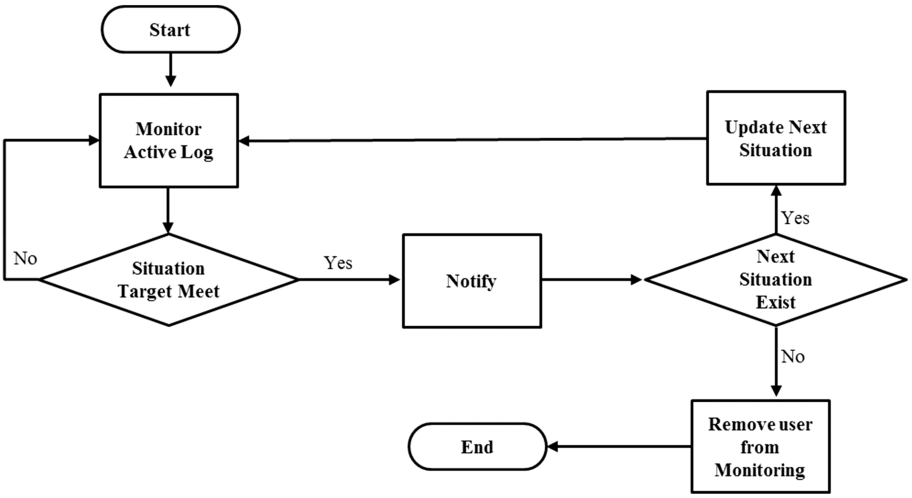

Fig. 4. Flow chart of life-log monitoring

There are lots of activities going on in a life span of the user, all of these activities are not considered as sedentary ones. ALM is the component that filters out the monitor-able sedentary activities and manage them separately. Therefore, the Active Log consists of only those activities which are considered as monitor-able with respect to the situation and verifies against all constraints associated to the constraints matching with the user profile. Consider, if age and gender of user is not according to the constraints of situation then that activity of respective user is not selected for the monitoring. Similarly, if there is no sedentary situation related to an activity then that activity is also not considered for monitoring. In active log, every activity is registered with its starting time and the situation targeted time.

The ASE is responsible for monitoring the Active Log at regular intervals. It carries out the comparison of monitor-able target duration with the difference of starting time and current time as shown in Fig. 4. The benefit of the ASE is that we can filter out different activities of users at the same time. We don't need to consider every activity individually.

4 Evaluation Methodology

To evaluate the working of proposed LLM in a real environment, we integrated it with Mining Minds platform V2.0. It is a platform for person centric health and wellness [9, 12]. It provides the facility to recognize these activities of the user through sensor-based technology. It supports the real time data acquisition of user activity, analysis and recognition of activity and wellness services to intimate the user at run time. The intimation is done in the form of appropriate action message alert on user mobile phone. Before integrating the proposed LLM, the user has to interact with the wellness services to know about activity status.

4.1 Experimental Setup

We have considered all those activities which are evaluated on the basis of time consumption. So that we can validate LLM against time base monitoring activities to highlight the prolonged duration of activity to avoid sedentary behavior. We selected users of different ages and gender, divided them into three age groups, as shown in Table 1, and they performed different activities concurrently.

Table 1. User age groups and ranges

Sr.#	Age group	Age range
1	Kid	Age <=17
2	Adult	Age > 17 && Age <=45
3	Old	Age > 45

We have selected five different activities: sitting, standing, walking, stretching and lying. The Mining minds platform expressed very high accuracy to identify the above mentioned activities [15]. Our expert (Physiotherapist) provides different prolonged unhealthy situations related to sitting and standing activities. Specific gender and age-group are provided to setup the constraints for the monitoring situations. For example a situation that is related to sitting activity i.e., sitting more than one-hour for healthy

Table 2. Situations for monitoring the activities

Sr.#	Activity	Duration	Age group	Gender
1	Sitting	1 h	Adult	Male & Female
2	Lying	3 h	Adult	Male & Female
3	Standing	2 h	Adult	Male & Female

adults. For evaluation, the situations are provided by the expert through the knowledge authoring tool of Mining Minds as shown in the Table 2. The table represents the continuous duration of activities when that become unhealthy for an adult male/female and need to be intimated so that the activity or posture should be changed. Consider an adult person continuously sit for one hour or more, it is not good for his/her health and it is consider as a sedentary activity. In this situation it is good to intimate him/her, so that he/she may take small walk or little exercise.

We have selected 10 volunteers who are fully informed for the usage of the system and provided guidelines to perform different actions regarding the alert messages. About 20 % of the volunteers do not fulfill the constraints of the situations. Rest of the volunteers are directed to perform different activities and follow the instructions on and off. In this way we are able to judge the working of LLM against multiple situations of an activity.

4.2 Evaluation Criteria

The performance of the LLM is monitored on efficiency basis that how correctly and timely it has generated the intimation for the wellness services on the occurrence of prolonged sedentary event. The delay between crossing the threshold value set against a particular activity and intimation is evaluated. We crossed check it with the help of intimation log and number of notifications generated for the expert in expert panel. The panel supports the expert while generating rules and defining situations against different activities.

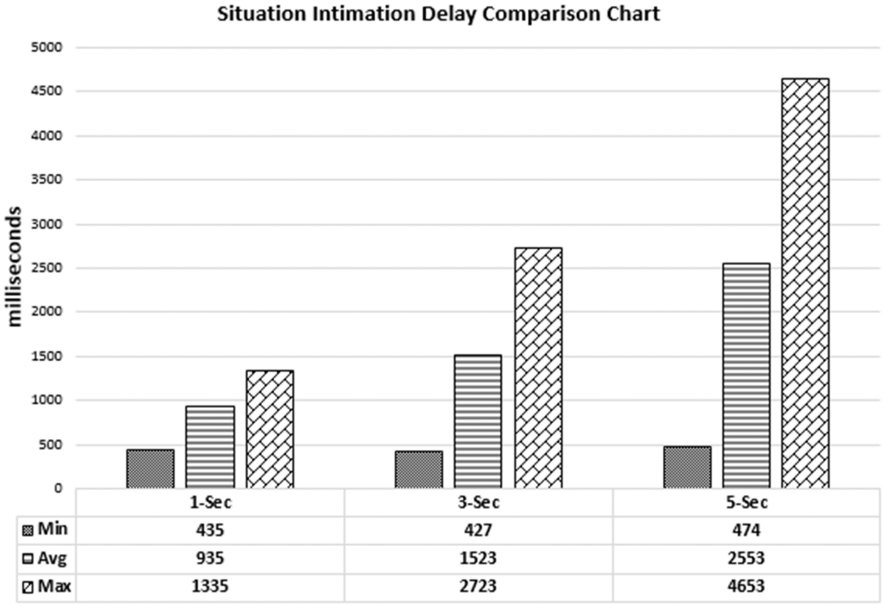

Fig. 5. Delay in situation intimation

4.3 Experimental Result Analysis

LLM starts monitoring of the activities which have a registered situation of sedentary from experts and the constraints of the situation match with the user profile. LLM intimates the stakeholders when the activity becomes sedentary with the maximum delay less than the interval of monitoring cycle as shown in Fig. 5. Results show that when we keep the interval duration greater than 1 s, all the situations are intimated in less than monitoring interval cycle for situation.

The delay in intimation is due to the wait for executing the next cycle. If duration of the activity reached the limits of the situation and there is no monitoring cycle at that time, then it has to wait for next cycle to be intimated. The platform is deployed on Microsoft Azure cloud that is the reason that execution of services required nearly 400 to 500 ms. The overall delay in intimation is quite affordable for our volunteers. The intimation log status is verified with the expert panel as shown in Fig. 6.

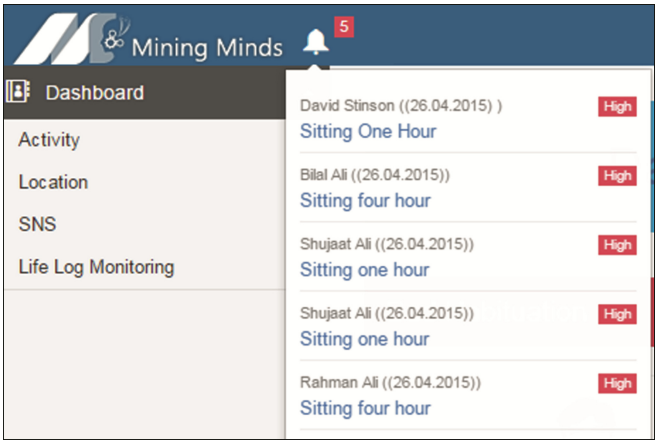

Fig. 6. Expert dashboard for Activity Log Analysis

5 Conclusion and Future Work

The designed LLM monitors the activities which become sedentary due to prolonged duration. It informs the wellness services as soon as the activity becomes sedentary. It is a novel way to monitor activities and push information instead of waiting for the user or expert to examine the daily or weekly routine. This novel technique can support the wellness applications in becoming proactive to avoid the sedentary behavior. The precautionary approach is adopted for more effective intimation against sedentary activities. Currently, the LLM monitors all those activities which have a situation designed by experts and are related to time domain i.e. sitting more than one hour. In wellness domain the diet has a big influence, in the future we will extend the LLM for monitoring the diet in term of calories.

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