Mobile Activity Sensor Logger for Monitoring Chronic Disease Patients

Manhyung Han, Yong-Koo Han, Hyoung-Il Kim and Sungyoung Lee

***Abstract*—Chronic diseases are long-lasting and therefore required continuous control over long periods. As the number of aged person is continuously increasing, the importance of chronic disease management is also getting raised. There are lots of symptoms such as frequency of eating, toileting or length of sleeping that indicates the progress of disease but it is hard to recognize by patients themselves.**

In this paper, we propose the MASoL (Mobile Activity Sensor Logger) for acquiring and logging patient's activity information includes physical movements, indoor/outdoor location and surrounding sound. Based on the logged data from the MASoL, an activity pattern of the patient and context information of the environment around the patient is able to be inferred. So the personalized system is able to keep trace of the patient's life pattern and progress of his/her disease. Also when a symptom of chronic disease has founded, it could notify to both care-givers and patients. We describe architecture and its components with technical details and represent how it could be applied to chronic care applications or services. There are 7 types of sensors on 8.5cm × 5cm sized single board. Its weight is less than 30g and runs over 20 hours.

***Index Terms*—MASoL, Life Logging, Chronic Disease, Activity Recognition, Context-aware**

I. INTRODUCTION

CHRONIC disease such as hypertension, diabetes and depression requires patient education to control and prevent deterioration of the disease [1]. Substantial increases in relative and absolute number of older persons in our society raise a number of chronic disease patients [2]. Also chronic disease is associated with the way a person lives and affected by environment around the person. So in order to provide chronic care to patients, recognizing human's behavior and life pattern is required.

Body-attached sensing device with accelerometer, gyroscope and other sensing units is widely used for obtaining human's behavioral information. This approach has the advantages of being with the user continuously. For instance, a falling detection application could use real-time gathering data to monitor activities of the patient and notify emergency situation to care-givers when the patient has fallen. Also it is well-suited to collecting data on daily activities over long periods of time as they can be integrated into clothing or worn as wearable devices [3], [4]. In body-worn system, accelerometer and gyroscope are the most highly used sensors for long-term life pattern monitoring [5] because they are relatively low cost, portable and required less processing than video-based activity recognition approaches. However the design of wearable systems is complicated because of limited size, weight, and power consumption requirements [6]. By advancement in body-attached sensor technology, many researches are trying to record personal daily life by analyzing lifelog data collected from mobile devices [7], [8], [9]. Some studies tried to differentiate same activity on different situation [10]. Contrarily others investigate to broaden number of activities that can be recognized such as walking, running, sitting, standing and lying etc. [11], [12]

However current sensor devices for gathering human behavioral data have some restrictions and limits. In our initial stage of studying on human activity recognition, we wanted that less devices for recognizing activities and a device working on both indoor and outdoor. But previous sensor devices that manufactured for activity recognition have only few sensors and location dependant which means there was no product which has multiple characteristics on single device. Therefore, in order to improve both correctness and number of recognizable activities, a novel device which contains diverse sensors on a single board and provides storing function for recording long-term activity logs is required.

As for recognizing activity pattern, several researches had been performed using one or more sensor devices. D. Tancharoen *et al* [9] tried to capture life logs by body-attached system with wearable camera, microphone, GPS and personal computer. They visualized and summarized life log but the system was quiet heavy to bring in daily living. In [13], photos, videos and sound clips which the user created on the mobile phone are automatically collected by Multimedia diary and web-based administration tool. But these approaches described above are required multiple devices and only visual data is available not the context and meaningful information.

In this paper, we propose the MASoL which has 3 types of inertial sensors, GPS, MIC and ambient light sensor on a single board. Also every data which produced by above sensors is stored at external storage medium (SD memory) up to 2GB.

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The proposed system recognize various activities with single device and could be used as a life logging device for further processing, e.g., history-based activity inference, long-term pattern analysis or chronic care. Although the MASol contains several sensor units and storage, it is small and lightweight (8.5cm x 5cm, less than 30g) enough to bring comfortably for hours.

We present technical details of the MASoL both software architecture and hardware platform specification, technical challenges for monitoring chronic disease, and discuss how the MASoL could be used for u-Healthcare applications in the following section.

II. MASoL System Development

For acquiring human's behavior information, we've developed the MASoL system from software design to hardware platform. Totally 13 types of data are collected by 3-axis Accelerometer, 3-axis Gyroscope, 3-axis Magnetometer, Pressure Sensor, GPS, MIC and ambient light sensor. All of these sensors are integrated on single board and automatically gathering and recording behavior information for long-term activity pattern analysis. We have tried to make this device with less size, less weight and integrate all the sensor units into single board for wearing on human body conveniently.

A. *Software Architecture*

MASoL consists of three core modules named SDD (Sensor Device Drivers), DLR (Dynamic Logging Scheduler) and SLR (Sensor Log Recorder). For interfacing with PC and other systems which process life log data, the MASol provides a USB connection and storing method using Micro SD under the Storage Manager. Software components of the MASoL are depicted on Fig. 1.

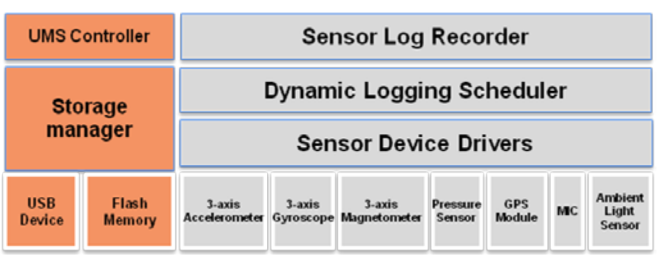

Fig. 1. Software architecture of the MASoL. There are three core components depicted on the right and components for recording life logs are described on the left.

Sensor Device Drivers (SDD)

SDD initializes all of sensor modules embedded in the MASoL and provides interfacing function between raw sensors and Dynamic Logging Scheduler. For communicating with sensor modules, I2C (Inter-Integrated Circuit) was used for accelerometer and magnetometer, ADC (Analog-to-Digital Converter) was used for gyroscope and pressure sensor. The used sampling rate of the accelerometer, gyroscope, ambient light and pressure sensor was set as 5Hz. On the other hand we had set the sampling rate of GPS module as 1 Hz or dynamic value depends on where the user has located.

Dynamic Logging Scheduler (DLS)

DLS initializes system variables and control sensing threads as requests of data collecting and terminating in the MASoL. DLS is continuously tracing operation period of each sensors and scheduling sensor operation in dynamic manner for reducing energy consumption. Once the MASoL has turned on, it starts to collect data from every sensor modules periodically. But if similar or same activities are recognized continuously, DLS dynamically changes the sensing period. For example, if the user is having a sleep and also the system is recognizing it, sensing period is going to be getting longer and longer until different activities are recognized.

Sensor Log Recorder (SLR)

SLR converts collected data from DLS and SDD into a unified format and compress it for recording at the USB Mass Storage (UMS). Tremendous data would be generated by each sensor modules irregularly. Therefore efficient recording and compression are quiet important for practical use of the MASoL.

B. *Hardware Platform*

Many recent wearable computing systems for recognizing human's activity are composed of single type sensors typically accelerometer, gyroscope or magnetic sensor. And these systems are attached on multiple spots of the human body. However this approach has limit to the number of recognizable activities [14].

In order to overcome these limits we propose the MASoL which has multiple sensors on a single board. There are several advantages if a device has multimodal sensors. We could collect various activities and environment information with fewer devices and less power consumption. Also we can avoid an installation error which occurs when accelerometer and gyroscope are attached without fixed direction on human body

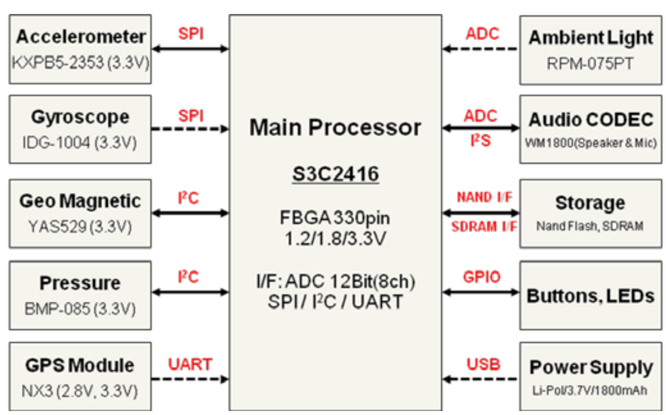

Fig. 2. System block diagram of the MASoL based on Samsung S3C2416 microprocessor. Interfaces between main processor and components are on red color. Manufactures of sensor modules are Samsung Electronics (S3C2416), Kionix (KXPB5-2353), InvenSense (IDG-1004), Yamaha (YAS529), Bosch (BMP-085), Nemerix SA(NX3) and Rohm(RPM-075PT).

TABLE I
CHARACTERISTICS OF INERTIAL SENSORS IN THE MASOL [16], [17], [18]

Sensor	Accelerometer	Gyroscope	Geo Magnetic
Full Scale	±2g (19.6/m/s/s)	±50°/sec	±300μT
Sensitivity	794~844counts/g	4mV/°/sec	≤0.6μT/count(X,Y) ≤1.2μT/count(Z)
Power Supply	2.5~5.25V	2.7~3.3V	2.5~3.6V
Power Consumption	300~700μA	9.5mA	4mA

by using with a geo magnetic sensor [15]. So users do not have to bring burdensome devices on their body.

Fig. 2 describes what kinds of sensor units are employed in the MASoL and interfaces between these sensors and main processor. We used a S3C2416 ARM9 mobile processor by Samsung Electronics as a microprocessor which is optimized for embedded and mobile systems such as PNDs, POS, E-book and Other Handhelds. For recording enormous life logs a 2GB NAND flash memory was used in the MASoL. Accelerometer and Gyroscope are employed for collecting basic element information of activity recognition and a magnetometer was used for not only collecting pose data but also correcting errors that could be occurred on operation in accelerometer and gyroscope. We also used a pressure sensor for recognizing movement among floors within indoor environment such as apartments or buildings where we hardly expect a GPS signal. It measures an absolute value of an altitude of the user so the system could infer relative location in a building. Both MIC and an ambient light sensor are utilized for gathering environmental information around the user.

Fig. 3. Front and back side of the MASoL with battery and ZigBee communication module. The size of it is 8.5cm x 5cm and the weight is less than 50g.

The device is small enough to bring it comfortably for long speriods of time. The size of the MASoL is 8.5cm x 5cm and the weight is less than 50g. It could run for more than 20 hours by using 1800 mAh Li-Polymer battery with only sensors and storing modules are enabled for logging. When we test the MASoL with sensing period as 5 Hz, it runs around 20 hours but it could be enhanced if we apply adaptive sensing period algorithm.

Fig. 4. MASoL has been worn by the patient. For avoiding installation error, we fixed the direction and location of the device to waist. User controls the device by three buttons(turn on/off, reset, resume etc.) above it.

III. MONITORING CHRONIC DISEASE PATIENTS

Chronic disease patients are suffered from several symptoms. In case of depression, pervasive low mood, loss of interest or pleasure in favored activities, waking up very early, difficulty to get back to sleep, anorexia and congestive heart failure are the major signs [19] of the disease. From these ambiguously expressed signs and symptoms, we have redefined them as follow: low lights, low movement, low going-out, low showering, low sleeping, low eating and weight loss. Similar to the depression, we've also redefined several symptoms of the diabetes from [20].

Redefined terms named SDAs (Symptoms Dependant Activity) are set of activities which are related to initial signs and symptoms of a specific disease. It is denoted as $SDA(d) = \{a_d^1, a_d^2, \dots, a_d^n\}$ for disease d has n kind of SDA. The example of SDAs of diabetes and depression are shown in Table II.

SDA represents current status or condition of the user which obtained by reasoning from one or more initial activities such as toileting, eating or sleeping etc. Fig. 5 illustrates how these two chronic diseases are inferred from simple activities based on Table II. The MASoL would be used as a proper device for collecting basic activities of the patient with its multiple sensors

TABLE II
AN EXAMPLE OF SDA: DIABETES AND DEPRESSION [19], [20]

Chronic Disease	Initial signs and symptoms	SDAs
Depression	Pervasive low mood	Low lights
	Loss of interest or pleasure in favored activities	Low movement, low going-out, low showering
	A person wakes very early and is unable to get back to sleep(oversleeping is less common)	Low eating
	Appetite often decreases, with resulting weight loss	Weight loss
Diabetes	Increase thirst	High drinking
	Increase hunger	High eating
	Fatigue	Frequent sleeping
	Increase urination, especially at night	High toileting
	Weight loss without trying	Low weight

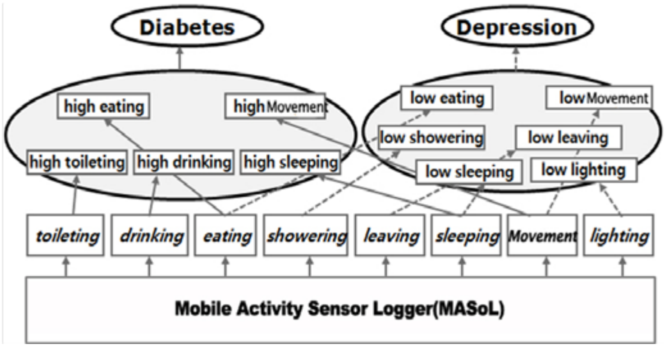

Fig. 5. Component graph inferring from simple and basic activities to high-level activities for chronic disease monitoring especially for diabetes and depression. If a number of recognizable activities are increased, the more symptoms and diseases could be inferred.

and mass storage. Although there are still many factors must be considered to infer the diabetes and depression more precisely, SDAs which we defined could be good references for providing warns or recommendations to the chronic disease patients, care-givers and clinicians.

IV. Future Works and Conclusion

Chronic disease patients are required continuous control over long period. However recent sensor devices for collecting human's behavioral information have several limits such as lack of portability, less sensors on single device and location dependant. In order to solve these problems, we propose a device which contains various sensors on a single board and provides storing function for recording long-term activity logs named MASoL. We provide technical details of both software architecture and hardware platform of the MASoL. Also providing relatively apparent syntax what kinds of elements have to consider for monitoring the diabetes and depression by defining SDAs and component graph.

But current works described in this paper is a beginning step to infer high-level activities, pattern analyzing and monitor chronic disease patient. We will apply an adaptive sensing period algorithm for enhancing energy consumption and carry out an experiment with subjects for recognizing chronic diseases. If this research has done, we can expect the longer operating hours. Also continue to define more elements for recognizing symptoms that the MASoL could be used as a sensing device. We also consider that the technology developed based on the MASoL could be applied to the smart phones which have powerful processing capability, inertial sensors such as accelerometer, gyroscope, location aware devices like GPS, WLAN and other sensors with sufficient storing spaces. In this case, we primarily have to consider power consumption problem because of continuous running various sensors for data gathering.

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