User Activity Tracking for Medication Adherence

Ramyya Hari
School of Electrical Engineering and Computer Science
Washington State University
Pullman, WA 99164 USA

***Abstract*— This paper presents a medication adherence monitoring system by user-activity tracking based on android wear sensors. Data collection was performed on a group of subjects to track the movement of their hands for different actions. Data collected from the sensors are transferred and processed. We identified and differentiate between the different actions based on the signal trends. We intend the system to be able to identify the act of pill intake based on which we may keep track of the medication adherence rate of a patient. The results of the experimentations carried out indicate that the developed medical adherence monitoring system identifies the act of pill intake with a high degree of accuracy and is more dependable than existing systems.**

Keywords—Wireless transimssion; data encryption; motion monitoring

I. INTRODUCTION

Motion monitoring refers to the methodology of collecting and analyzing data using motion sensors. The applications of motion analysis have increased at an exponential rate in the past few years. From the diagnosis of physical ailments and clinical research to the personal evaluation of physical activities, the motion monitoring provides an interface to gather precise and accurate information. It offers an objective and real-time method for the extraction of the movement parameter.

A smart android phone equipped with tri-axial accelerometer and gyroscope acts as a data collection device as the motion analysis is done based on the movements of the user. For example, the gait information is dependent on the walk of the user. Similarly, some medical study may require a patient's hand movements when they consume their medicine. All these motions are detected by the sensors in all three dimensions and stored into a .csv file.

The study of motion analysis involves a large sample group. A medical study would include a lot of doctors and researchers who would want access to the data has been collected. The .csv files need to be sent to each of the participants of the research project. The medium that we chose for this transmission is Bluetooth ince, all the android devices are equipped with it.

Usually, the data collected by motion sensors is relative to a particular individual and is personal and sensitive. A patient's medical study might reveal his/her health which is a private matter. Hence the analysis of data needs to be with great care. To make sure there is no leak of first-hand information, we created an application to encrypt .csv files before transmitting them over Bluetooth. The encryption is secure and based on the receivers. A single file is encrypted into two different files for two different receivers. This ensures that only the intended person can access and read the file. Another application, on the receiver's end, automatically decrypts the file to the original form. The encryption makes use of MAC addresses of receivers to ensure integrity. The entire process is explained in detail in the next sections.

Advancement in medical care alone doesn't improve the patient outcomes but adherence to medication regime is equally important. Medical adherence is extremely important when treating patients with major psychiatric disorders, aged patients, patients with memory losses etc. Here in spite of available medications compliance with treatment continues to be an issue of concern.

A number of factors are most consistently associated with non-adherence to medical treatment. Poor insight, a pessimistic approach medication, prior history of non-adherence, substance abuse, inadequate discharge planning, and a poor therapeutic alliance with a treating clinician.

II. RELATED WORK

Current systems deal with medication management systems which aren't a very accurate way of measuring medication adherence rate. The PillPack consists of a dispenser which has a roll of packs of pills for a particular time. Each individual pack is labeled with the time and day, the pills are to be taken and a list of all the pills in the particular pack. This is a simple yet cost effective method of medication management, yet these require the person to be proactive and recall to take pills every day. Pill bottles such as the ones by GlowCap and AdhereTech operate with systems where we're able to keep track of when we open the pill bottle. They have a sensor on the lid which tracks the number of times the bottle is opened and based on the tilt of the bottle to dispense a pill, we can tell the remaining number of pills. GlowCap has an in-built mobile SIM which it uses to communicate with a local transmitter which notifies the patient to take the pill or refill by having a blinking light. There are also precautionary measures where it notifies a relative or the doctor of the lapse.

The systems we have described above still aren't being used by a vast majority of the populous due to the ineffectiveness of the mechanisms, which is why this project would really make a difference in making a real impact in making a change and improving the medication adherence rate by a big percentage.

Fig.1. Pill Pack

Fig.2. GlowCap

Fig.3. PillPack Dispenser

III. MOTIVATION

Current medication adherence systems don't have a way of confirming if the patient did consume the pill which would decrease the efficiency of the system. The proposed system tracks the movement of the hands of the patient from the values obtained from the accelerometer and gyroscope based on which we can say if the person follows a certain set of actions in a sequence such as opening a pill bottle and taking the pill and then putting it in the mouth. There are no commercially available systems that address this issue. The ultimate purpose of this project is to improve medication adherence rates.

IV. METHODOLOGY

The person is outfitted with the android watches on both hands. An application is used to manually record the data for a given set of movements from the Accelerometer and Gyroscope of the device. After data collection the device is set in debugging mode to manually extract the data or transmit the data. This data is then segmented based on action and repetitions. We may then try to recognize actions based on statistical trends in the data. Machine learning algorithms can also be used to predict actions and confirm the consumption of pills.

A. *Application*

Figure 4 shows the android application the devices are installed with, which are designed to collect the data from the device. The application is made to collect the data from the accelerometer and the gyroscope of the device. The data is stored in the format of a csv file. The application is designed in Java programming language. We use the application which acts as a user interface, this then connects to the package handlers which then gain access to the hardware layer of the device to retrieve the above mentioned data. We then connect the watch to a computer to retrieve the data collected over a given time frame.

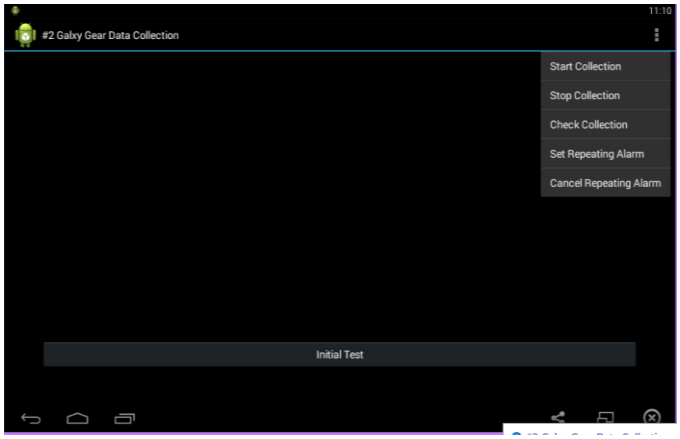

Fig.4. Data Collection Android Application

B. *Data Collection*

We defined five different scenarios for which the person was to repeat each action for ten times. The reason behind the selection of these particular actions were so that we could identify how the data was different for actions related to the consumption of a pill versus actions that are similar or completely unrelated. We defined the following five different scenarios to collect the data:

Drinking water from the bottle. The action consisted of lifting a bottle placed on a table, opening a bottle and drinking water from it and placing it back on a table.

Eating a pill from a bottle whilst sitting. This action consisted of lifting a pill bottle from the table then opening the bottle and then consuming the pill. We observed that there were many variants in the action such as alternation in usage of the left and right hand in lifting the bottle, opening the bottle, holding the bottle while extracting the data and so on.

Eating a pill from a bottle whilst standing. The same action as before was followed but in this the person was standing.

Using a pen to write a word down. This was chosen as an action that is completely irrelevant to the act of pill consumption, the person was to open a pen, write down the word "good" and close the pen and place it back on the table.

Eating candy from a pack. This action was chosen as something which would be similar to the act of pill consumption and we would like to observe as to how they were different based on the signals collected from them.

C. Protocols

The protocols that have been observed during data collection were the following. The reason for the selection of the unique set of actions have been mentioned above. Each scenario was carried out for 10 repetitions so that we would be able to train the data on the trend of the data. All actions started with the hand on the lap while sitting and by the side of the body when standing. It was also followed as a rest position between repetitions. This helps to differentiate between movements when the data is processed. A waiting period of 1-2 seconds was observed between repetitions. Each action was started and ended at the rest position. The 10 subjects that participated in the study were in the age range of 20-25 years.

D. Data Transmission

We use the Bluetooth adapter to communicate with our application. We initially start by checking if the device has Bluetooth capabilities and once this has been done we may enable the Bluetooth. We use the isEnabled() function to check if the is not enabled then we use the Bluetooth adapter to request enabling the service.

The scanning procedure searches the local area for Bluetooth enabled devices. However, a Bluetooth device within the area will respond to a discovery request only if it is discoverable. On discovery it shares information such as the device name, class or the MAC address. We've designed it such that only paired devices are displayed, hence we compare the available devices against the inbuilt list of paired devices and only those that coincide both these lists.

We may check if the device listed is already paired by performing a querying operation using the getBondedDevices() function. We may from this list retrieve the MAC address and Bluetooth address of the device that we use in the encryption of the data.

Creating the connection requires the connecting of the BluetoothSocket of both the devices. They must be on the same RFCOMM channel. We initiate server sockets on both ends and they are listening to receive an incoming connection. The client service will open once it receives a connection and it is accepted. We may then use the OutputStream on the Server end to transmit the data and InputStream on the Client end to receive the data.

Accessing the file system is done by using an abstract representation of the file system which is identified by the pathname. We may use the inbuilt methods to access and manipulate the data.

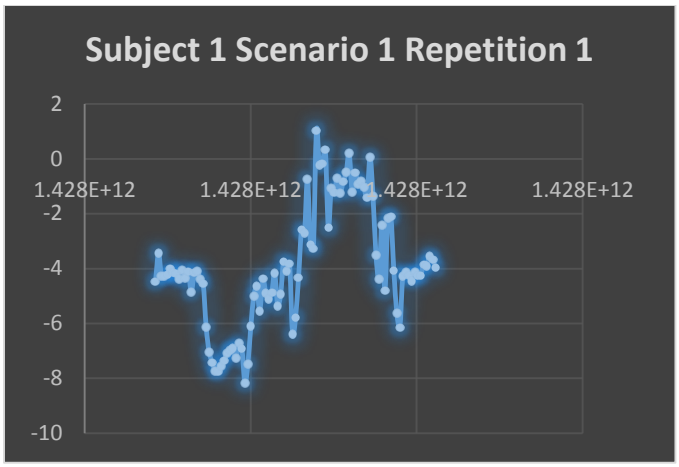

Fig.5. Graphical representation of the data from one action

V. HARDWARE SPECIFICATION

The device that is mainly utilized in the project is the Samsung Galaxy Gear Watch. It consists of a memory of 4GB and a processor of 0.5GB. We have observed that the battery life of a watch on full charge exists for a minimum of 48 hours on extensive usage of the device. Assuming that the android operating system utilizes around 1GB of the memory leaving the rest as memory storage for the application. In terms of memory usage, each file that we collected from a user over a test run of around ten minutes had a size of 150KB which means that we should be able to collect data for at least ~20,000 actions in terms of memory usage and the battery life would exist for around 34 hours.

VI. CHALLENGES

There were many challenges faced during implementation of the project. One of the major problems faced was the fact that data collection had become a cumbersome work because of the fact that different people had different ways of carrying out each particular action. Moreover, people have different dominant hands and hence a completely different orientation of hand for every particular action. The segmentation in the project had to be done manually. It was time consuming as we had to identify and segment a large amount of data manually. During the initial stages of the project we were required to manually retrieve the data from the watches.

VII. CONCLUSION

In this project we have demonstrated the use of android mobile phones and watches to build a comprehensive medical adherence tool with a feedback and recording option. It can be implemented easily because of the existing hardware. The data also can be sent to the doctors who can track the non-adherence. The aim of the project is that we will be able to start collecting and processing the data remotely in live time and provide feedback to the patient on his adherence to the prescription, the failure of which would notify the doctor. This

is a positive mechanism to improve the medication adherence rate of a person.

VIII. FUTURE WORK

Since the project is still in the initial stages we'd like to see that certain improvements are made. One of the major improvements possible is implementing an algorithm or software that is able to identify movements based on the statistical data obtained by the Smart watch in real time. Remote processing of the data and sending real time feedback to the subject can be implemented for improvement in communication of the system. The data collection between the watches should be synchronized.

REFERENCES

[1] Mohini Chaudhari, Kanak Saxena, "Fast and Secure Data Transmission using Symmetric Encryption and Lossless Compression," International Journal of Computer Science and Mobile Computing, Vol.2(2), p.58, 2013

[2] K. Rajasri, S. Sathiyadevi, S. Tamilarasi, "A Secured Data Transmission using Genetic based Encryption Techniques over Wireless Networks," International Journal of Advanced Research in Computer Engineering & Technology (IJARCET), Vol 2, Iss 3, Pp 1099-1105 (2013), 2013

[3] HIPAA, "Transmission Security Encryption: What to Do and How to Do It," http://www.hipaa.com/transmission-security-encryption-what-to-do-and-how-to-do-it/

[4] R. Umarani, G.Ramesh, "UMARAM: A Novel Fast Encryption Algorithm for Data Security in Local Area Network," Communication Control and Computing Technologies, Oct. 2010, pp.758-768

[5] Shaikh Rasool, Md. Ateeq-ur-Rehman, G.Sridhar, K. Hemanth Kunar, "Enhanced Fast and Secure Hybrid Encryption Algorithm for Message Communication," International Journal of Computer Science and Information Security, 2011, Vol.9(7), p.83

[6] Demijan Klinc, Carmit Hazay, Ashish Jagmohan, Hugo Krawczyk and Tal Rabin, *On Compression of Data Encrypted with Block Ciphers*

[7] Hridesh Verma, Indu Shailaney, Meenakshi Gautam, Harshit Gupta, Wireless Secure Data Transmission With Face Detection: A Two Way Security Approach, International Journal of Emerging Technology and Advanced Engineering, ISSN 2250-2459, ISO 9001:2008, Volume 3, Issue 4, April 2013

[8] Sabaté E, editor. , ed. *Adherence to Long-Term Therapies: Evidence for Action*. Geneva, Switzerland: World Health Organization; 2003.