A MEDICATION ADHERENCE MONITORING SYSTEM WITH MACHINE LEARNING APPROACH USING ANDROID BASED APPLICATION AND BODY-WORN SENSORS

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ABSTRACT

One of the most important challenges in chronic disease self-management is medication non-adherence, which has irrevocable outcomes. Although many technologies have been developed for medication adherence monitoring, the reliability and cost effectiveness of these approaches are not well understood till date. We develop machine learning algorithms that track wrist motions in real-time and identify medication intake activities. Patient adherence levels vary between 50% for depression to 63% for enlarged prostate. According to interviewers, on average adherence levels drop over the course of the patient journey from 69% of patients filling their first prescription to 43% continuing their treatment as prescribed after 6 months. We propose a novel data analysis pipeline to reliably detect medication adherence by examining single-wrist motions. Our system can achieve a good accuracy in adherence detection without need for medication pillboxes and with only one sensor worn on either of the wrists.

Keywords *: Medication Adherence, Decision tree, Flex, Accelerometer, Machine learning, Feature Analysis, Classifier Training.*

I. INTRODUCTION :

Adherence means "sticking to" or "being faithful to", such as your adherence to your diet even when chocolate cake is around, or student's adherence to school rules — they do not use cell phones or music players in class. Medication adherence usually refers to whether patients take their medications as prescribed, as well as whether they continue to take a prescribed medication.

The issue of medical adherence is growing in importance in the entire healthcare world. In various reports over the last decade, several voluntary health organizations – the World Health Organization (WHO), the National Institutes of Health (NIH) and the National Council on Patient Information and Education (NCPIE) – have identified poor adherence as a significant public health issue.

Increasingly, medication non-adherence is becoming a severe issue, leading to significant costs for the healthcare system and for the pharmaceutical industry.

In general, elderly people are more prone to forget the correct prescribed time; they usually take more medication and have difficulty reading medical information about medicines, which is part of a problem called medication non-adherence [6].

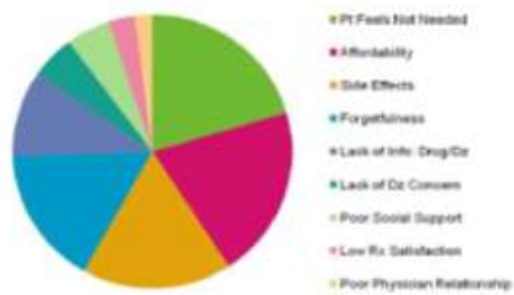

Fig. 1. Reasons for medication non-adherence [12].

II. EXISTING WORK:

There are several examples of current medication adherence monitoring technologies.

PillPack consists of a dispenser with a roll of packs of pills for a particular time. Each pack is labelled with the time and day, the pills are to be taken, and a list of all the pills in the particular pack [3].

Philips Medication Dispensing Service proposes a method for reminding patients to take their pill. The price of this service is about $800. It is not affordable for majority of the patients [3].

Two other technologies that are similar to Philips Medication Dispensing Service are GlowCaps and AdhereTech. GlowCap uses a built-in mobile SIM to communicate with a local transmitter which notifies the patient, using a blinking light, to take the pill or refill.

III. PROPOSED WORK:

We hypothesize that tracking wrist motions can be quite accurate in monitoring medication intake and inferring adherence versus non-adherence.

The smaller motions of the wrists (e.g. opening the cap, taking pill from the bottle, taking the pill, closing the cap) form a logical sequence of motions that can be tracked using machine learning algorithms and therefore could be sufficient for monitoring medication adherence.

The ultimate purpose of this study is to improve medication adherence without use of special pillboxes or as a complimentary technology that tracks wrist motions to ensure that the medication is taken.

Another novel aspect of our work is that it predicts medication intake regardless of the location of the sensor on human body and the number of sensors.

IV. SYSTEM ARCHITECTURE:

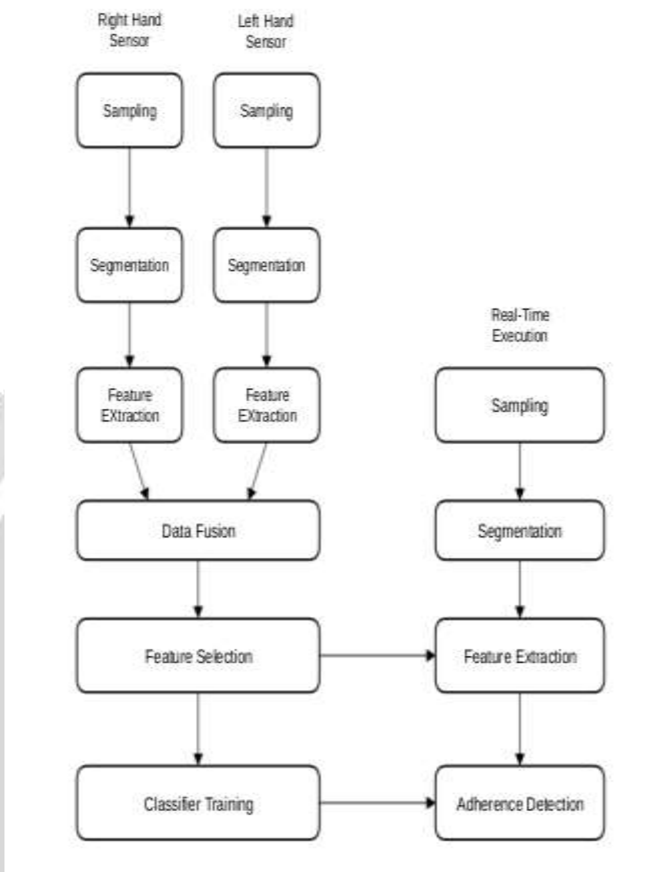

Fig. 2. Architectural Diagram

The overall architecture of our system and the process of data analysis are described. For collecting data, we develop an android application that gathers data from gyroscope and accelerometer sensors in all three dimensions.

The motion monitoring technique that will be developed in this topic is based on supervised learning methodologies.

There are a number of methods for event classification in supervised learning research. Examples include rule based learner, probability based learner, decision tree based learner, etc.

In this topic, we employ decision tree classifiers due to their simplicity and scalability. The proposed classifiers predict movements based on statistical features that capture trends in hand motions.

A. DATA COLLECTION AND ANALYSIS:

As mentioned previously, an android application is developed to collect motion data by locally storing accelerometer and gyroscope readings and to transmit the data to a computer via Bluetooth connectivity[1].

a.) Data Collection

b.) Signal Segmentation

c.) Feature Analysis

d.) Classifier Training

e.) Real-Time Execution

B. HARDWARE ARCHITECTURAL DIAGRAM:

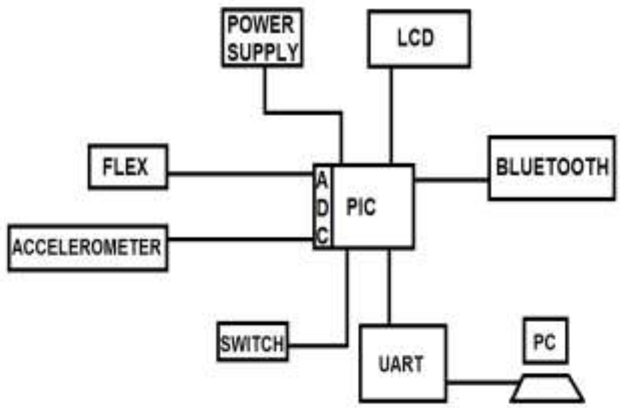

Fig. 3. Hardware Architectural Diagram

V. COMPONENT DESCRIPTION:

The different components or modules that will be involved are: -

1. Front End Module
2. Back End Module

A. Front End:

1. Android Application Module:

- After receiving the sensor readings from the microcontroller, the android application will store the readings locally in the device and the results will be displayed.
- When the user wants to use this android application the user should have this application installed in his/her smartphone.
- Then user should have his/her username and password for login.
- After this user will go through number of windows for getting the appropriate report of their medicine intake.
- User can set reminder for medicine intake.

The windows which the user will go through are:

1. **Login window:**
   In this window, user should have his/her username and password for login

2. **Connect to device through Bluetooth:**
   In this, user's phone is paired with the hardware device using Bluetooth to transfer data.

3. **Show records:**
   Select the Show Record button from this window to know your report.

4. **Set Alarm:**
   Here you can set alarm for medicine intake if required.

5. **Logout:**
   Click logout to successfully get logged out from the application.

B. Back End:

1. **Data Collection Phase:**
   In this module, different sensors like Accelerometer & Flex will track the different action/motions of the patient and forward the sensor readings to the microcontroller.

2. **Data Processing Phase:**
   After receiving the data from the sensors, the microcontroller will first convert the analog readings to its digital form.

3. **Data Transfer Phase:**
   Here, the digital data is forwarded to the android application.

VI. MEMS SENSOR:

The micro-electro-mechanical systems (MEMS) sensors, a class of devices that builds very small electrical and mechanical components on a single chip [11].

With their low power consumption and small size, MEMS sensors can be comfortably attached to the human body and operated for hours without stop [11]. We use accelerometers and flex.

A. ACCELEROMETER:

An accelerometer is a device that measures linear acceleration along three axes (x, y, and z) [11]. In the case of wrist motion tracking, an accelerometer can measure the linear motion of the wrist as it moves about in space [11].

In a MEMS accelerometer, the mechanical motion is converted into an electrical signal [11]. Accelerometers can only measure linear motion in the absence of any rotation and when the direction of gravity is known, so it can be subtracted out [11].

Fig. 4. Accelerometer sensor.

B. FLEX:

The Flex Sensor patented technology is based on resistive carbon elements. As a variable printed resistor, the Flex Sensor achieves great form-factor on a thin flexible substrate. When the substrate is bent, the sensor produces a resistance output correlated to the bend radius—the smaller the radius, the higher the resistance value.

Fig. 5. Flex.

VII. DECISION TREE ALGORITHM:

Assume that dataset D is labeled class tuple training set, the dataset has n categories, defined n different class Xi (i=1…., m),Xi,D is a subset of the class D in Xi, |D| and |Ci,D| are the number of D and Xi,D tuples.

D to desired information in a tuple classification is required:

$$\text{Info}(D) = -\sum_{i=1}^{n} \text{pi} \log 2(\text{pi}). \quad (1)$$

Pi is the probability of D tuples belong to the class C, with |Ci,D|/|D| represents, Info (D) is to identify the tuples in D which belongs to the class of entropy required, Info (D), also known as D of entropy.

Now assume that A is an arbitrary attribute in D,A is having j different values, then D can be divided into different subsets j with A {D1,D2,D3,…..,Dj}, which we can get by properties a division of D needed information:

$$\text{InfoA}(D) = \sum_{i=1}^{j} \left(\frac{|\text{Di}|}{|D|}\right) * \text{Info}(\text{Di})) \quad (2)$$

Information gain is defined as:

$$\text{Gain}(A) = \text{Info}(D) - \text{InfoA}(D). \quad (3)$$

Decision Tree algorithm based on ID3 algorithm and the introduction of the concept of split information to improve the shortcomings of ID3 algorithm:

$$\text{SplitInfoA}(D) = \sum_{i=1}^{j} \left(\frac{|\text{Di}|}{|D|}\right) * \log 2 \left(\frac{|\text{Di}|}{|D|}\right) \quad (4)$$

This value represents the information of the attribute A divide D to j subset.

Gain ratio is defined as:

$$\text{GainRate}(A) = \text{Gain}(A)/\text{SplitInfoA}(D) \quad (5)$$

VIII. EXPERIMENTAL RESULTS :

The android application is developed such that user needs to login using user id and password. After logging in, User will connect to the hardware using Bluetooth device using “Connect to Bluetooth” button. “Show Record” button will show all the stored records of medicine intake. Each record will have attributes like DATE and TIME. “Logout” button will be used to logout from the account. The below given screen shots are from the android application which is used to display medication intake report.

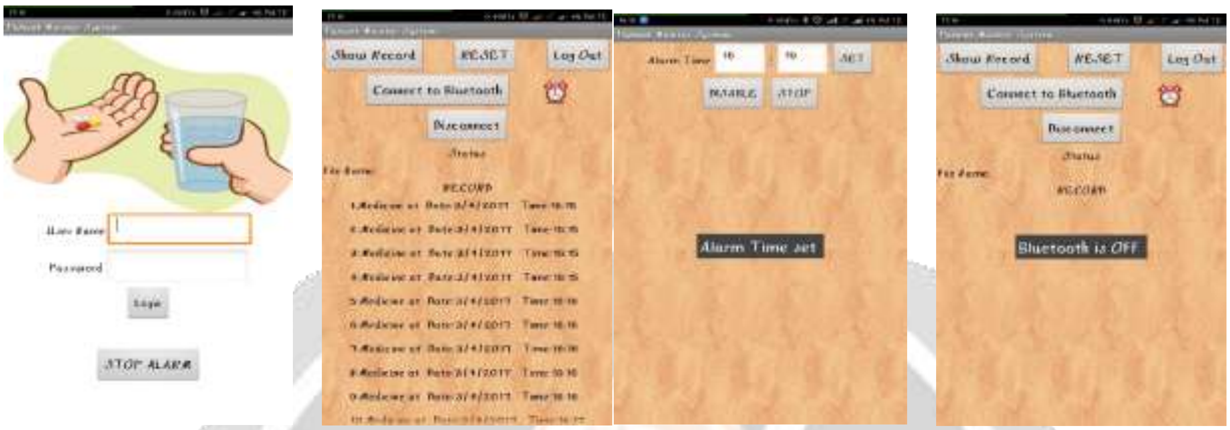

Fig. 6. Screen shots of the android application used to access medication intake data.

IX. ADVANTAGES:

1. Easy to use system:
   As this system is interfaced with the android application and nowadays all the people have smartphones, so this system will be easily available to the patients and the android application is easy to use.

2. Help to reduce risk of diseases:
   With the help of android application, the doctor and the patient will efficiently be able to decide to continue with the same medicine thereby reducing risk of diseases.

3. Size of sensors:
   As sensors is small in size and is of lightweight so it is easy to carry.

X. APPLICATIONS:

1.Doctors:

This system can be used by doctors to efficiently decide future medication for their patients.

2.Patients:

This system is used by patients for self-monitoring of medication adherence.

XI. CONCLUSION :

In this paper, a medication adherence monitoring system for pill intake using wrist motions has been introduced on a low cost wearable sensor. A supervised learning based methodology is proposed to monitor medication adherence using wearable sensors. Medication non-adherence has irrevocable impacts on patients and healthcare system. An approach to train a machine learning classifier for motion detection and adherence inference is presented. The proposed supervised learning based methodology monitors patient's activity and recognizes the action of pill-taking. Using the proposed system, the reliability will be improved as compared to existing systems. The front end focuses on displaying medication intake report using android application while the back end focuses on collection of various patient data.

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