AsthmaGuru: A Framework to Improve Adherence to Asthma Medication [*] [†] [‡]

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ABSTRACT

Asthma is a widespread chronic disease. Poor management of Asthma results in a large number of hospitalizations each year, the majority of which are avoidable through strict adherence to medication. AsthmaGuru is a system which aims to provide personalized guidance to users on their health state, with an aim to improve their compliance to medication. To achieve this aim, AsthmaGuru aggregates three forms of data: (a) automated and unobtrusive measurement of medication adherence using a low-power portable electronic attachment to an inhaler, (b) lung function measurement based on portable spirometry and (c) local air quality metrics. We leverage a custom low-power hardware platform for augmenting the inhalers and spirometry and develop a custom Android API for delay-tolerant data collection.

Categories and Subject Descriptors

C.5 [**Computer System Implementation**]: Microcomputers; J.3 [**Life and Medical Sciences**]: Health

General Terms

Design, Measurement

Keywords

Asthma, Adherence, Electronic Monitoring, Spirometry

1. INTRODUCTION

The compliance level for asthma medication reported by a number of studies carried out using electronic metered-dose inhalers (MDI) is less than 50% [5]. The main challenge associated with improvement of compliance is collection of accurate and reliable data for adherence to medication. The current systems for monitoring adherence are inefficient and cumbersome leading to a drop in adherence over time [2, 6, 4]. The collection of inaccurate compliance data fails to identify non adherence in patients and causes increasingly frequent exacerbations. A second challenge is collection of data for the risk-factors associated with asthma, for example medication adherence, lung function data through spirometry, location of usage and air quality information, and presenting them in a clear, user-understandable format. A summarization of the different forms of data is crucial to provide more meaningful personalized metrics to assess asthma control [6].

AsthmaGuru is a system designed to solve the challenges associated with non-adherence to asthma medication. It automatically and reliably measures adherence using an electronic monitoring attachment for MDIs solving the first challenge. For the second challenge, AsthmaGuru collects data for the risk factors using (1) medication monitor, (2) a portable spirometer for accurate spirometry, (3) WiFi Positioning System (WPS) for determining location of use and (4) a public website [1] for collecting air quality information to quantitatively understand current and predicted air quality indices in the geographical regions of the user. The data from all these sources is imported to a smartphone/tablet using a custom app and further analyzed.

2. SYSTEM DESIGN

AsthmaGuru has been built with three main data components: measurement of compliance, lung function and environmental factors. First, we develop a low-power portable electronic attachment, labeled *mobileHaler*, to automatically and unobtrusively record inhaler usage. The attachment records the time and location of dosage and is ultra low power, having a battery life of almost 3 years. Second, we use the same hardware core as the mobileHaler to develop a turbine-based portable spirometer, *mobileSpiro*, which can accurately measure lung function. The turbine-based mobileSpiro improves upon our pressure-based spirometer [3]. Much like mobileHaler, the new mobileSpiro can record time and location of a test. Also, both mobileHaler and mobileSpiro directly talk to a smartphone via Bluetooth, an Android device is used for the prototype built as a proof of con-

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cept. Finally, we develop a full Android application, to collect all three forms of data (medication adherence, spirometry and public air quality data from the government website [1]) in one application, opening the door to personalized analytics on the spatio-temporal user data.

Hardware Design: The hardware platform, shared between AsthmaGuru devices mobileHaler and mobileSpiro, mainly consists of a low power microprocessor (TI's MSP430), wireless modules and other shared components required for performing the desired operations. It is powered by a rechargeable Li-ion battery. This multi-purpose hardware platform has an analog front-end that fits both mobileHaler and mobileSpiro, resulting in low-cost and portable modular devices.

The mobileHaler contains a Force Sensing Resistor (FSR) which detects dosage dispensed by the inhaler. It is small with a diameter of 5mm, very robust and supports up to 10 million actuations (dosage delivery on pressing the MDI). The shared hardware core in the mobileHaler and mobileSpiro has a CC3000 WiFi chip on board which can be used to establish *indoor* location through WiFi Positioning System (WPS). The WiFi chip scans the local access points and records their SSIDs (service set identification). The Android application uses Google Geolocation APIs to determine accurate indoor location using the SSIDs sent. However if the user travels to areas with limited or no WiFi coverage, then GPS based location determination is essential. The low power feature of the MSP430 enables it to operate in two modes, active and sleep. The inhaler operates in the active mode only during actuation and syncing with the Android device enabling the battery life to be 3 years. A reminder system implemented using timers available on the Real Time Clock (RTC). Both Bluetooth 2.0 and 4.0 chips are available on board for future implementation on iOS devices. The size of the data packet per actuation is of the order of few bytes and millions of readings can be stored in microSD cards.

The current version of the mobileSpiro used for AsthmaGuru utilizes turbine flow-meter for a more compact and low cost design as compared to the pressure sensor based design built previously [3]. The turbine is attached to the hardware platform shared between mobileHaler and mobileSpiro, and therefore, has all the features described above. Its portability allows the users to perform on-the go spirometry. The mobileSpiro meets the ATS standards for spirometers.

Software Design: The software application has been currently built for use on an Android device but can be easily expanded to other platforms. The first layer of the software architecture is the hardware interface API layer which implements low-level drivers to communicate with mobileHaler and mobileSpiro. The next layer aggregates the medication, spirometry data and Air Quality Index (AQI) information from websites [1] and stores the data as inhaler usage and spirometry logs with corresponding AQI . The third layer performs analysis of the data history and displays trends of each of the variables over time.

The automatic, simple user interface makes AsthmaGuru easy to operate and doesn't require the patient to learn new maneuvers.

3. RESULTS

In order to test the accuracy of key features of AsthmaGuru, two small-scale studies were carried out. First, to test the mobileHaler hardware, a user trial was carried out to validate the mechanical actuation and the recorded timestamp feature. The trial was conducted with 17 healthy students (14 male and 3 female) from Rice university, aged 18-34. The participants were asked to operate three different types of MDIs, to ensure the safety of the individuals, two of the inhalers were empty and the third was a placebo. Since the attachment does not interfere with the dosage delivery in the front of the inhaler, the amount of medication dispensed remains the same and therefore, reaches the benchmarks set for a standard inhaler. The mobileHaler was able to detect 100% of the total 250 actuations by all the users. However, it is to be noted that the trial doesn't account for patients deliberately trying to falsify adherence data. Our prototypes are being modified such that in the future mobileHaler can also perform accurate patient identification while using the medication.

Second, the accuracy of the indoor location feature using WPS is tested. Since the firmware for WiFi hasn't been implemented for the mobileHaler yet, the SSIDs were obtained using separate programmable WiFi modules. The SSIDs for access points in ten different indoor locations in Houston were collected and the location was determined using Google's free Geolocation API. The geolocation API was able to detect 9 out of 10 locations accurately.

4. CONCLUSION

Reliable and accurate measurement of adherence to long-term medication is required for improving asthma control. AsthmaGuru is a comprehensive system built for effective management of this disease. It accurately measures a number of variables associated with asthma control viz., medication adherence, spirometry data for lung function and air quality index. Future versions of this system will be used to address patient identification, development of a personalized index/score for Asthma control and gamification.

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