Medication Adherence Monitoring using Machine Learning

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***Abstract*— Poor medication adherence threatens an individual's health and is responsible for substantial medical costs in the United States annually. In order to improve medication adherence rates and provide timely reminders, we developed a smartwatch application that collects data from embedded inertial sensors to monitor an individual's medication intake. Using distributed machine learning algorithms, we are able to learn a generalized series of motions that occur during an intake.**

I. Introduction

In 2010, patients in the U.S. spent $295 billion on prescription medicines, while the medication non-adherence rate was between 25% and 50%. Such a low medication adherence rate costs between $100 and $300 billion annually, representing 3% to 10% of total health care costs in the US. Beyond the overhead expenses, low medication adherence can lead to higher copayments for the patient and their families[1].

In order to improve medical adherence, recent studies have focused on developing systems that utilize low cost and wearable sensors which can remind, monitor medication intake and provide feedback [2][3]. In this study, we utilized a smartwatch to build a medication adherence monitoring system that records a patient's motion data from the watch's accelerometer and gyroscope. With scalable solutions for storage, data processing and the application of multiple machine learning algorithms, the system is able to predict several discrete actions including medication intake.

II. Methodology

Six participants were recruited to perform various activities that collected sensor readings while wearing a smartwatch. The activities included medication intake, walking, texting, writing, and drinking bottled water. Since each activity varied from 2.85 to 16.13 seconds, the data needed to be discretized per activity and extracted with the same number of features. This enabled us to apply machine learning algorithms for activity classification. The features used include a sliding window average for each bin with statistical values such as the maximum, minimum, median, and standard deviation over the time series. Figure 1 shows the data workflow using Amazon Web Services S3 and Apache Spark.

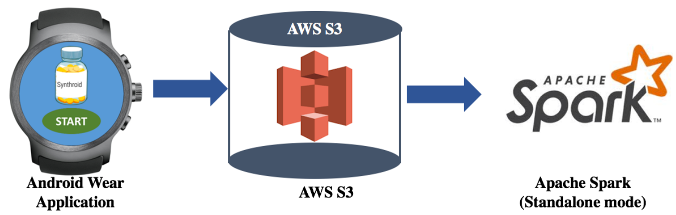

Fig. 1: Android application, AWS S3 and Apache Spark for data collection, storage and processing accordingly.

After preprocessing the data, it was split into a training set using 80% of the samples and a test set containing the remainder 20%. We used random forest (RF) models for activity classification. RF is an ensemble method that trains several decision tree models separately and aggregates predictions from each decision tree to make final predictions. It generalizes well on unseen data and is implemented in Apache Spark, allowing our solution to be scalable. To evaluate performance, we used observed the recall, precision, and confusion matrix of each model.

III. Results & Discussion

We compared model performance with different feature bin sizes ranging from 10 to 60. We achieved a recall of 1.00 and precision of 0.80 for the medication intake class at bin size 40. The average precision and recall across all activities were 0.91 and 0.93, respectively. Overall, we correctly classified all 12 medication intake activities and misclassified 3 other activities that have high variation such as drinking water.

In future studies, we would like to utilize near-field communication sensors (NFC) and biosensors to expand on our results. As an NFC allows data to be exchanged between electronic devices within close proximity, attaching such sensors on a medicine bottle would allow us to more accurately detect medication intake and therefore enhance study results.

References

[1] A. O. Iuga and M. J. McGuire, "Adherence and health care costs," *Risk management and healthcare policy*, vol. 7, p. 35, 2014.

[2] C. Chen, N. Kehtarnavaz, and R. Jafari, "A medication adherence monitoring system for pill bottles based on a wearable inertial sensor," in *Engineering in Medicine and Biology Society (EMBC), 2014 36th Annual International Conference of the IEEE*. IEEE, 2014, pp. 4983–4986.

[3] H. Kalantarian, N. Alshurafa, and M. Sarrafzadeh, "Detection of gestures associated with medication adherence using smartwatch-based inertial sensors," *IEEE Sensors Journal*, vol. 16, no. 4, pp. 1054–1061, 2016.