Multimodal Sensing for Tracking Medication Adherence Behaviors

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1. Description

We plan to build a system for tracking medication intake behavior using a combination of inertial sensing and computer vision. By combining these two modalities, we plan on detecting the following events: when the user picks up a pill bottle, when a user opens a pill bottle, when a user takes a pill, and when a user closes and puts down a pill bottle. Our hardware will consist of five small cameras and a phone (containing an inertial sensor) mounted on a large pill bottle. Four of the cameras will be mounted orthogonally on the pill bottle cap to capture a 360 degree view of the bottle's surroundings. The last camera will be mounted on the underside of the cap to detect whether the pill bottle is opened or closed. These cameras will likely be cubical with side lengths less than one inch. To detect when the pill bottle is being picked up or put down, we plan on leveraging two separate machine learning models applied to data from both the inertial sensor and cameras. Finally, we plan to use a convolutional neural network applied to data taken from the external cameras to detect pill-taking gestures.

To train our models and test our design, we will collect data from no less than five participants. During data collection, each of the sensors will be turned on, and each participant will be asked to repeatedly perform the relevant actions in whatever order they choose, while taking breaks between each sequence of actions. For example, a sequence may consist of a participant picking up the bottle, taking a pill, then putting down the bottle, or they may just choose to pick up and put down the bottle. Later, we will manually label the data based on the video collected from the external cameras. Additionally, we will also record data when the bathroom is in use but no pills are taken and when the bathroom is not in use. For our study, tic-tacs will be used instead of actual pills. After each session of data collection, the SD cards will be removed from the cameras, the recorded video will be downloaded, and the inertial data will be downloaded from the mounted phone.

2. Motivation

Estimates from the World Health Organization indicate that patients in developed countries only take about 50% of prescribed medicine for chronic diseases like hypertension and diabetes. Although seniors are the largest consumers of healthcare resources, studies indicate that as many as 55% of them do not properly take their medications and up to 30% of all hospital readmissions are due to medication non-adherence [7]. Not only is this non-adherence damaging the health of the individuals it affects, in many cases it can be life threatening. It's reported that as many as 125,000 people die every year due to failure to take their prescription medication [8]. Additionally, in patients that suffer from chronic mental illness medication non-adherence rates can be as high as 40-50%. Unlike senior citizens, medication non-adherence in chronically mentally ill patients is often conscious and not due to forgetfulness. Medication non-adherence in these patients can lead to hospitalizations, self-harm, violence or suicide [9].

Because medication non-adherence can cause financial and social harm, it would be beneficial for both physicians and patients to be able to track and detect instances of medication adherence, and by extension, non-adherence. Furthermore, a system for detecting medication adherence would have to be both mobile and robust for instances in which a patient tries to 'trick' the system. Our project aims to provide a proof-of-concept in which both camera and inertial data is used to distinguish pill taking

behaviors. Future works could extend this system to obscure the cameras and inertial sensors while also taking steps to eliminate privacy concerns - thus providing a mobile system that is more difficult to 'trick' than the smart pill bottles currently on the market.

3. Related Work

A significant body of research has been conducted to improve adherence to prescription medications through various interventions. Several researchers have attempted to detect pill-taking gestures using wrist-mounted inertial sensors [1][2]. One group equipped a pill bottle with an inertial sensor to classify activities [3]. Others have embedded pill bottle lids with sensors that detect whether the container is open or not [4][5]. One approach involved RFID chips on pill bottles to detect if the bottle is taken from a medicine cabinet combined with face detection and tracking from a stationary camera [6]. Many of these papers tried to increase adherence by reminding the user when they fail to take their medication. We aim to develop a system that could be applicable for senior citizens as well as mentally ill patients who don't take their medicine by choice rather than by accident. We believe that our approach is novel due to the combination of inertial and video sensing, and because the cameras are able to move with the bottle.

4. Resources

Our hardware will consist of five miniature cameras, a smartphone, and a large pill bottle. The five cameras can be found on sites such as Amazon for as little as $15. The smartphone will be mounted to the side of the bottle and collect accelerometer and gyroscope data. To train any neural networks that we used in our final product, we will use a GPU.

To collect and download the accelerometer and gyroscope data we will use an app such as SensorLog. We plan to program solely in python3, and to use the keras and sklearn libraries to build our models. We plan to use the keras library to build any neural networks we might use, such as a convolutional neural network to detect pill taking gestures. To build all other models and perform data manipulations, we plan to use the scikit-learn library. We may also use the OpenCV library for image and video manipulations, and tensorflow for creating more complex neural networks.

5. Expected Timeline

Week 1 (Oct 26th) - Order miniature cameras from amazon, create pill bottle mount, set up a website template
Week 2 (Nov 2nd) - Collect data from 5+ users, begin building our models
Week 3 (Nov 9th) - Build model to detect bottle opening and closing using the internal camera, begin model to detect pill taking gestures
Week 4 (Nov 16th) - Build model to classify activity using inertial sensor, complete model to detect pill taking gestures
Week 5 (Nov 23rd) - Refine and integrate models, write presentation, fill out web page
Week 6 (Nov 30rd) - Presentations Begin
Week 7 (Dec 7th) - Web Page Due

6. References

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