Smartphone-Based Anomalous Human Activity Detection and Prediction

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We propose a framework for real-time detection and prediction of *anomalous human activity* (AHA) using smartphones. AHA is any activity that indicates harm, or possibility thereof, to the individual carrying the phone. Examples of such activities include being pushed, being dragged and lifted. The above examples are of aberrant human *mobility*. Other examples of anomalous human activity, which can be in response to harm or in expectation of harm, include expression of *fear* (screaming, nervous walk) and *flight*. Our motivation originates in the staggering numbers of assaults on women in the metropolis of Delhi [1]. On the other hand, we have the proliferation of affordable smartphones that come with a variety of sensors including the microphone and the accelerometer.

The challenge is to achieve a high detection rate of anomalous activity at a small false alarm rate, using sensors in an individual's smartphone. Note that smartphone usage varies across people. They may place it in their pocket or in a hand bag. They may travel with it through crowded areas or may pass through areas that are mostly silent. The average activity levels are likely to vary too. Together with this is the loss of information that occurs when *all* human activity is encoded as a phone's sensors' readings. This can lead to confusing different activities to be the same. Recent works [2] that detect falls in the elderly have been shown to experience large false alarm rates. This is despite the fact that the mobile is attached to the elderly subject in a specific way.

Broad Proposal: In this work we propose to use a mix of inferring activities and their context, using models to better detect and/or predict anomalous activity, and humans-in-the-detection-loop, to achieve our goal of high detection rate and low false alarm rate. Note that on detection of AHA by the framework, the mobile phone will contact law enforcement. Hence, even a moderate false alarm rate of 5%-10% may not be desirable. Also, we do not expect a (likely) victim to physically interact with the phone, say by pressing a button, with the intent of indicating an anomalous activity.

Activity and Context: We propose to infer both the individual's activity and its environmental context. To exemplify, an individual may be in a hurry and walking at a brisk pace in a crowded market place. The walk pattern of the individual, as recorded by an accelerometer, while similar to a typical brisk walk in parts, is likely to contain many starts and stops. These abrupt changes in acceleration are explained by the environmental context, which is a crowded market place. Area being crowded may be inferred by the microphone by detecting above average decibels in the audible frequency range. Lack of this environmental context may make the start and stops look anomalous.

Modeling: We further propose to model the dynamics of anomalous and normal human activity to better separate the two and improve the detection and prediction of AHA. Currently, we are exploring pendulum based models to fit accelerometer data to natural human mobility. We also plan to model unnatural human mobility, for example, being dragged.

Humans-in-the-detection-loop: Lastly, we propose humans-in-the-detection-loop to reduce the possibility of a false alarm. Specifically, we are looking at the ability of people to accurately detect the call for help or scream of a friend in real world (noisy) circumstances. The friend's phone decides that the audio clues it is receiving correspond to its owner's scream. However, there is a reasonably large probability ($10 - 20\%$ in our current attempts) that the phone is triggered by what is not a scream. We are exploring the efficacy of using humans-in-the-detection loop to reduce the alarm rate in a timely manner. The phone will send the audio it thinks is a scream to a priori selected people. The final detection of AHA will involve the feedback of these people.

Current Status: We are collecting normal and anomalous human activity data using an Android application. Normal activity data is collected in controlled and uncontrolled settings. In the former, the subject is asked to perform a specific activity a certain number of times. In the latter, the subject uses the data collection phone instead of his/her personal phone. He/she is also asked to create an activity log. At the end of a few hours of use, the subject is asked to tag the collected sensor readings with the corresponding logged activity. We have collected such data from about 10 subjects. We have also collected a few traces for the anomalous activity of being dragged. Lastly, we have collected scream samples and also real world noise samples, which act as an input to our scream detection algorithms. Pendulum based models are being fit to collected human mobility data. We are also exploring Wavelets as a means of distinguishing AHA sensor readings from normal activity. Studies that help understand the efficacy of humans-in-the-detection-loop are on going.

Related Work: Work such as [3], uses mobile phones to classify users and/or activities. [4] is an example of work that models human gait dynamics. Recent work with respect to gathering audio clues includes [5] where the authors perform scream detection using a microphone array and a linux box. In our work we look at scream detection using a smartphone in noisy outdoor/indoor environments. In [6] the authors use pitch of voice and speaking rate to analyze the mental health of a subject. None of these works use mobile phone sensors to *predict* an anomaly in real-time. They also do not explore modeling of anomalous activity.

References

[1] "The problem with crime against women in delhi," *The Guardian*, Feb. 2011. [Online]. Available: http://goo.gl/yKZHL

[2] F. Bagal, C. Becker, and et al., "Evaluation of accelerometer-based fall detection algorithms on real-world falls," *PLoS ONE*, vol. 7, no. 5, p. e37062, May 2012.

[3] Matthew Boyle, Avraham Klausner, and et al., "Poster: Gait-based user classification using phone sensors," in *(MOBISYS 2011)*, pp. 395–396.

[4] M. G. Pandy, "Simple and complex models for studying muscle function in walking," *Philosophical Transactions of the Royal Society B: Biological Sciences*, vol. 358, no. 1437, pp. 1501–1509, Sep. 2003.

[5] W. Huang, T. K. Chiew, and et al., "Scream detection for home applications," in *Industrial Electronics and Applications (ICIEA), 2010 the 5th IEEE Conference on*, 2010.

[6] M. Rabbi, S. Ali, and et al., "Passive and in-situ assessment of mental and physical well-being using mobile sensors," in *Ubicomp*, 2011.