Smartphone-Based Intelligent System Using Motion Sensors for Real-Time Intervention During Heavy Alcohol Consumption Events

Jackson Albert Killian

Advisors: Dr. Kevin Passino and Dr. Arnab Nandi

Departmental Co-Signer: Dr. Jeremy Morris

Computer and Information Science, The Ohio State University

Introduction

Excessive alcohol consumption is an avoidable health risk, yet a significant percentage of deaths globally can be attributed to the drug [1]. On college campuses, where binge drinking is common, alcohol-related risk is especially dramatic. Recent work has shown that weekly mobile-based interventions can be effective in reducing alcohol consumption in students [2]. However, few studies characterize the efficacy of delivering mobile interventions in real-time during heavy drinking events; though such interventions could theoretically reduce event-level risks such as drunk driving, alcohol poisoning, and violence by ending drinking episodes before these outcomes. Such studies will not be desirable until a method exists for measuring real-time intoxication levels outside of a study setting at large scale. Some technologies exist for this purpose, but those currently available are impractical (user must answer surveys), expensive (smart-watches), or both (ankle bracelets). To address these shortcomings, we propose a smartphone-based system to passively track a user's level of intoxication to support the delivery of mobile-based interventions in real-time during heavy drinking events.

Prior Work

Applying machine learning to classify levels of intoxication has recently gained popularity. In 2015, Arnold et al. [3] trained an intelligent system on accelerometer data from a smartphone to classify with 70% accuracy the approximate number of drinks that participants consumed. However, their data was generated in a controlled lab setting rather than a real-world field setting. A model trained on data from the latter is more desirable since an end application needs to process data from a real-world setting. Additionally, a small sample size (N=6) and the use of self-reports to establish intoxication levels limited the reliability of their model.

In 2017, Bae et al. [4] built on this idea by conducting a field study (N=38) to gather a multitude of smartphone sensor data such as keystroke speed, sent/received calls, location and more. Their model correctly classified 96.6% of self-reported drinking episodes, allowing for theoretical intervention within the half-hour. This level of accuracy is promising. However, the intoxication level of participants was established using self-reports which the authors note is susceptible to biased, inaccurate, or missing data. Additionally, the accuracy of their model relied on constantly sensing and storing data for up to 3 days at a time, even outside of drinking events. Such prolonged activity can drain smartphone resources such as battery life, potentially forcing a user to stop using the application in a real-world setting.

For the study proposed, I developed an application (on iPhone and Android) to measure and store accelerometer motion data from smartphones, then collaborated with Dr. John Clapp's lab to install the application on the phones of subjects participating in the yearly "senior bar crawl" field study. I collected X, Y, and Z accelerometer readings as well as transdermal alcohol content (TAC) readings from an ankle sensor from 19 subjects over a period of 12 hours. TAC serves as a proxy for Blood Alcohol Content which is the standard for measuring intoxication levels. (IRB approval number: 2016B0092)

Problem Statement

I will use the data I collected to train a smartphone-based intelligent system to classify levels of intoxication given arbitrary smartphone accelerometer data, which can then intervene during heavy drinking events. My work will build on and directly address the shortcomings of recent studies and of currently available alcohol monitoring technologies. First, the data I gathered was from a field study, rather than a lab setting, making the end application viable for real-world use. Further, I will rely on accelerometer data to make classifications in real time. Thus, future users will only need the application to be active during drinking episodes, making prudent use of smartphone resources. Most importantly, our model will be trained on TAC data to classify levels of intoxication, ensuring that our final results are free from the bias inherent to self-reports.

Methodology

The research will consist of three main stages:

(1) Cleaning and developing a preprocessing method to feed data to our model.

(2) Choosing the optimal intelligent machine type for our model.

(3) Developing a smartphone application to house our model.

(1) Both the accelerometer and TAC data sets were generated by sensors in a field study, so both contain noise that must be cleaned. Notably, our model must make classifications while a subject is in motion, so we will filter out readings near zero (i.e. the subject was seated or their phone was off) and focus on walking-like trends as in **Fig. 1.** For the TAC data (seen in **Fig. 2)** we will employ a smoothing algorithm to make the data more closely match typical human alcohol metabolism trends [5]. Next, we will develop a method to preprocess the accelerometer data so that our intelligent system can effectively analyze them. Lamoth et al. [6] used accelerometer data to statistically validate a difference in the ability to control balance (center-of-mass) between leg amputee walkers and normal walkers. We plan to use this same metric as a starting point to classify the difference in center-of-mass control between sober and intoxicated subjects.

(2) Next we will design an intelligent system to classify the data. Many different intelligent systems exist for making classifications, but each must be designed and tested to determine the best for a given use-case, as exemplified in Bae et al. [4]. Thus we will develop and train many different systems on our data, comparing and reporting the performance and accuracy of each.

(3) Finally, we will develop a smartphone application to hold the optimal intelligent system from the previous step, retraining and testing the system on our data. To use the application, a user must activate the application once at the start of a drinking event, then they may use their smartphone as usual. The application will work in the background to track the user's motion during a drinking episode, constantly processing and classifying accelerometer readings from their smartphone. When the application makes classifications that indicate the user is experiencing a heavy-drinking episode, it will then trigger a basic intervention by notifying the user. More complex interventions can be built in as research progresses on effective real-time mobile-based intervention strategies made possible by our platform.

As the sole student researcher on the project, I will perform all methods described herein.

For this study, I plan to develop a manuscript for publication, publish the final application in open source, and make the application freely available to the public on smartphone app stores.

Conclusion

College age adults are susceptible to excessive drinking episodes, an avoidable health risk. By introducing a free, reliable, and widely adoptable application that tracks intoxication in real-time, we will enable development of effective real-time mobile-based interventions. Using our application, these interventions can then be delivered intelligently in real time, providing a means to reduce unnecessary alcohol-related injury and death. Our results and application will also serve as a platform for future studies in this growing field, as new technologies and sensor-bearing devices become widely adopted.

Personal Statement

I am a 5th year Physics and Computer and Information Science double major, graduating in Spring 2018. Two years of application development experience and two semesters of Intelligent Systems coursework have prepared me to lead this project. Further, I am passionate about this field; namely, developing artificially intelligent systems for social good. I will carry out this work to gain unique exposure in the field, and prove myself as a capable researcher. I am also currently applying to PhD programs in Computer Science (focused in Artificial Intelligence.) This study will distinguish me as an attractive candidate to those schools.

Figures

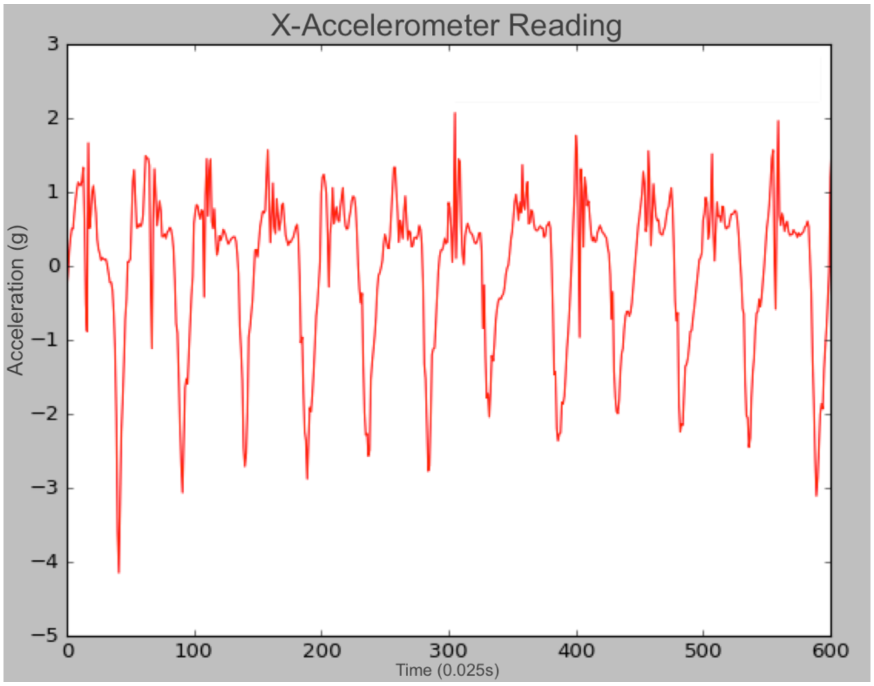

Figure 1: Accelerometer reading along the X axis over 15 seconds from a subject during a walking event. Features such as the average amplitude (peaks) and variance over many cycles will be used to classify sober vs. intoxicated subjects.

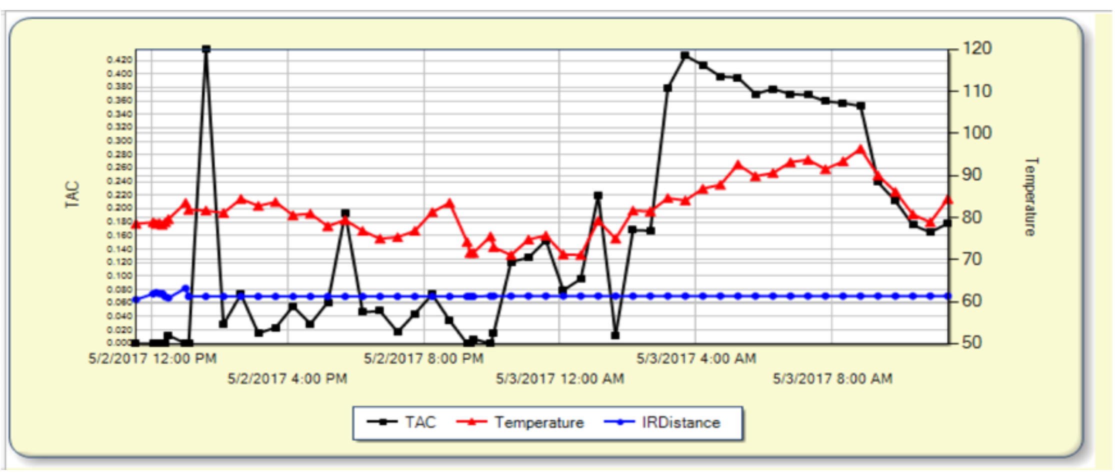

Figure 2: Readings over 24 hours from a Transdermal Alcohol Content (TAC) Sensor (black.) We will apply a smoothing algorithm so that data more closely mimics how alcohol is metabolized, serving as a better measure of true intoxication.

Bibliography

1. Rehm J, Mathers C, Popova S, Thavorncharoensap M, Teerawattananon Y, Patra J. Global burden of disease and injury and economic cost attributable to alcohol use and alcohol-use disorders. Lancet. 2009;373(9682):2223-33.
2. Suffoletto B, Kristan J, Chung T, Jeong K, Fabio A, Monti P, et al. (2015) An Interactive Text Message Intervention to Reduce Binge Drinking in Young Adults: A Randomized Controlled Trial with 9-Month Outcomes. PLoS ONE 10(11): e0142877. DOI: https://doi.org/10.1371/journal.pone.0142877
3. Arnold Z, Larose D, Agu E. Smartphone inference of alcohol consumption levels from gait. Healthcare Informatics (ICHI), 2015 International Conference on. IEEE. 2015. 417-426. DOI: 10.1109/ICHI.2015.59.
4. Bae S, Ferreira D, Suffoletto B, Puyana JC, Kurtz R, Chung T, Dey AK. Detecting Drinking Episodes in Young Adults Using Smartphone-based Sensors. Conference: PACM Interact. Mob. Wearable Ubiquitous Technol. (IMWUT), At Maiu, Hawaii. 2017;1(2):5. DOI: 10.1145/3090051.
5. Clapp J, Madden D, Mooney D, Dahlquist K. Examining the Social Ecology of a Bar-Crawl: An Exploratory Pilot Study. Submitted to PLoS one for review. 2017.
6. Lamoth CJC , Ainsworth E, Polomski W, Houdijk H. Variability and stability analysis of walking of transfemoral amputees. Medical engineering & physics. 2010;32(9):1009-14. DOI: http://dx.doi.org/10.1016/j.medengphy.2010.07.001.