Design of a Human Activity Recognition Solution Resistant to Measuring Device Inaccuracy

Assessing the Success of Heart Rate Monitoring Technology and Applying it to Human Activity Recognition

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

The way somebody is moving can give a lot of information about somebody that cannot be seen on the surface. Do they have an injury? Are they stressed or anxious? Are they fatigued? Human activity recognition can be applied to areas such as health, where it can help detect unseen problems or track the effects of injury. It can be used to study someone's psyche during a conversation based on body language or jitters. It can also be applied to sports, where it can be used to study an athlete's form when moving.

Recently, there has been work in creating machine learning and artificial intelligence solutions in order to be able to automate and effectively read body language and movements to be applied to such uses (Shah, 2023). Approaches using video footage can be easily obscured by foreign objects, models may only be able to make accurate judgements from a certain angle of view if the dataset was insufficient, and it becomes difficult to make such a technology widely applicable for everyday use as it’s unrealistic to expect quality live video footage of a person to be available at all times. Other approaches use wearable devices or phones. This method allows for the technology to be much more accessible to the general public; however, it is not able to pick up on subtle movements as well as a video feed. Furthermore, gyroscopes, magnetometers, and accelerometers can be imprecise and have variability depending on how the devices are fitted on a person. My work at MITRE looks to improve upon these solutions by inserting noise to data collected by wearable devices in order to train a machine learning model that can overcome the shortcomings of devices’ measuring accuracies and limitations and is not susceptible to malfunctions.

Improvements to predictive algorithms and measuring technology are not the only factors that benefit the greater adoption of human activity recognition technologies, societal aspects also play a role. Using actor-network theory, I will analyze the stability of the growth in use of Apple Watches based on public opinions and concerns, government regulations, and unforeseen possibilities.

With both my technical project and sociotechnical analysis, I look to explore the viability of creating an improved human activity recognition system for wearable devices while also assessing the plausibility of its long term adoption by examining the foreseeable success of the Apple Watch. It's necessary to carry out both projects as their successes are directly correlated. The success of a new technology can lead to a greater perceived need of the Apple Watch and the success of the Apple Watch determines if such a technology will be accessible to the general public. The results of the STS analysis will also prove useful in shaping the design of my technical project as it will highlight what concerns potential users of my project will potentially have that need to be addressed, for example, data security needs or a threshold for minimum acceptable accuracy.

Technical Project Proposal

With the omnipresent use of devices which can constantly record one's physical actions and the availability and presence of high quality cameras, the way has been paved for computer vision and machine learning technology to advance in the field of human activity recognition.

A computer vision approach was investigated by Vrigkas et al. where they tested several categorization techniques on video data with a subject performing an action in frame. Their work explored both unimodal techniques (techniques that base their categorizations solely on the subject's movement) and multimodal techniques (techniques that use extra information such as audio with motion to create categorizations). By using videos and supplemental sources of data for information in their algorithms, their models are able to make strong conclusions as the data they draw from are able to capture nuanced, fine details of the subjects behavior. However, this approach falls short for everyday purposes as it's too idealistic; such quality data is not going to be so easily obtainable at all times for any users. It's unrealistic to expect someone to have a high definition unobstructed video recording of themselves at all times; therefore, such an approach to human activity recognition would be more preferred for applications that occur in a controlled environment.

Another common approach to human activity recognition is to use data obtained from wearable devices or phones. One such work was done by Bayat et al. where they used random forests and SVMs, which are two common machine learning algorithms, to create their categorizations. Using this data format is suitable for everyday use as phones and smart watches that have accelerometers, gyroscopes, and magnetometers are deep-rooted in our society. There are some drawbacks: wearable device data can be imprecise depending on the orientation of it on a person and data obtained this way doesn't pick up on subtle features.

During my time at MITRE, I worked on creating a human activity recognition solution that takes advantage of the availability of wearable device data while also attempting to be unaffected against the presence of inaccurate data due to unreliable measurements. The goal of this work was to explore if software could overcome some shortcomings of hardware which would indicate that human activity recognition technology was ready for greater adoption.

The core foundation of my project used convolutional neural networks (CNNs) as the method to create predictions. Convolution neural networks are a popular form of machine learning which are commonly used to detect defining features in an image to categorize them. In order to take advantage of this, we must transform human activity data into images. Human activity recognition data from wearable devices typically comes in the form of numerical time series data, which is where measurements are recorded over allotted time intervals. This data can be transformed into spectrograph images to be used with CNNs. In my case, the data I used was time series and contained the actions jogging, walking, sitting, standing, walking up stairs, and walking downstairs. By using CNNs, my project benefited from the fact that CNNs are a well established technology. There are well tested and documented CNN architectures that I was able to use, specifically, ResNet18.

Uniquely, my project explored the possibility of creating a model that would be effective regardless of whether or not the given data was fully accurate. In order to do this, a CNN was trained using different combinations of faulty data to see how its performance was affected. To create faulty data, gaussian noise was added to different sections of the spectrograph to simulate inaccuracies resulting from device error. Ideally, by training on a mix of clean and noisy data, the resulting CNN would still be able to accurately make categorizations and recognize the need to ignore incorrect information.

STS Project Proposal

In 2015, Apple released the first iteration of the Apple Watch. Since then, the Apple Watch has become the best selling wearable device and has become a common daily item for millions of people. The Apple Watch's heart rate and movement measuring capabilities have enabled the development of health and human activity recognition tools; therefore, the device's success plays a direct role in the viability and adoption of these technologies.

Currently, Apple's dominant success has been attributed to the quality of life functionalities and fitness tracking ability. Apple watches are used for taking calls or texts, playing music, gaming, and making reminders. On top of being able to track users' movements, Apple Watches can also monitor heart rate to accuracies comparable to clinical measurements

(Evans, 2021). Although these features do contribute to the growing adoption of the Apple Watch, people are wrongly led to believe that the steady increase in use of Apple Watches is unquestionably stable. In order to fully assess the future of Apple Watch, the societal aspects surrounding the technology must be analyzed.

Apple Watches suffer from some data security issues. Attackers are able to access location, passwords, text, and data information because of vulnerabilities in the Apple Watch due to lack of encryption or unsafe transmission practices (Arnow, 2016). Despite these red flags, many businesses have not improved their security measures. Also, consumers are accustomed to sharing such information on social media and are seemingly unworried of these dangers (Arnow, 2016). These concerns have led to government intervention, where federal restrictions have been suggested such as the Smartwatch Data Act. This would place health data collected by wearable devices under HIPAA privacy protections, which are the same protections placed on doctor patient information (Rifkin, 2021).

Furthermore, Apple Watches are not as reliable as the public believes them to be. For heart rate monitoring, when the user manually activates for the data to be recorded, the data is reliable; however, when the watch is passively recording data in the background it’s found to be unreliable (Altini, 2023). Despite many consumers wrongly believing that an Apple Watch is able to, cardiologists and Apple have warned that Apple Watches are not able to detect heart attacks defined as myocardial infarction (Pearson, 2019).

The versatility of the Apple Watch makes it so there are uses and effects that are not immediately apparent. There is a growing concern that fitness trackers could be used in workplaces to monitor workers’ productivity leading to the debate on whether or not this is an invasion of privacy (Collins, 2021). Health tracking can be useful, but the unreliability can also lead to healthy users falsely believing they need medical checkups which then needlessly costs resources (Doris, 2017).

I argue that consumers' lack of concern for privacy, the government's slow implementation of regulations, consumers overconfidence in the technology, and lack of thought on unforeseen consequences has led to the overperformance and success of the Apple Watch. To frame my analysis of the Apple Watch, I will use the concept of actor-network theory (ANT). ANT claims that technologies can be viewed as a network of relationships between human and non-human actors which affect the technology in some way. The strength of these relations would then determine the success or failure of the technology within society (Cressman, 2009). I look to use evidence mainly from articles, surveys, and professional opinions.

Conclusion

The deliverable for the technical project will be the results of experimentation and the potential creation of a human activity software solution that can overcome shortcomings of measuring devices and make accurate categorizations with faulty data. Using actor network theory, the STS research paper will review the factors that affect the stability of the growth in adoption of the Apple Watch and how it pertains to the growth of human activity recognition technologies. The combined results of these reports will assess the potential breakthrough of the success of human activity recognition, the current direction that the technology is progressing, and what actors must be considered to promote the success of the technology.

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