Physical Activity Monitoring using Accelerometers

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Abstract

In today's society there are those who would like to keep track of how active they are. These situations span across a wide range of lifestyles such as those that are extremely active to those who are prescribed to be more active. Designing a system to monitor an individual's physical activity would assist the desires or needs of these individuals. We have developed algorithm that can detect differences in activities (e.g. walking, running, and jumping) as well as inactivity. With these algorithms, we constructed an application that can monitor, store specific data of activities, and report various statistics of the user's activity throughout the day. This system could be used in hospitals, nursing homes, or for one's personal use. This system is an ongoing research project that allows for educational experience by developing methodologies and testing each one. The system is designed to read data coming from a 3 axes accelerometer sensor, filter the data, and then analyze aspects of the data to determine the current activity. The data is first filtered by summing the square of each axes and then taking the square root of that sum. This is called the magnitude. After, we take the average of every ten magnitude calculated. From here the derivative is calculated roughly every tenth of a second. Based on the results of the algorithm, the system displays the current activity that is detected, time active, total time recorded, and calories burned. Many devices today, for example smart phones, have an accelerometer sensor inside the device. This system was implemented into an Android application to function on Android smart phones. The development of this application took place within the Eclipse software environment. By combining this algorithm and more data analysis we can merge this design into medical devices or smart phones of individuals interested in the product.

Introduction

By using a tri-axial accelerometer to gather data about the user provides an advantageous approach in determining the current activity being performed. An accelerometer is a device that measure proper acceleration. In this case the measurement is based on the acceleration of Earth's gravity. Gravity "pulls" on objects using 1 gravitational force (g) or 9.8 meters per second. So if the accelerometer were to lay face down or up the Z axis would have a measurement of 9.8 meters per second and the X and Y axes would show 0 meters per second.

A system that involves monitoring the physical activity of an individual can be very valuable. Research has shown that people who have activity trackers have higher levels of activity than those who do not [3]. These higher levels of activity from users of activity trackers can help prevent the rise of obesity [4]. If the trend from these studies were applied to the general public then the benefits of being more active would lead to healthier lives and lifestyles.

Activity monitoring systems could easily be made adaptable to emergency systems in case of emergencies. Accelerometers make these systems easy to create and with the current market system availability to these systems are just as easy. There have been other projects that monitor physical activity as well. These projects analyze accelerometers, GPS data, or require the user to have multiple sensors either on their person or within their living quarters [5]. With the use of GPS they determine the activity by how fast the user is moving [6]. This approach however requires external communication to gather data. This same concept also plays a vital role in systems involving multiple sensors. Systems involving accelerometers are more responsive since the data is collected as the user moves.

Our project is an Android application that uses the accelerometers embedded within smart phones. The Android application is compatible with Android versions 4.0 and higher. The application was developed within the Eclipse software environment. Our algorithms were derived from our interpretations of the data as well as concepts from other applications. In order to conduct our interpretations, we plotted the data in many variations using Gnuplot.

Analysis and Development

The system is designed for the accelerometer to be place within a pants pocket. From here there exist some standards in manipulating the data from the accelerometer. A common filter used is to calculate the magnitude of the data. This calculation involves squaring each axes, summing each axes, then taking the square root of that sum [1]. With the magnitude calculated, algorithms analyzing the data become much less complex in terms of the number of parameters being reviewed. This data is easier to manage but still can be very sporadic. So, in order to minimize this attribute we add another filter on the data.

This additional filter works by calculating the average of every ten magnitude points received from the first filter. This method is implemented by gathering ten points, calculating the average, deleting the first point received, and adding the next point generated [2]. By using this method the data simplifies even more and allows for continued analysis instead of waiting for a new set of points every time an average is calculated. Even with this set of filters, the data can still be misleading and pose a challenge to incorporate an algorithm that can handle any situation given. Therefore an additional view of the data was added.

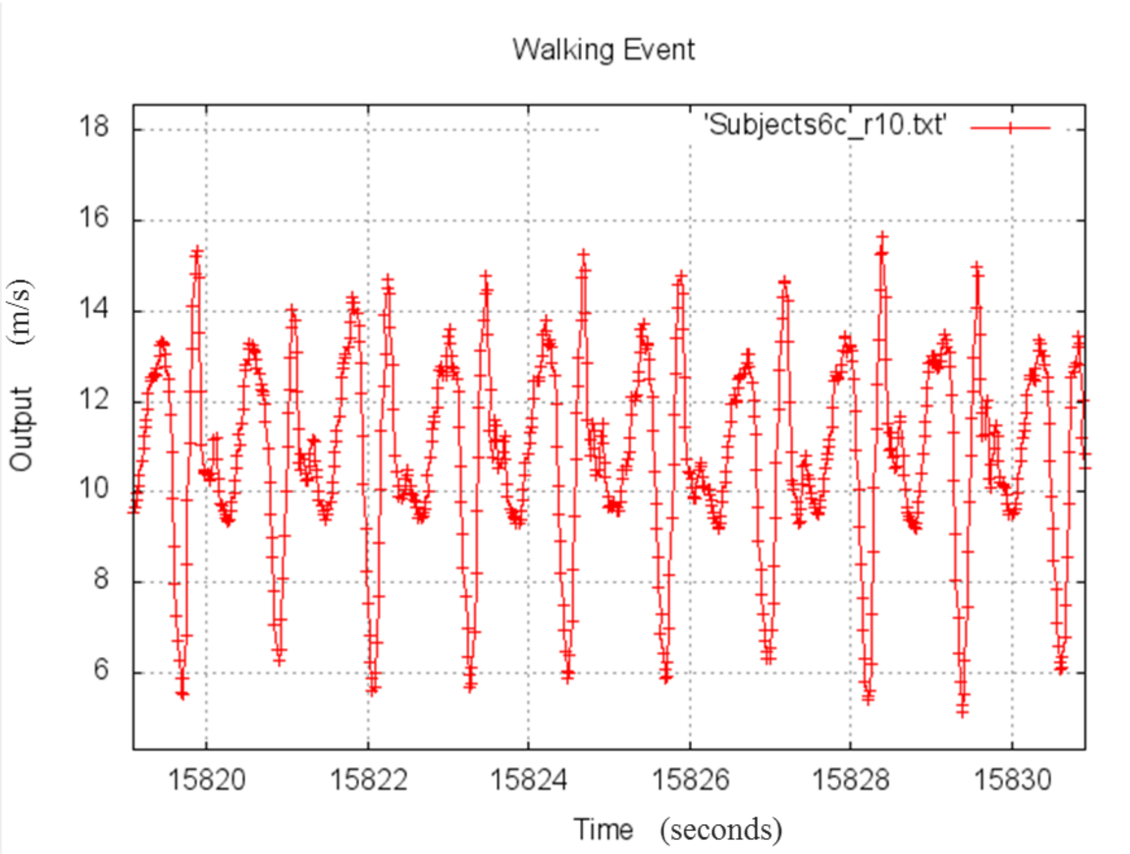

Figure 1: A graph of the average of every ten magnitude points

To further simplify the data, the derivative of the average from the second filter is used. This calculation is performed about every tenth of a second. Figure 2 helps to show how the data has become simplified in comparison to figure 1. Whenever there is an increase in activity the derivative rises and falls in accordance with the activity being performed.

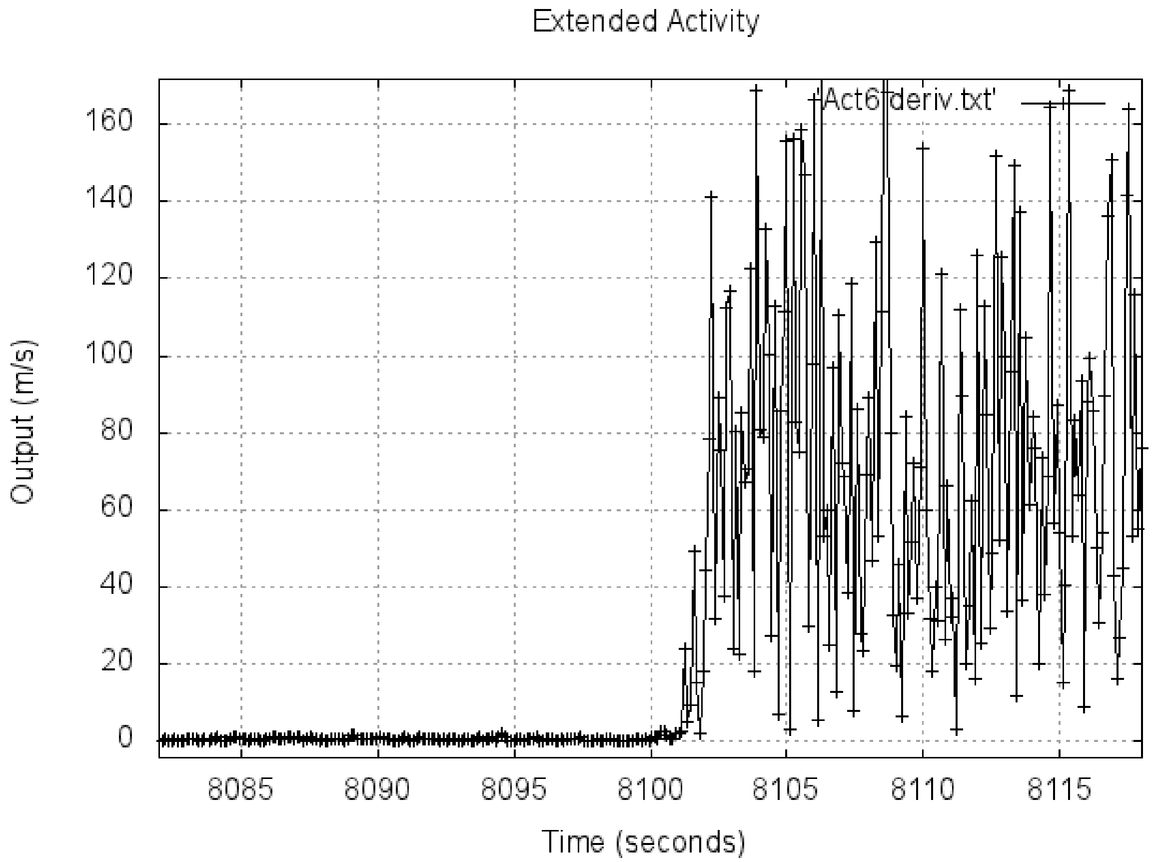

Figure 2: A graph of the derivative of the average every tenth of a second

Upon reviewing the derivative values produced, we notice a distinctive difference between activities. Figure 3 provides a visual of the difference between walking and running. While analyzing the graph, walking appears to have many data points below 55 and the values for when one is running are typically higher. When there is no activity the derivative is essentially zero since there is very little change occurring. This behavior is consistent with observations of how active an individual is when walking in comparison to running. From here we constructed an algorithm that can determine when an individual is walking, running, or inactive.

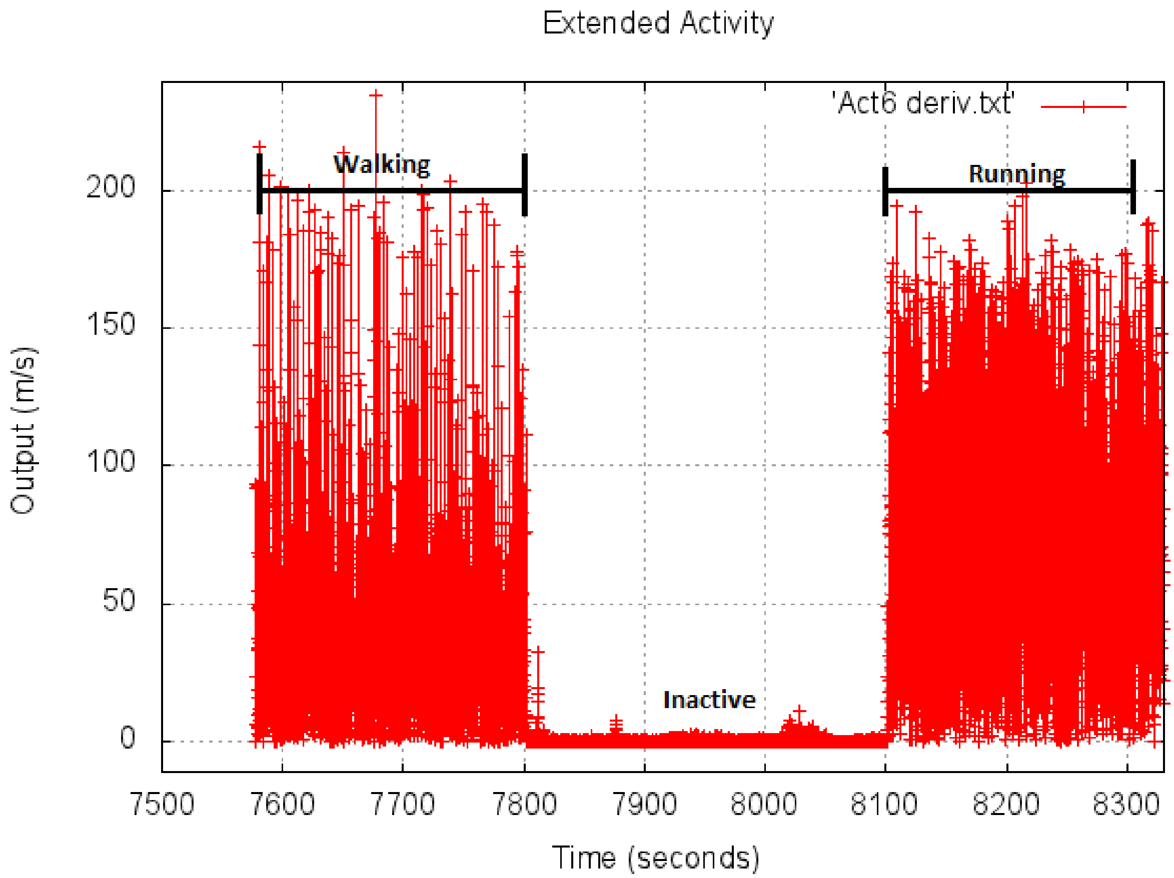

Figure 3: A graph of the derivatives between inactive, walking, and running

For practical purposes we define running as a rapid movement state. Walking is viewed similarly except the rate of movement is drastically less. Following these practicalities, the algorithm performs checks on the derivative values produced to determine the activity of the user. The algorithm reports a two for running, one for walking, and zero for inactive. Since the data still produces some fluctuations the average of a set of twenty derivative points is calculated. This is roughly equivalent of calculating the average of the derivative every two seconds. From this value we perform a check to see if the average is above fifty five and the state is not one. If so, the state of the activity is set to two. If above twenty and below or equal to fifty five and the state is not two, the state is set to one. Otherwise the user is inactive and the state is set to zero.

This process performs well in determining the user activity, but with fluctuations in the data there are opportunities that the algorithm will report incorrect states. So another check is made to validate the current activity. If the derivative is above forty and the state prior was two, then the state is still reported as two. Another validation is the check if the derivative is above fifteen and the prior state was one then a one is reported. If the first check and validation are not met, then the state reported is zero. This accounts for the data fluctuation attempting to corrupt the algorithm. Figure 4 conveys the simplicity of the algorithm in a block diagram.

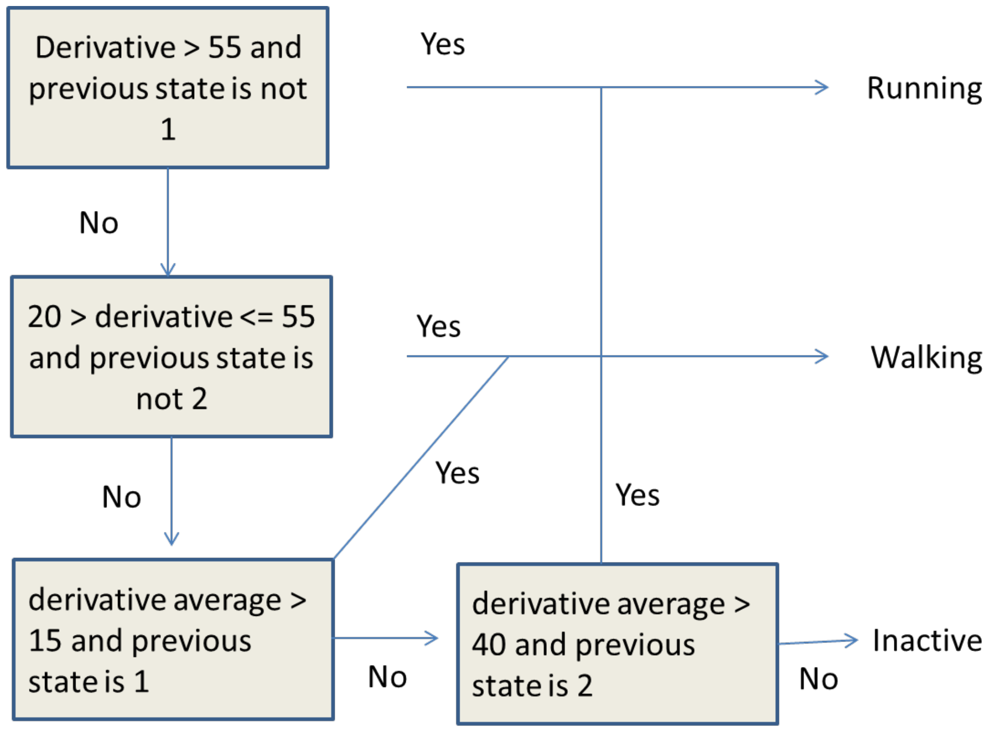

Figure 4: Block diagram of the algorithm core

The process of breaking down raw data helped to create this algorithm and provide relatively simple solutions to solve the given problem. In this case the problem was to figure out the activity of an individual. This also provides a simple approach in determining the physical activity of an individual as well as easy implementation into any system designed that could use output of such an algorithm.

Results

The Android application was then created and the algorithm was implemented to analyze the accelerometer data. After which ten tests were performed on the purposed algorithm.

Each test lasted twenty minutes in which the subject would perform variations of walking, running, or inactivity for five minute intervals. Every possible combination with this testing method was performed. The output of the state was written to a file to be reviewed if the algorithm was performing correctly. Figure 5 shows the output during one of the tests.

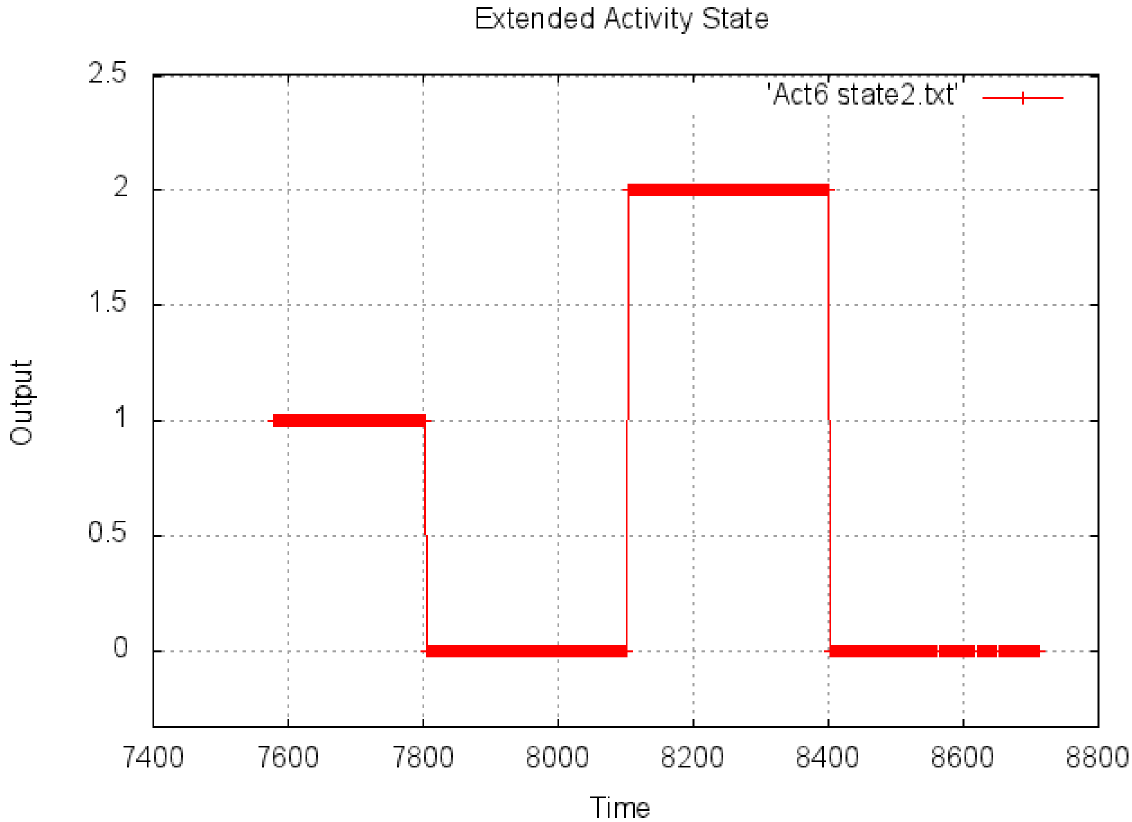

Figure 5: A graph of the output of algorithm during the test

From here a review was performed over every output file from the algorithm. After being reviewed, the algorithm performed 100% success on determining the activity of the subject on every file. Although the success rate was very good, these tests were only performed with one individual. So therefore more tests would need to be conducted to verify the results performed from these experiments.

While reviewing other projects designed to determine physical activity very few analyze the derivative of the accelerometer data. The projects that do analyze the derivative appear to be designed for only individual use. By using filters such as these provided and orientation of the phone, determining any activity becomes simpler. This leads to a simpler algorithm with high effectiveness and efficiency. Projects that do not filter accelerometer data can lead to very complex scenarios in which developing an algorithm to determine physical activity would be difficult.

With the success of this project, a physical activity monitoring system that is reliable and adaptable is easily achievable. This system can be combined with algorithms that check for emergency situations such as falling. In which case, the system would send an emergency response to a medical unit for assistance. This addition could be very useful in nursing homes, hospitals, or elderly/disabled persons living alone.

Future tests will consist of longer periods of testing the algorithm to ensure accurate results. In attempts at adjusting minor thresholds, small scale tests will be conducted to try and produce incorrect output. This will be a benefit as potential data could be misleading. Also to widen support for the algorithm, tests with subjects who volunteer will be pursued to ensure the algorithm is tested outside the lab to ensure accurate results.

Relevance to Engineering Education

This project provides an intricate view on the concepts of computer science. Creating methods and processes that are effective, efficient, and definitive results are crucial in computer science. A project such as this requires knowledge of mathematics and computer science principles in order to achieve an accurate system using accelerometers. While working on this project, abilities involving problem solving and programming were heightened. If one were to participate in this project they would need to be able to practice computer science concepts on various problems. Maintaining high attention to detail is crucial in creating a system that could potentially run indefinitely. This type of project is extremely valuable as it provides new ideas in the medical field and a chance to improve problem solving abilities that could help within academics.

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