MOBILE MEDICAL APP FOR REMOTE SCREENING OF APPENDICITIS

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Mobile Medical App for Remote Screening of Appendicitis

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SUMMARY

This study aimed to identify the possibility of using the sensors found in mobile devices as tools for remotely diagnosing or assessing the risk of appendicitis. The study was performed by created a mobile application on an Android device and testing the repeatability of the palpations a physician would perform on a patient across patient groups and across mobile environments.

CHAPTER 1

INTRODUCTION

Appendicitis is a serious medical emergency in which the appendix becomes inflamed and must be surgically removed. Unfortunately, symptoms are fairly non-specific, consisting primarily of generalized abdominal pain, which could also be due to benign causes like heartburn or indigestion. Physicians currently screen for appendicitis by conducting a physical exam that involves palpating (applying pressure to) the patient's abdomen. If the patient's abdomen is exquisitely tender upon palpation, the likelihood is high that the patient has appendicitis and that he/she would require immediate surgery. As such, appendicitis screening currently involves direct patient to physician contact. Most cases result in benign abdominal pain that is not tender upon palpation and require no further intervention1. Unfortunately, appendicitis screening can be a significant time and cost investment for the patient and the physician. Despite the ubiquitous availability of smartphones with high precision inertial sensors integrated with highly capable processors there is still an uncertainty in the Telehealth field of the extent to which smartphones can remotely assess the risk of a serious ailment2. In order to determine the efficacy of the risk assessment capabilities of smartphones, this study created a smartphone application that enables physicians to remotely screen for appendicitis.
A physician calibrates the application by performing palpations on themselves using their own mobile device. The calibration information from the physician's phone will be sent to the patient's phone. This information is used to teach the patient's phone how much force the patient should be applying while performing palpations. This is a necessary step

because it ensures that the physician can objectively analyze how much force the patient is exerting. Using visual and auditory notifications, the application will help the user recreate the intensity and duration of the desired palpation. Ideally, the physician will be able to watch the patient both perform the palpations, and estimate their pain level through visual cues. This information would enable the physician to recommend future treatment. This research has implications for the medical field because it will provide additional information on how smartphones and mobile devices can be used for diagnostic or risk assessment purposes.

CHAPTER 2

MATERIALS AND METHODS

The application will be programmed in Java on the Android platform. In order to test the consistency within the device across varying compression depths and intensities a mechanical testing fixture that can perform palpation motions on an abdominal model will be built. The abdominal model that will be used is ten centimeters of upholstery foam as it will provide support and elasticity similarly to those of an abdomen. The test for internal consistency will consist of five different rates of compression and five different depths of compression. The compression will then be characterized as a hyperplane in the third dimension. This characteristic surface can then be used to test for consistency within the mobile device. The consistency test will consist of eight compressions at each of the corner cases. A t-test will be used to determine if there is significant predictability in the repetition of the corner cases. If there is the capacity of prediction, the study will then test the algorithm across devices with the same methods for the consistency test within the device. After IRB approval is obtained the intra- and inter-user variability among different subjects will be determined. Subjects will consist of Georgia Tech students, and two physicians in the lab will be present to assist in the experiment. To test for consistency within users a subject will perform a compression and then attempt to mimic that compression eight times. This procedure will be repeated with multiple subjects to determine if there is significant repeatability. To test for consistency across subjects the subject will be provided with a target return value and will perform compressions to attempt to repeat the target return value. This procedure will be repeated with multiple subjects in order to determine if there is significant repeatability of compression given a target return value.

CHAPTER 3

RESULTS

The results of the compressions of the mechanical testing fixture to examine internal precision of the mobile device can be seen in Figure 1. The set of peaks for each of the four corner cases occupy a unique space on the graph of acceleration against time. The black lines represent a slow and deep compression, the red lines represent a fast and deep compression, the green lines represent a slow and shallow compression, and the blue lines represent a fast and shallow compression.

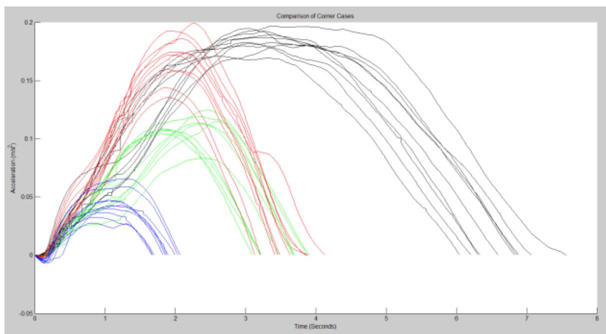

Figure 1. The data from the test for internal error in the mobile device. The black lines represent the data from the slow and deep compression, the red lines are fast and deep, the green lines are slow and shallow, and the blue lines are fast and shallow.

The compression test of the repeatability of the physicians yielded two main types of curves seen in Figure 2. Curve A was produced by simply compressing and then decompressing rapidly. Curve B was produced by compressing and then holding, therefore decreasing the acceleration, before decompressing.

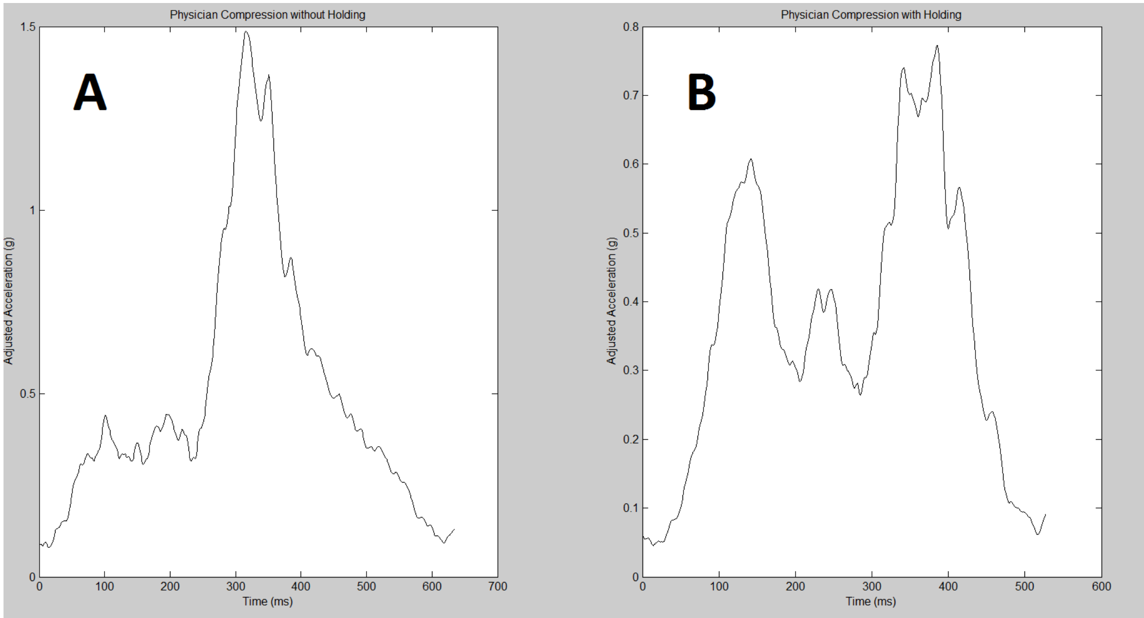

Figure 2. Curve A shows the adjusted acceleration curve of a physician who compressed the mobile device and rapidly decompressed the device. Curve B shows an adjusted acceleration curve of a physician who compressed the mobile device and held it compressed before decompressing.

Figure 3 shows a compression performed by a physician in which the mobile device was compressed and then rapidly decompressed without holding. The rising section is the acceleration curve of the compression. The peak of the curve is the point at which the device has been compressed completely. The falling section of the curve is the decompression of the curve.

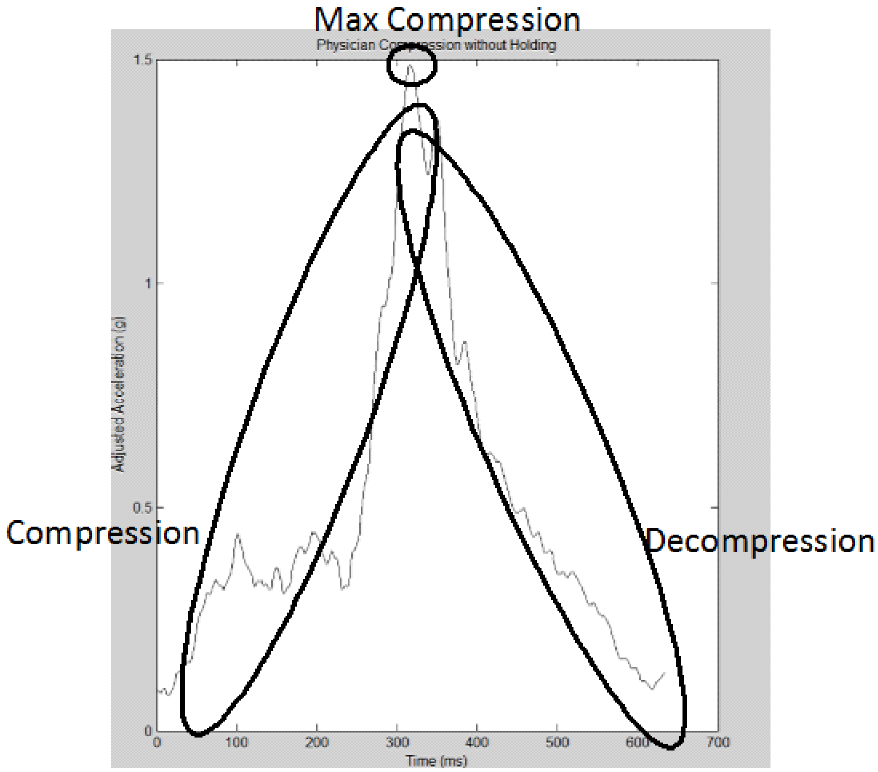

Figure 3. An example of a palpation performed by a physician in which the device was compressed and released very quickly without holding while compressed. The rising section of the curve represents the compression of the device, the peak represents the max compression and the falling section of the curve represents the release of the device

Figure 4 shows a compression performed by a physician in which the mobile device was compressed, held at maximum compression, and then rapidly decompressed. The rising section is the acceleration curve of the compression. The peak directly after the compression is the point at which the device has been compressed completely. The falling section of the curve is the decompression of the curve. The horizontal section between the compression and decompression is the holding of the compression.

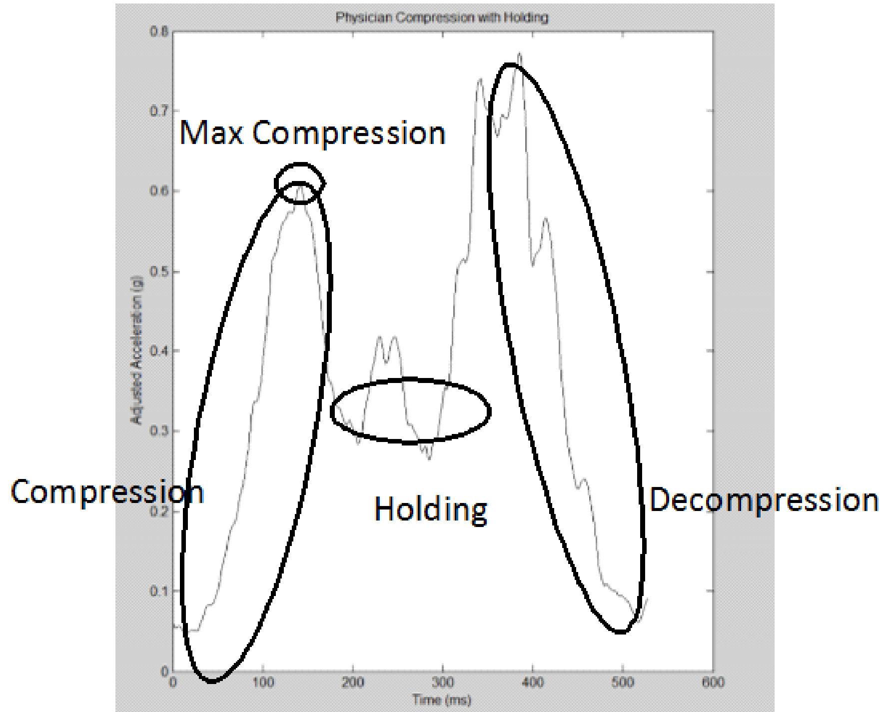

Figure 4. An example of a palpation from a physician that holds the device when compressing. The rising section of the curve represents the compression of the device, the peak above the rising section represents the max peak, the falling period and the relatively flat section after the compression represents the holding of the device and the rising and falling section after the holding period represents the release of the device.

The compiled average of the target compressions from all ten physicians is shown in Figure 5. It is shown alone in addition to overlaying a sample of acceleration curves from four different physicians.

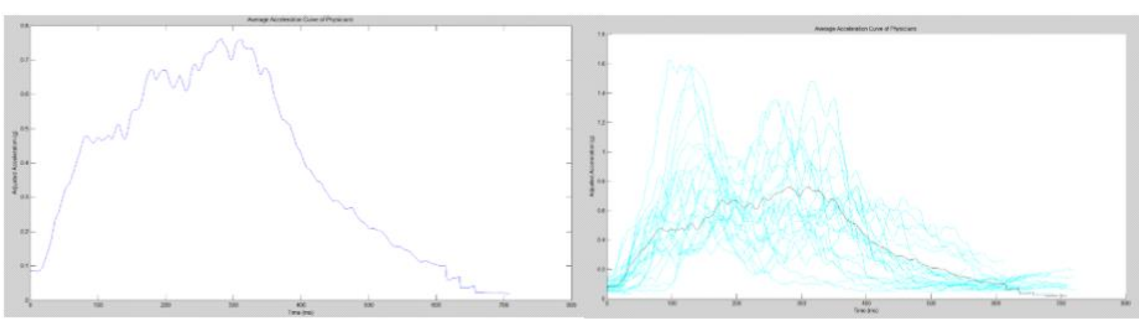

Figure 5. The average of all ten target compressions from physicians is shown on the left. On the right it is shown overlaying a sample of acceleration curves from four physicians.

Figure 6 shows two samples of patients attempting to replicate their own compressions. Out of the seven patients tested, three were able to immediately replicate their target compression. The other four varied in repeatability.

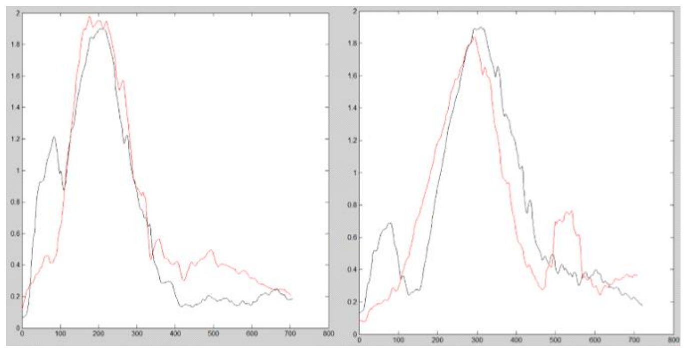

Figure 6. Two samples of the patient repeatability test. The red line in both images represents the target curve and the black line represents their attempt to match their target curve.

Figure 7 shows a patient who initially had trouble repeating their set target compression. The red line represents the target curve, the blue lines are the intermediary curves, and the black line is the curve that matched the target curve.

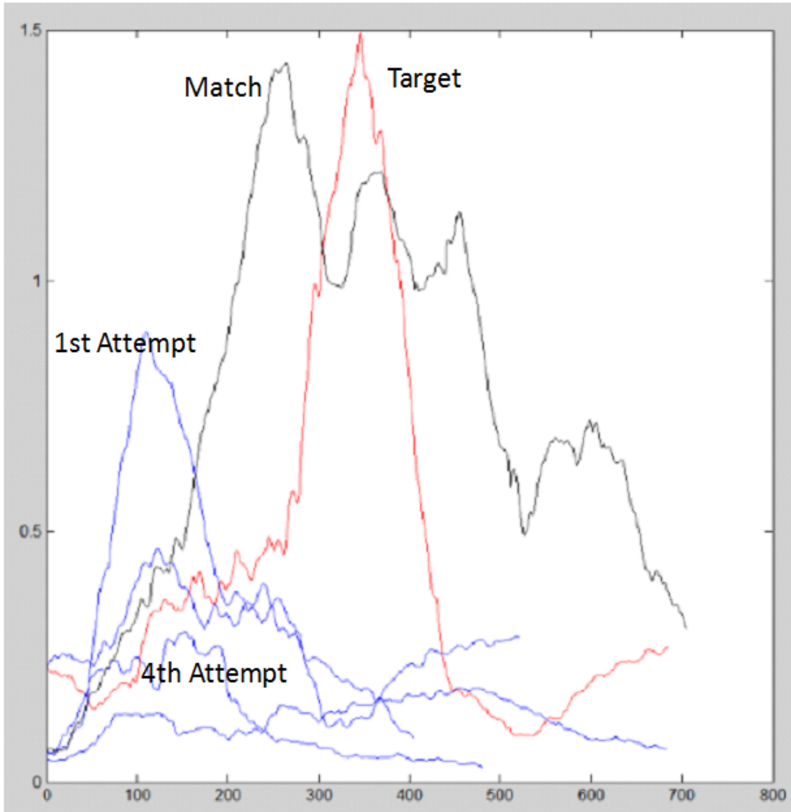

Figure 7. A patient's self-set target acceleration curve (red), the first attempt to match the curve (blue), the 4th attempt to match the curve (blue) and the final and successful attempt to match the curve (black)

In the test to examine how patients could repeat compressions performed by physicians a sufficiently matched compression is one in which the peak of the patient's acceleration curve is within 5% of the physician's peak in both the x-axis and the y-axis. A graphical representation of this can be seen in Figure 8.

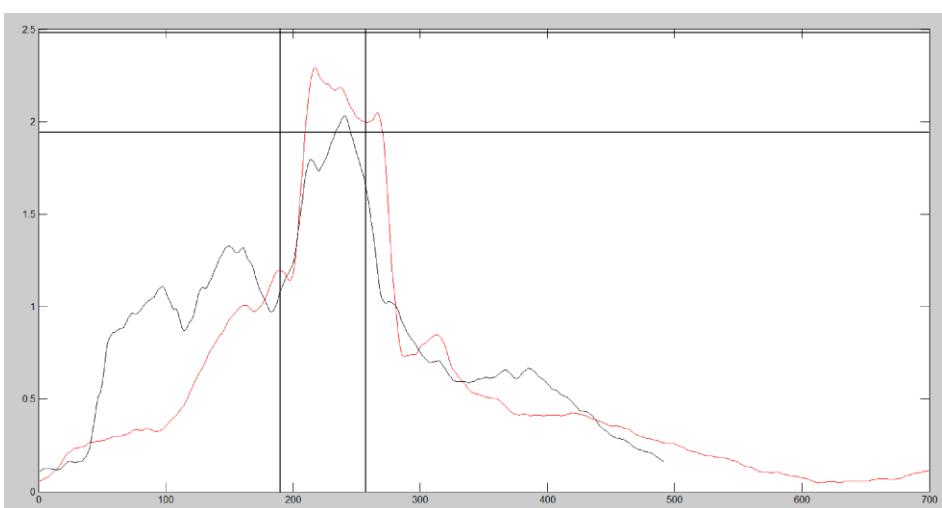

Figure 8. The two vertical lines surrounding the physician's curve (red) represent the allowed error (+/- 5%) of the speed of the compression. The two horizontal lines surrounding the physician's curve represent the allowed error (+/- 5%) of depth of the compression. The peak of the patient's curve (black) can be seen to be in this 5% box so it was classified as a matched curve

With instructions, patients were able to replicate the physician's acceleration compression. A sample of one of the patient's compression iteration can be seen below in Figure 9. The physician's curve is shown in red, the patient's matched curve is shown in black and the two failed attempts are shown in blue.

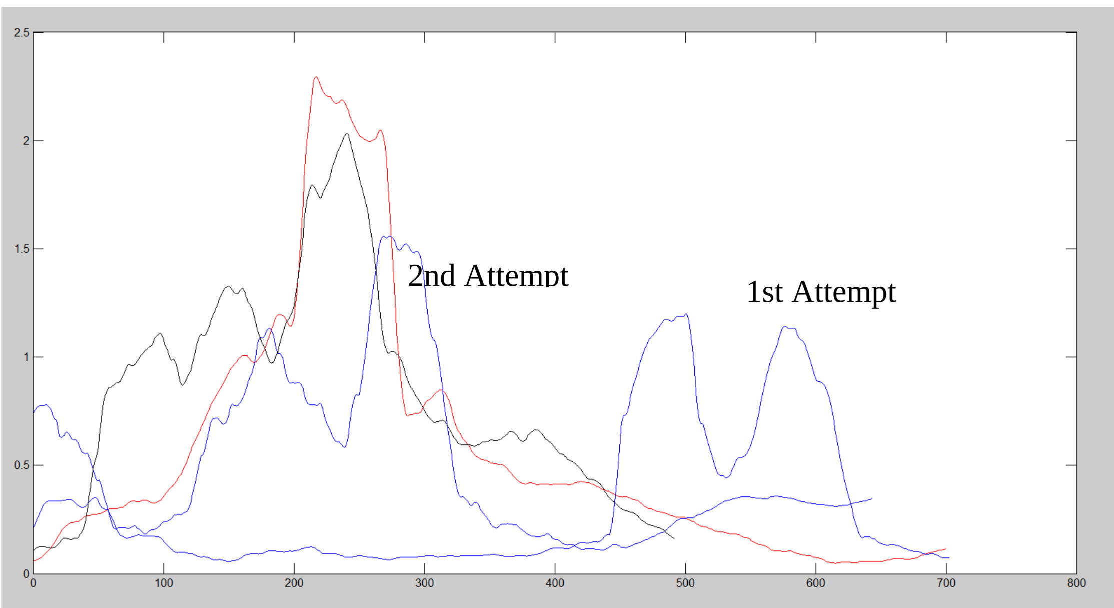

Figure 9. The first two attempts at matching the physician's compression with both too shallow. The first attempt was also too slow. The third attempt sufficiently matched the physician's target acceleration.

CHAPTER 4

DISCUSSION

From figure 1 it can be seen that there is a clear difference between the corner cases of the compression scale. A computer algorithm can be, and has been, written to distinguish one type off compression from another based on velocity and compression depth. The significance of the difference between the corner cases is that it shows that the device is consistent. This is shown because the apparatus that controlled the mobile device was controlled by a precision servo motor and was able to create distinguishable trends for the compressions.

When collecting and studying the compressions from the physicians it was interesting to note that there was a large inconsistency within and between physicians. There were two types of compressions which led to there being two types of curves. Some physicians would compress and hold the palpation while some would compress and then immediately release the palpation. Additionally, many physicians were not able to easily recreate their own compressions with feedback from the algorithm. A possible explanation for this is that there was more focus on variables other than the two variables, depth and velocity, that were included in the algorithm. Some physicians also had trouble performing palpations with the mobile device in their hand. It is possible that because they are specifically trained to do it with only their hands, the addition of another tool could have made the test more difficult.

When testing patients, it was found that there was again a wide variance in the ability to recreate compressions. While some patients had no trouble recreating their compressions, as seen in figure 6, others were not able to accomplish this as efficiently.

One noted reason for this is that some of the patients were holding the mobile device incorrectly. Due to the fact that the mobile device only records acceleration in the z-axis, the patients were instructed to hold the device in such a way to maximize the acceleration in that axis. One of the patients misinterpreted this and was not able to quickly match the target compression.

It was initially believed that patients attempting to recreate a compression target set by a physicians with feedback from the algorithm, they would initially start with a compression very different from the physician and then gradually make their way to match the physician's compression. This was found to not always be the case. In many instances the patient's compression would start relatively close to the physician curve and then the next curve would be even farther away until the patient recreated the curve. A possible explanation for this is the patient was not correctly holding the device, however this was only observed in one patient. Another explanation that has been observed is that when creating the target compression curve, the patient inadvertently shakes the device causing a rapid increase in acceleration and rendering the algorithm useless unless it is noticed immediately. Figure 9 shows an example of one patient who was able to use the algorithm to successfully approach the target.

While this study has limitations in the sense that only compression velocity and depth were used in classifying palpations it was still able to demonstrate the functionality of the process. The mobile device is capable of recording the precision needed to identify a type of compression, and patients are able to recreate compressions from physicians when given feedback. Additionally, this was all demonstrated while just using one axis of an accelerometer.

CHAPTER 4

DISCUSSION

This experiment has demonstrated the capability of mobile devices to allow physicians to easily and effectively communicate with the patients in a risk assessment setting. Expansion in this field can help patients get medical help more efficient from their care givers. Further research should be done on how the use of the two additional axes and possibly a gyroscope would allow greater repeatability or accuracy.

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