Development of a Mobile Sensor Platform for a Therapeutic Infant Smart-Mobile Device

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Abstract - **Cerebral palsy is the most common motor impairment disorder in children. In order to help decrease the overall effects of cerebral palsy, a new way and faster way of diagnosing cerebral palsy is needed. A smart mobile application called the Infant Smart-Mobile was developed to help infants who are at risk of cerebral palsy. Once the device is complete it will help encourage more normal kicking patterns in an infant who is at risk. Integrated sensors are needed in order to track the kicking of an infant. The sensors will be placed in a baby suit that the infant will wear in order to track the kicking patterns of the infant. An app was created in order to implement the sensors so that they could collect relevant data on the kicking. Multiple tests were run in order to determine the placement of the sensors in the baby suit.**

INTRODUCTION

Cerebral palsy is the most common motor impairment disorder in children [1]. William Little an orthopedic surgeon was the first to describe this non-progressive phenomenon in 1862 [2]. Cerebral palsy is a motor impairment disorder that stems from the damage of the brain during the developmental stages of life for a young child, whether the damage occurs prenatal or postnatal [2]. The definition of Cerebral Palsy proposed by the International Executive Committee is: "Cerebral palsy describes a group of permanent disorders of the development of movement and posture, causing activity limitation, that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain. The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, perception, cognition, communication and behavior, by epilepsy, and by secondary musculoskeletal problems" [2]. One of the main causes for cerebral palsy to occur is a premature birth, which is less than a 37-week gestation period leading to an underweight infant [2] [3]. The risk of cerebral palsy increases from 1.9% to 17.7% when the gestation period is less than 33 weeks [3]. No two infants are affected by cerebral palsy in the same manner. The severity of cerebral palsy depends on the location and the severity of the damage to the brain.

There are major milestones that a developing infant usually accomplishes within a given period of time; however, when the infant has cerebral palsy the milestone accomplishments are moderately to tremendously delayed. For example, and infant should start kicking its legs within two to nine months after birth, but when the infant has cerebral palsy the infant begins to kick at a much later age [3]. Cerebral palsy is not the only cause for the infant to be delayed in learning how to kick. In order to narrow down the cause of the delayed kicking of the infant an MRI can be used. If the infant does have cerebral palsy, then there is an 85% chance that the scan of the brain will appear abnormal [2]. There is a copious number of other tests that have to happen before there is a diagnosis making diagnosis very difficult before the age of two [3]. The minimum recommended age for diagnosis is between 4 or 5 years old [4]. Since there is a long period of time to begin tests in order to figure out if the infant has cerebral palsy and the actual diagnosis, it is harder for the child to positively progress through rehabilitation and learn how to better live with cerebral palsy than if the child had started rehabilitation sooner.

In order to shorten the long wait time and reduce the involved processing time for the diagnosis of cerebral palsy, the Human-Automation Systems (HumAnS) Lab created a project called The Infant Smart-Mobile Project. The Infant Smart-Mobile is designed to assess the motor skills of an infant who is possibly at risk of having cerebral palsy. There are four main parts to this project. There is the infant baby suit; there are multiple MetwWear CPRO sensors by MbientLab embedded into the baby suit. Each CPRO sensor is about the size of a quarter. There is also a sensor anklet, which uses a TI CC2650STK. Both the baby suit as well as the anklet are able to record data of the kicking of the infant wearing the device. There is the mobile component of the project as well: one is physical while the other is virtual. The physical mobile is connected to an app and is a hanging mobile designed to begin turning when the infant kicks for a certain amount of time and stops after the infant stops kicking for a while. The virtual mobile essentially has the same main function as the physical mobile except it is on a tablet. The mobiles are also designed to help facilitate a more typical kicking pattern in an infant in order to help combat cerebral palsy. The piece I worked on was to get the MetaWear sensors working properly as well as figuring out where the sensors should be placed in the baby suit. The goal of the whole project is to provide an alternative method to the long process of diagnosing an infant with cerebral palsy. The HumAnS Lab also wants to provide an affordable product that can be used in a home environment as well as have a product that is easy to use for both the clinician and the parent. If cerebral palsy can be diagnosed sooner, the treatment for the infant can begin sooner which in the long run helps the child immensely.

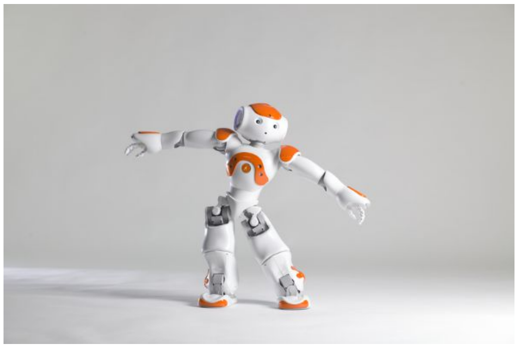

Figure 1. An image of a Nao Robot.

RELATED WORKS

There have been other studies done regarding creating devices or methods of tracking cerebral palsy in infants. Emily Rogers has done research where she and her team developed an infant onesie with integrated joint angle sensors. Two joint angle sensors are in each leg of the onesie. The sensors work in pairs that are on the same leg in order to calculate the joint angle of the leg. If the joint angle is at a certain degree, then the hanging mobile will begin to move for a certain amount of time. If the angel decreases below a certain threshold, then the mobile will stop moving [3].

METHODS

This section focuses on the MetaWear CPRO sensors that will be placed in the baby suit. The sensors are powered by a coin cell battery. My task in the greater scheme of the project was to get the multiple sensors to connect to a cellphone via Bluetooth as well as collect the needed data in order to determine if the infant, or in this case for the experiment the Nao Robot, was kicking or not (Figure 1). A separate app from the app that runs the physical mobile was created in order to be a testing ground for the sensors. The app was created in Android Studio in Java with the help of Android Developers documentation as well as MbientLab documentation. Once the app was able to successfully support two sensors being connected to the phone at the same time, the next step was to get the sensors to record the needed data, in this case gyroscope and accelerometer, and stream the data. After that the app needed to store the data in order to send the data elsewhere, whether it was to another e-mail or to the Google Drive. Once the app could send the data to another location, then it was time to start testing the sensors with the robot. For the test we used the NAO Robot. One of the researchers in the group programmed the robot in order to simulate a baby's spontaneous kicking. The NAO Robot was programmed to do high intensity kicks, wide kicks, and low kicks. The kicks occurred in a random order in sets.

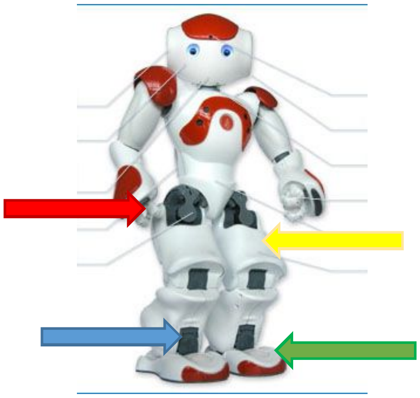

Figure 2. Locations of the sensors for each trial. Green=top of foot, Blue=front of calf, Yellow=front of thigh, Red=side of hip.

RESULTS

For each trial a pair of sensors were secured on the legs of the NAO Robot. In this test run sensor 1 was secured on the right leg while sensor 2 was secured on the left leg. The locations I decided to use were the hip, the thigh, the calf, and lastly the foot. The quantitative data of the experiment is given in the graph. Only the graphs of sensor 1, the right leg, will be shown in this paper because the data from sensor 2 is basically identical; the only difference is that the time of the kick is at a slightly different time because one leg would kick before the other. The sensor was able to record the data. The data was then put into graphs in order to see what kicking looked like in acceleration and gyroscope data. When the data is relatively at a constant slope of zero then it means that the robot was not kicking. If the slope is not around a constant zero, then the data represents a kick. Video was recorded of the NAO kicking in order to match up what was kicking on the graph and what was not. When the sensors were on the foot the sensors were able to record data on all six sets of kicks (Figure 3 a-b). Sensor 1's data was not very clear. Not all of the data was distinct enough in order to differentiate each kicking set. When the sensors were on the calf the sensors were able to record data on all six sets of kicks relatively well, but it was not the best (Figure 4 a-b). When the sensors were on the thigh the sensors recorded distinct data on all six sets of kicks for both the accelerometer as well as the gyro (Figure 5 a-b). When the sensors were on the hip the sensors recorded distinct data on all six sets of kicks; however, sensor 2 did not pick up the same magnitude of kicks as sensor 1 did (Figure 6 a-b).

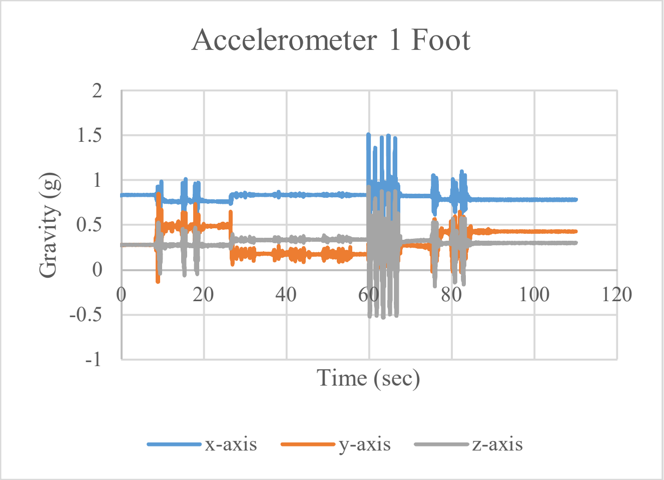

Figure 3a. Foot accelerometer data from sensor 1.

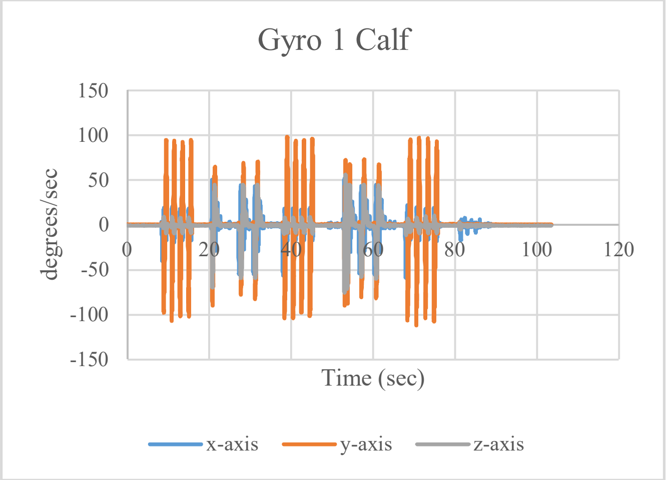

Figure 4b. Calf gyro data from sensor 1.

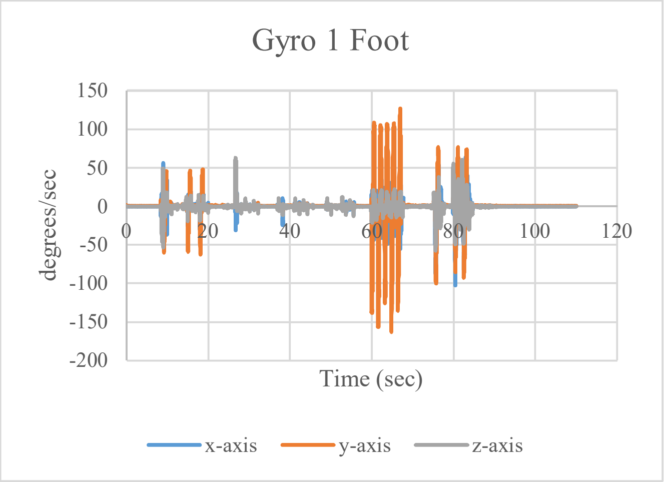

Figure 3b. Foot gyro data from sensor 1.

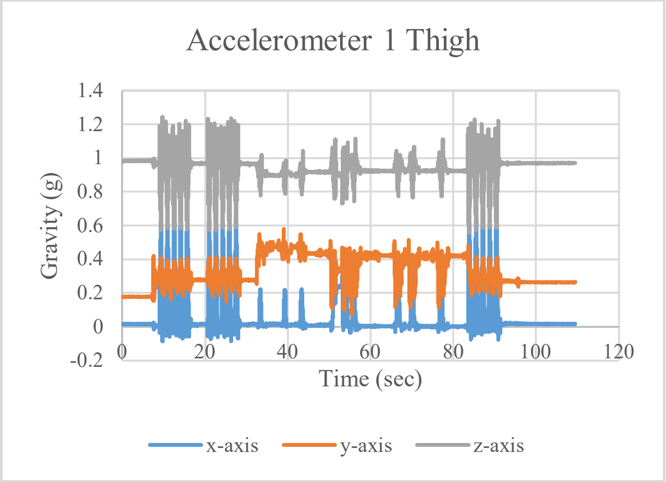

Figure 5a. Thigh accelerometer data from sensor 1.

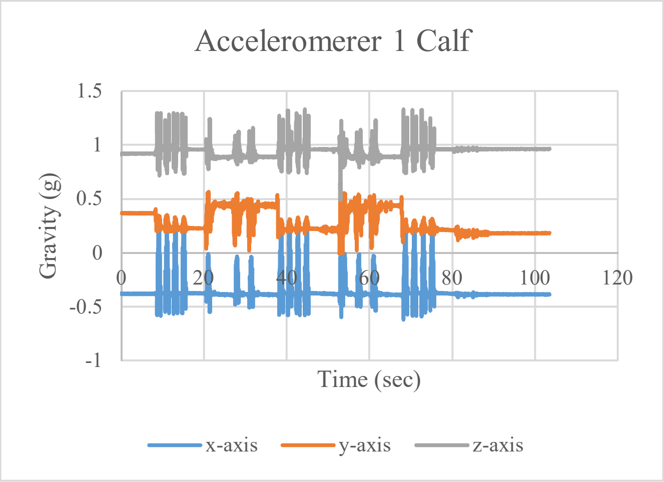

Figure 4a. Calf accelerometer data from sensor 1.

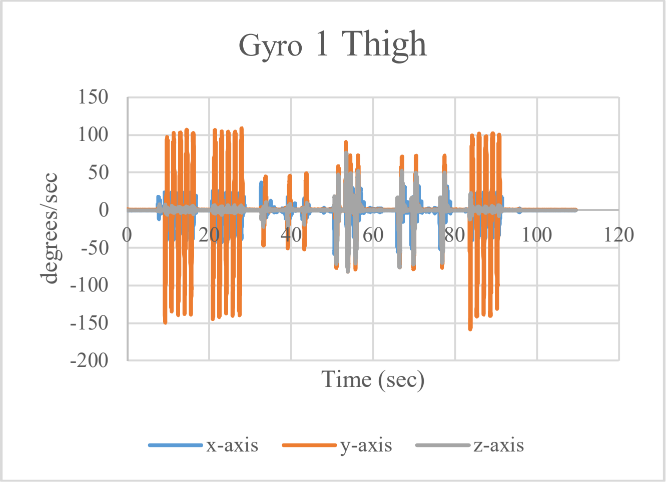

Figure 5b. Thigh gyro data from sensor 1.

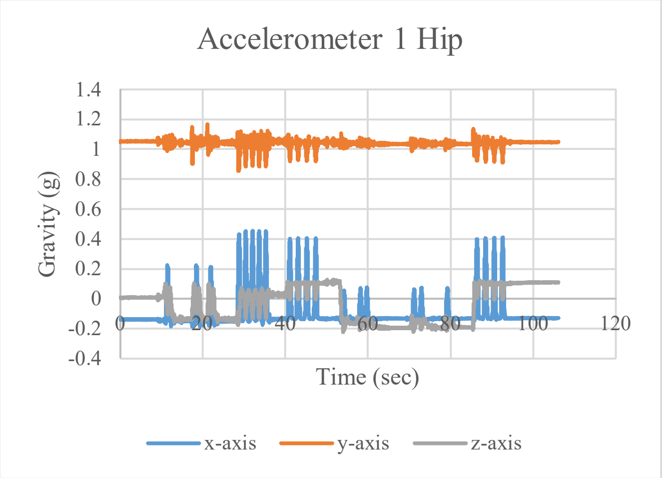

Figure 6a. Hip accelerometer data from sensor 1.

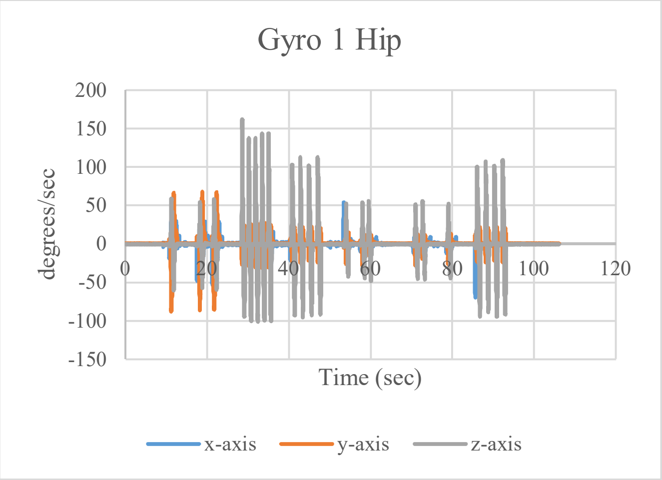

Figure 6b. Hip gyro data from sensor 1.

DISCUSSION

The reason why the data for the foot is so much different than the calf or the thigh is because when an infant kicks the foot does not always point or flex in relation to kicking. This is shown in the difference the graphs look between sensor 1 and sensor 2. The section in particular is from around 25 seconds to 60 seconds. The data for the calf is slightly different from the other data locations. The calf does not do a good job of catching the intensity of kicks that are more like leg lifts. When the sensors were located on the thigh the sensors were able to pick up distinct magnitudes of kicking. This is because in order to move a leg in any way the thigh must move. For the hip the gyro did better that the accelerometer. This could be because even though the hip starts the movement of the leg the distance it moves is not very far so the accelerometer may not be able to pick up the movement as much. On the other hand, the gyroscope was able to pick up the intensity of the kicks.

CONCLUSION

When there is only one set of sensors being used the most optimal location is to have the sensor located on the thigh. The second best location would be the hip. There is still work that is needed to be done for this project. This became very evident when the research group met with the clinician who helped propose this project. There needs to be three sets of sensors on the baby. One set at the hip, one set near the knee, and one set on the feet. Together these three sets of sensors should be able to calculate the joint angle of the leg which is one of the features that the clinician wants to have incorporated in the product. Also we need to figure out a way for the baby suit to have multiple sizes because no two infants are ever exactly the same size.

ACKNOWLEDGMENT

This project was completed at Georgia Institute of Technology. I would like to thank Dr. Ayanna Howard for being my mentor as well as the other lab members during the summer internship.

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