# Wearable ML Model to track Roll and Pitch: Creating a Hands-Free Transportation model for those with Cerebral Palsy

**Shlok Kaneria** [1] **Ricardo Silva** [1]


## Abstract

This paper delves into the specifics regarding an assisitive wearable technology model that tracks motion and degrees of movement on a three axis plane. This data can be collected and eventually used as input for wheelchairs to assist with transportation. The main goal of this paper is to elaborate on the methods used to create the device and how the program uploaded for this device functions. The intended audience of this paper includes individuals who may be interested in learning more about the implications of a 3-axis accelerometer circuit and its uses for specific transportation purposes.


## 1. Introduction

Nowadays, transportation is of paramount importance, understanding how to get from one place to another in the most efficient way possible is key. Over the past few years, there have been countless advancements in the scope of transportation. In this paper, I explore methods to make wheelchair transportation more efficient than modern control implementations such as joysticks for directional movement. I aim to present a model that analyzes directional movement in 3 different axes, the X, the Y, and the Z. I present a successfully programmed chip-set that incorporates integrated circuits to detect the degrees of motion and tilt on the X and Y plane, simulating the same sensory input received from modern joysticks.

Through this research and implementation, I attempt to find a solution for my close friend Liam, who suffers from Cerebral Palsy (CP). Cerebral Palsy is a group of permanent movement disorders that appear in early childhood. Symptoms include poor coordination, stiff or weak muscles, and tremors. There may also be problems with sensation, vision, hearing, swallowing, and speaking. In Liam's case, he has poor motor control of his hands, and he cannot walk, thus his need for a wheelchair as his primary mode of transportation. Without fine coordination in his hands, he often cannot fully operate the wheelchair via the joystick on his own due to muscle spasms and other medical inhibitors. He often has to have an assistant who helps him with the task of moving around for most of the day.

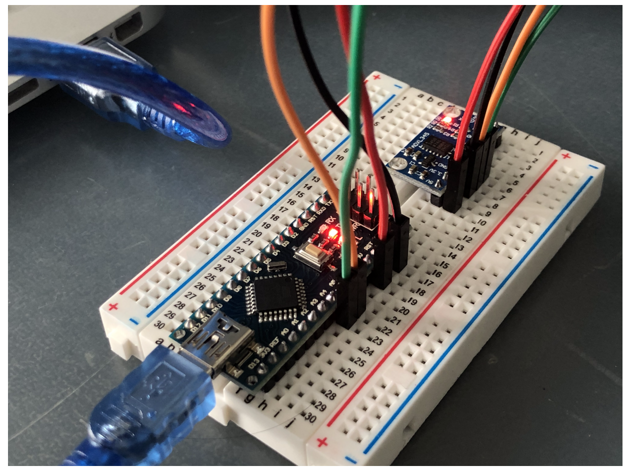

*Figure 1.* This image shows the fully assembled product that is created when the Arduino processor and the Integrated Circuit ADXL345 Accelerometer are connected via jump wires and attached to a power source.

The goal of the assistive technology I created for the purposes of this project aims to replace Liam's joystick with a simple device that can be placed on his head using a hat or other attachment interface. The device will utilize the built in accelerometer and uploaded code to detect the forward tilt and lateral/sideways movements of his head. The information collected from this integrated circuit will consist of measurements in terms of degrees or radians (settings can be altered) that can be directly fed into the wheelchair as input.

The ultimate goal of this project is to present a model that can easily be integrated into wheelchairs to assist Liam, as well as others who may have CP or motor control limi-

[1]Department of Computing Sciences, Villanova University, Villanova, PA. Correspondence to: Shlok Kaneria <skaneri1@villanova.edu>.

*Proceedings of the $35^{th}$ International Conference on Machine Learning*, Stockholm, Sweden, PMLR 80, 2018. 

*Figure 2.* Arduino Nano individual component without connection to power source or integrated circuit

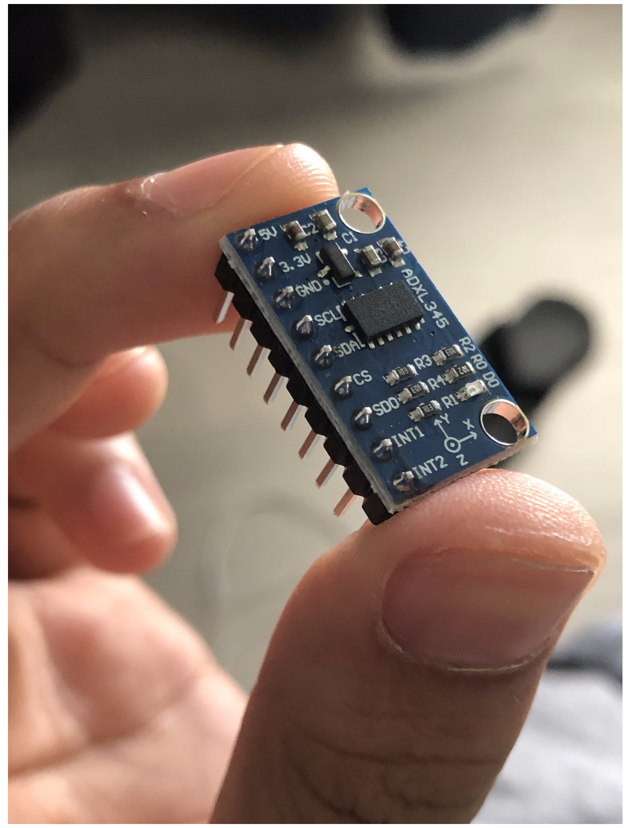


*Figure 3.* ADXL345 Accelerometer individual component without connection to Arduino processor

tations, in using a ”hands-free” way of providing sensory information for transportation purposes. In the following sections, I present the following:

1) Methodology of how I went about constructing the model given the problem I was initially trying to solve

2) Elaborate on the various components used in creating this integrated circuit

3) Present how I programmed the model to function and return information that could be used as input for wheelchairs

4) Resulting product and future work that can be conducted to further the research for this topic and create a fully functioning integrated device

## 2. Methodology

When attempting to create the final product for this project, I resorted to doing research on what technological components would best suit my needs for trying to create this model. Due to limitations in supply of processors due to the current circumstances, I researched components on Amazon that I could easily order and receive in time to assemble and create the desired result. To be able to track the Roll and Pitch motion on two axes, I needed a reliable accelerometer to be able to monitor this data and return the information I was looking for.

After doing some research on scientific papers written on topics of similar interest, mainly by (Ding et al., 2003) I gained substantial knowledge on the workings of integrated sensors that could help me understand how to tackle this problem.

I realized that I would need hardware that would allow me to mimic the idea of a head control mouse based on a traxial inertial sensor. This technology relays real-time head motion tracking that translates the head orientation into pointer positions and measures kinematic parameters through the 3D inertial sensor.

### 2.1. Arduino Processor

I found that the best way to achieve my end goal for this product was with the use of an Arduino processor. Arduino is an open-source prototyping platform used for building electronics projects. It consists of both a physical programmable circuit board and a software, or IDE (Integrated Development Environment) that runs on a local computer, where you can write and upload the computer code to the physical board. I decided to utilize an Arduino Nano board with an ATmega168 Processor. This processor wasn’t the latest version, however, for the purposes of this project, this much processing power was more than enough. The dimensions of the Arduino Nano was about 43.18 mm x 18.54 mm or [1.70 in x 0.73 in]. As for the power source, a 5V input via a USB-C cable was all that was required. The total cost of a singular Arduino Nano processor chip on Amazon turned out to be about $6.99.

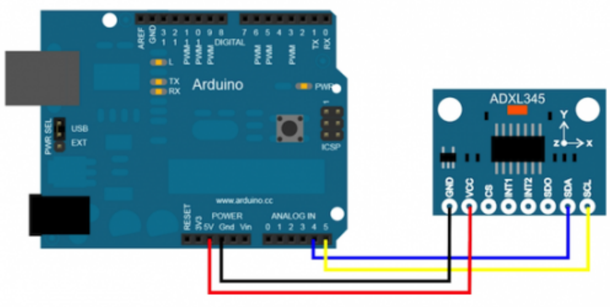


*Figure 4.* We show the appropriate connections required to enable reading input data from the Accelerometer to the Arduino processor via four jump wires. In this figure, an Arduino Uno is depicted, however, for the use of our project, we simply used an Arduino Nano instead. The connections depicted remain the same.

### 2.2. ADXL345 Accelerometer

Once I had secured my processor and ordered the hardware for the Arduino, I had to figure out how to find a module that would be able to replicate the traxial inertial sensor for monitoring the three axis movement. I realized that an Integrated Circuit Accelerometer is all that is required. I found that an Arduino Compatible ADXL345 Accelerometer was perfect for tracking pointer positions. The ADXL345 is capable of 3-axis tracking with high resolution. The digital output data is formatted as 16-bit two's complement, that we are able to manipulate these values via the programmed application we uploaded to the processor. In terms of connecting the Accelerometer to the Arduino Nano, we relied on an I2C digital interface. The ADXL345 does not have its own power supply, but rather, we are able to draw power supply from the 5V connection that is made to the Arduino Nano.

For more complex problems or a possible deviance from this project, Arduino also recommends an integrated Accelerometer and Gyroscope that can perform similar motion tracking rather than the use of a singular accelerometer.

### 2.3. Connections

In order to connect the components given the time allotted for this project, I decided to resort to the use of a simple 480 pin breadboard where both the Arduino Nano as well as the ADXL345 Accelerometer could sit seamlessly. Given that the accelerator does not have its own power supply (mentioned above in Section 2.2), we used jump wires to create a power chain as well as an I2C connection to read data as described further below.

Two jump cables were used to power the ADXL345. We created a connection between the 5V to 5V terminals as well as the GND to GND terminals on the Arduino Processor to the Accelerometer respectively.

Two cables were also used for I2C communication to read hardware monitors and diagnostic sensors from Integrated Circuit to Processor. These connections included a connection from the A5 terminal of the Arduino to SCL terminal as well as A4 terminal to SDA.

Now that the connections have been secured, we have a fully functional operating device that is ready to monitor motion on three axes.

### 2.4. Code

To program this model, I utilized the Arduino IDE as well as a third-party software called "Processing" to create a visual for the capabilities of this product. for the Arduino code that is uploaded to the processor, I first included the Wire.h library which is used for the I2C communication.

Each device that uses the I2C communication has a unique I2C address, and this address can be found in the datasheet of the ADXL345 datasheet. So, once we define the address and the variables for the three outputs, in the setup section, first, we need to initialize the wire library and then set the accelerometer in measuring mode. In order to do that, if we take a look at the datasheet again, we can see that we need to set the bit D3 of the POWER_CTL register HIGH.

Using the beginTransmission() function we start the communication, then using the write() function we tell which register we want to access, and again using the write() function we set the D3 bit HIGH, by writing the number 8 in decimal which correspond to setting the bit D3 HIGH.

We can now finally calculate the Roll and Pitch, or the rotation around the X-axis and the rotation around the Y axis in degrees, as visualized by the formulas used in Figure 5.

For Processing, we created a three-dimensional model to depict what the implications of this data could be on a visual scale. The input received from the sensors fed into the local IDE back into the serial port can be used to show how the model interacts with its own environment.

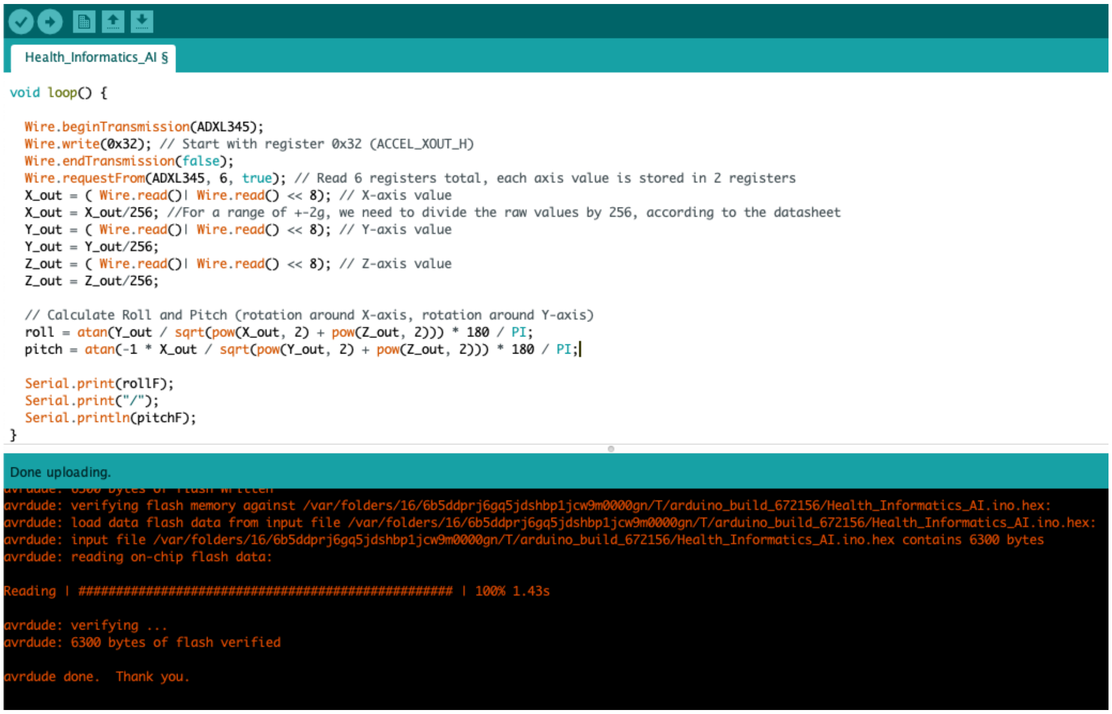


*Figure 5.* This image shows the setup section of the code, and how we configured the processor to read data using the I2C connection and feed this received input back into the ports. Ultimately, this coordinate information could be used as input data for wheelchairs that take in the same metrics from joysticks currently.

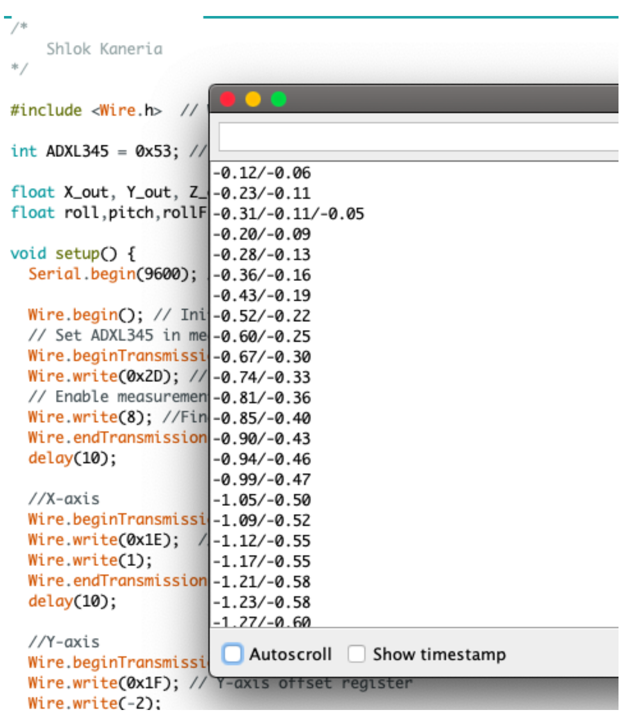


*Figure 6.* Final output of the code shows continuous output of information read from the ADXL345 sensor and shared as a ”coordinate” of X and Y points that is separated with a slash.

## 3. Results

After successfully uploading the code onto the Arduino Nano and seeing both a working implementation of my program and a proper execution of the I2C connection between the integrated circuit to the processor, I was able to build a 3D environment to use the input details for the creation of a virtual model. The uploaded code pulls the sensory data from the ADXL345 and returns it to the serial port, or the connection to the power supply, where the information can be used to manipulate the object it is controlling in real life applications.

This project allowed me to explore the field of assistive wearable technology and how they can connect with present machines to produce a viable solution to modern problems. This working model of a traxial sensor shows how with some future work, we can easily create a complete working prototype of traxial sensors in useful application.

## 4. Discussion and Future work

Working on this specific project for this course has allowed me to delve into the scientific and research aspect of trying to find a solution to a real life problem. Initially thinking about my friend Liam’s disability and how I had the resources to make a solution or a model of a solution helped me think outside the box. From brainstorming a solution to help him with transportation using his wheelchair, to researching previous implementations of hands-free technology, I was able to familiarize myself with the niche scope of assistive technology and how I could apply the knowledge I had gained into a final product. After creating the traxial sensor to monitor roll and pitch from the X and Y axis data collection, I showed in my results that we were able to produce a successful trial of the end goal.

Some key details I considered when looking at future work and how I can further this idea would be to actually implement my concept into a motored wheelchair and replace the joystick for a hands-free transportation solution. Reading work by other authors such as (Raya et al., 2010) who have done extensive research in the field of joystick tracking for wheelchairs specifically helped me understand what type of input they usually require to prompt motion, and this is exactly what I configured the Arduino Nano to return in the output. The next step would simply be to connect the chip set to the actual wheelchair, for which we may need to throttle power from the wheelchair itself to enable the Arduino to work. We would also have to return the input data to the processor on the chair itself, whether that be via a Bluetooth or Wi-Fi circuit I would have to configure on board my prototype.

Another key research point is how I can make my concept smaller in size so that it can be versatile enough to be placed on a hat or a headband on the forehead region of the wearer. This would mean researching how to remove the clutter from the breadboard as well as jump wires, and instead aim to create a direct connection between the processor and the accelerometer. I would love to continue to further my work on this project in the near future to build some sort of working prototype given the technology I have researched so that my friend Liam, or anyone else who this may benefit, can use this device.

## 5. Acknowledgements

I would like to thank Dr. Ricardo Silva for the ongoing support for helping me through this final project, as well as mentoring me in narrowing the scope to achieve a concept and propose a viable solution to the problem at hand given the limited time.

## References

Ding, Dan, Lopresti, Edmund F., Simpson, Rich, and Cooper, Rory A. Interpreting joystick signals for wheelchair navigation. *RESNA 26th International Annual Conference*, 2003.

Raya, R, Roa, J.O., Rocon, E, Ceres, R, and Pons, J.L. Wearable inertial mouse for children with physical and cognitive impairments. *Sensors and Actuators, A: Physical*, 162:248–259, 2010.