Letter of Submittal

March 1st, 2024

Andrew Nuxoll

Associate Professor

Shiley School of Engineering

University of Portland

Dear Dr. Nuxoll,

We, the Go Baby Go Project team of Multi-Disciplinary Capstone II – 484A, have prepared our Final Capstone Project Report for your approval. This report details the design process of our Adherence Sensor. This letter serves as our formal submission for your evaluation and approval.

The primary purpose of this report is to introduce our project, problem, and steps to solve it. With the help of figures and tables, we will describe our design criteria and considerations, and what led to our final design. We also provide an analysis of our results and provide future recommendations. The appendices include information regarding the team members' roles and contributions and a budget overview for the Adherence Sensor prototype development.

Thank you for your time and consideration. We look forward to your response.

Sincerely,

Margaret Brown

Kaylee Mock

Anna Yrjanson

Go Baby Go: Final Design Report

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Client: Bethany Sloane, Go Baby Go Oregon

Advisor: Dr. Tammy VanDeGrift

Instructor: Dr. Andrew Nuxoll

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University of Portland Capstone

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Executive Summary

Mobility aids for children lack integrated tracking capabilities, which caused a reliance on repurposed toy car wheelchairs and external GPS devices that have difficulty tracking motion indoors. The Adherence Sensor attaches to the back of the Permobil Explorer Mini and records critical timestamps such as the beginning of a movement and the end of a movement. Practitioners then use the data to determine if children are developing skills to have full navigational capability. Our improved version of the device provides user interface improvements, including Bluetooth data file transfer and light indications of low power and device idling. The device provides a comprehensive solution for tracking adherence and improving mobility programs, particularly in home settings, promoting accessibility for young children needing powered wheelchairs.

Acknowledgments

We are grateful to Bethany Sloane and Go Baby Go Oregon for trusting us to improve on the Adherence Sensor. We appreciate the faculty and Shiley School of Engineering for their support and invaluable resources. Lisa Bassett, Dr. Aziz Inan, Dr. Andrew Nuxoll, and Dr. Tammy VanDeGrift have been incredible resources, mentors, and instructors, and their guidance and patience are appreciated immensely. We would like to thank the previous Go Baby Go capstone team, comprising Ashlee Mei Balignasay, Kyler Mento, and Tara Peterson, whose development and collaboration facilitated our design process.

Introduction & Problem Statement

Disabilities tremendously impact people's abilities to move, interact with others, and complete daily activities. Besides these physical changes, mobility disabilities can influence social development. Understanding and addressing these deficits can promote equality and justice for all.

One potential solution for assisting those with physical disabilities is to provide tools and devices that assist disabled people in gaining access, including wheelchairs, walking canes, and hearing aids [6]. Mobility devices like wheelchairs and walkers benefit older children and adults with disabilities. However, they are inaccessible for disabled babies and toddlers who do not have the coordination or strength to move their body weight. Over 1.3 billion people worldwide are born with disabilities, and despite this, few devices help disabled babies and toddlers navigate their environment and develop independence [2].

We are motivated to improve the current capabilities of the cart to help shape the future of people with disabilities and the medical field. While the current product is functional, these changes will improve system accuracy, efficiency, and cost. Most importantly, these changes will enhance the experiences of disabled children, parents, and clinicians.

Background / Literature Review

In January 2019, Trexo Robotics created Trexo Home, a therapeutic mobility device that assists children in developing a proper gait pattern, as shown in Figure 2 [6]. It features a tablet that can monitor the mobility device's speed, data, and child's progress. Families can purchase the Trexo product for just under $40,000 or lease it for about $1,200 monthly [25]. This product is expensive and insufficient for toddlers who can barely hold their body weight or move their legs. For this reason, an assistive device should be made for toddlers with little bodily control to promote independence and development.

Permobil, a company created to help provide advanced mobility technology for individuals with disabilities, created the Explorer Mini cart, as shown in Figure 1. The cart supports children ages 12-36 months old and has been safety tested and FDA-approved in 2020. The cart is unavailable for the general market; families need to get a pediatrician's prescription even to get one. These carts are then adjusted to fit each child's individual disability needs. The cart has a customizable chair that allows the child to sit comfortably and dangle their legs. Attached to the chair is a table with a joystick in the middle that the child can use to move the cart in the direction they want. The entire chair is supported on a four-wheel platform [26]. The Permobil Explorer Mini was listed in TIME Magazine's "Top 100 Best Inventions of 2021" [1].


Figure 1: (Left) Child sitting in the Permobil Explorer Mini

Figure 2: (Right) Child standing in the Trexo Home

Design Criteria & Considerations

Design Criteria

The Adherence Sensor should consistently monitor the child's data and offer user-friendly functionality for guardians and physicians. It should ensure accurate and secure storage of the child's data on a micro-SD card, which can transmit data via Bluetooth through a discreetly placed button, accessible only to the physician. The adherence sensor case will feature Velcro strips to enhance practicality, facilitating secure attachment to the back of the Permobil Explorer Mini. The external features of the Adherence Sensor case should include an on/off switch and an LED indicator with color-coded signals for various statuses. A green light signifies that the device is active and recording data, red indicates a battery level below 20%, blue indicates Bluetooth usage, and green signals that the cart has been idle for over 30 seconds. It is imperative that the adherence sensor case seamlessly integrates with the cart's design and is easily reproducible following our documentation. Rigorous testing of the sensor is essential to ensure all functional requirements are met effectively.

Source of Criteria	**Requirements**	**Completed**
Cost	Build an adherence sensor that does not exceed $200.00.	
Security	Encryption and decryption to access child’s data.	
Simplicity of Usability	Have the on/off switch and port easy to access.	
	LED display adherence sensor’s status.	
	Button to activate Bluetooth.	
Performance/Reliability	Accurately gather and store the child’s movement data.	

Table 1: Design Criteria

Design Considerations

1) Public Health, Safety, and Welfare

Our adherence to U.S. Food and Drug Administration (FDA) regulations requires refraining from altering the internal circuitry of the cart to uphold safety standards. Our primary concern is the integrity and security of the data within the device. Currently, a microSD card stores all the data; while it does not contain sensitive medical or location data, it will be used in research and within medical settings. This data is subject to the security guidelines set by internal review boards and medical associations. Therefore, we plan to implement encryption measures to fortify the data against potential compromise or unauthorized access. Additionally, the adherence sensor circuitry will be housed within a durable plastic electrical junction box, ensuring the prevention of electrical injuries and overall safety for all individuals, particularly the child and guardians, interacting with the device.

2) Global, Cultural, and Societal

As previously mentioned, over 1.3 billion people worldwide are born with disabilities and few devices help disabled babies and toddlers [2]. With this in mind, we wanted to take steps toward improving the future of people with disabilities and the medical field. By creating a user-friendly Adherence Sensor, more devices can be made accessible to those who need it. Similarly, by incorporating data transfer with Bluetooth, physicians can efficiently access the data and guide the child's guardians.

3) Environmental

During the design process, environmental considerations limited and guided the design. The production of circuit parts requires raw materials such as metals, silicon, and rare earth elements. The extraction process can destroy habitats, create pollutants, and soil degradation, impacting ecosystems and communities. Fabrication and manufacturing of these parts require large energy consumption and various toxic chemicals. This energy consumption contributes to greenhouse gas emissions and climate change. The solvents, acids, gases, etc., used in creating the hardware are also extremely dangerous for workers and the earth. The disposal of chips and circuit parts contributes to electronic waste generation. Improper disposal practices can release toxic materials into the environment and harm humans and animals. With these impacts in mind, we decided to use the less wasteful and smallest electrical parts and chips possible.

4) Economic

The parts and resources to make the sensor are very accessible and affordable. The electrical parts are small and cost under a few dollars, and the programming can be done on a device with Arduino Software (IDE) downloaded. We always tried to stay within our budget of $443.73 and have an adherence sensor that would cost less than $200 to make.

Design Comparisons

The LIS3DH Triple-Axis Accelerometer is a popular triple-axis accelerometer made by Adafruit. It supports both I2C and SPI interfaces, offers a range of data rate options from 1Hz to 5kHz, and provides interrupt outputs. Additionally, the LIS3DH draws a low current of 2uA and has features like freefall detection, tap detection, and tilt orientation detection. It is compatible with various microcontroller platforms like Arduino and costs $4.95 [8]. The SparkFun Triple Axis Accelerometer Breakout - KX132 (Qwiic) is a simple digital and power-efficient accelerometer made by Kionix [9]. It is a 16-bit resolution three-axis accelerometer. It has a maximum of 10kHz output data range and is the size of a quarter. This product relies on Arduino IDE and can be purchased at $14.95 from the SparkFun website.

The LIS3DH in the adherence sensor and KX132 are very similar accelerometers. They have similar dimensions and features like freefall detection, directional Tap, and double-tap detection. However, the KX132 is faster and more sensitive to motion than the LIS3DH. The KX132 sensitivity range can be set to a higher caliber, so it is better at processing high-speed data rates and high-sensitivity measurements. However, the KX132 is pricier, but because it is a powerful accelerometer, parents and clinicians can get more precise data.

Final Design Overview

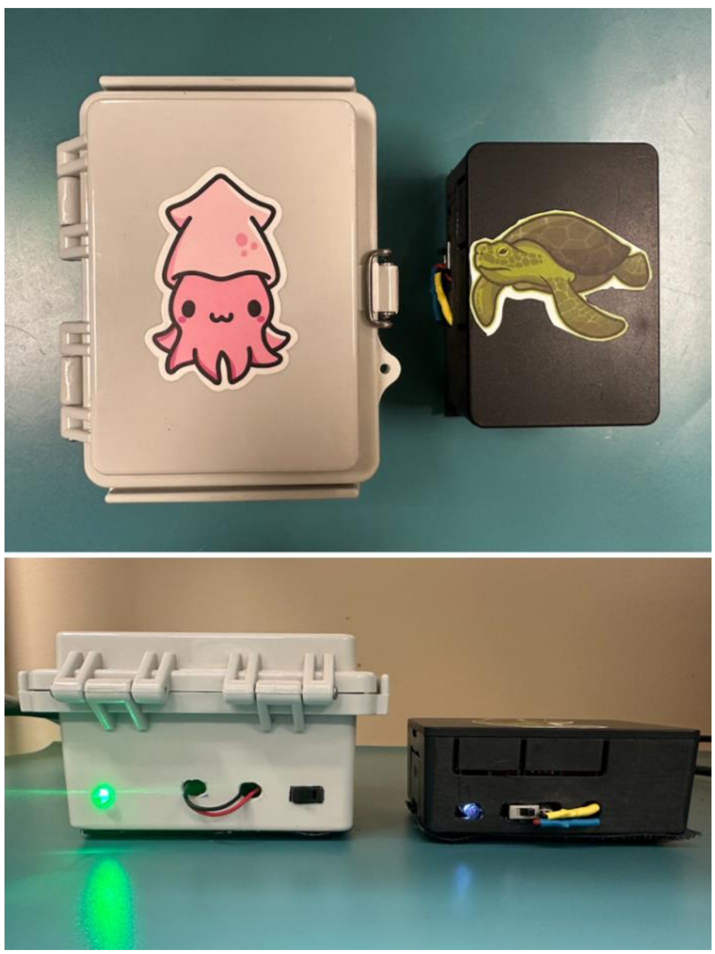

Figure 3: Adherence Sensors side by side (left: current sensor; right: previous team's sensor)

Figure 4: (Left) Current Adherence Sensor Design

Figure 5: (Right) Previous Adherence Sensor Design

Analysis of Final Design

Two replicas or prototypes of the previous adherence sensor were produced as a precautionary measure to enhance efficiency. In the event of one replica malfunctioning, it was set aside for any reason, and the other replica assumed the role of the primary sensor. Unfortunately, such an occurrence did transpire, leading to the disassembly of the defective replica. However, salvageable non-faulty parts were repurposed for further testing. The Arduino-based project's troubleshooting and error-checking processes were straightforward and continuous.

The Adherence Sensor, programmed in Arduino using C++, featured essential functions: "setup" and "loop." Before the setup function, a variety of variables were declared, encompassing PINs on the ESP32 and electronic components such as the Real-Time Clock Variable (RV8803), Accelerometer Variable (Adafruit_LIS3DH), and Battery Variable (SFE_MAX1704X). Additional variables included readings for the X, Y, and Z axes, acceleration calculations, the number of detections, a Boolean variable for motion detection, and the threshold of change to be considered movement in each axis.

The setup function served several purposes, including calibrating output pins and electrical components, setting the Inter-Integrated Circuit Protocol to 115200 baud, and calibrating the accelerationdata.txt file while noting the device start-up time. On the other hand, the loop function executed different tasks. It checked if the Bluetooth file transfer button was pressed, initiating the file transfer protocol and changing the LED color to blue. After a successful file transfer, the loop resumed its regular operations.

Furthermore, the loop function monitored the device's idleness, transitioning the accelerometer into low-power mode and changing the LED color to orange if the device remained inactive for over 30 seconds. The motion detection function was then activated. The loop also checked if the ESP32 Microcontroller's battery level dropped below 20%, signaling the LED to turn red, followed by the execution of the motion detection function. In cases where none of these conditions applied, the program ran the motion detection function while setting the LED color to green.

Conclusions & Recommendations

Not applicable yet

Appendix A: Roles and Responsibilities

Collectively:

- Rotated roles as team lead.
- Completed all documentation and presentations.
- Managed troubleshooting and testing.

Margaret Brown:

- Encryption and decryption programming
- Bluetooth file transfer programming and protocol

Kaylee Mock:

- Manage and research hardware components.
- Solder adherence sensor circuitry.
- Construct adherence sensor case.
- UP alumni liaison.

Anna Yrjanson:

- Budget/Purchasing manager.
- Industry advisor liaison
- LED programming
- Battery-level programming
- Accelerometer idle-mode programming

Appendix B: Budget

Project Materials/Supplies (Individual Items Under $500)

Adafruit LIS3DH Triple-Axis Accelerometer (x2) [8]	$9.90
SparkFun Triple Axis Accelerometer Breakout – KX134 (x2) [9]	$43.90
SparkFun Real Time Clock Module – RV-8803 (Qwiic) (x2) [10]	$35.00
Lithium Ion Polymer Battery – 3.7v 2500mAh (x2) [11]	$29.90
Tenergy Fire Retardant LiPo Bag (Set of 2) [12]	$11.99
USB Lilon/LiPoly Charger – v1.2 (x2) [13]	$25.00
Amazon Basics USB-A to Mini USB 2.0 – 3ft (x2) [14]	$12.64
microSD Card – 1GB (x2) [15]	$11.00
YETLEBOX Waterproof Electrical Box with Mounting Plate (x2) [16]	$35.98
SparkFun IoT RedBoard – ESP32 Development Board (x2) [17]	$59.90
LED – RGB Addressable, PTH, 5mm Diffused (5 Pack) (x2) [18]	$7.00
LED – Assorted (20 Pack) (x2) [19]	$3.95
TUOFENG 24 awg Wire Sold Core Hookup [20]	$14.99
Qwiic Cable – Grove Adapter (x10) [21]	$16.00
USB Wall Charger, GiGreen Dual Port Electrical Cube 5V (Set of 3) [22]	$13.99
Gikfun Solder-able Breadboard Gold Plated Finish Proto Board (Set of 5) [23]	$11.98
E-Projects 10EP5121K00 1k Ohm Resistors (Set of 10) (x2) [24]	$10.82

Subtotal: $352.94

Miscellaneous

Shipping Total Cost	$15.79
Cost Overage	$75.00

Subtotal: $90.79

Estimated Total: $443.73

Budget Justification

The previous capstone team had an estimated budget of $470.32 and underestimated their costs by around $100. Our team will purchase enough items to create two prototypes: one prototype that will remain at the University and another that can be tested by researchers at OHSU. Each of these prototypes can be produced for around $150 each. The University of Portland will be handling the costs of any necessary parts.

Appendix C: Ardunio Program

```
//Libraries
#include <SPI.h> // Communication with Serial Peripheral Interface (SPI) devices (ex. microcontroller and other circuits)
#include <Wire.h> // I2C communication between chips
#include <SparkFun_RV8803.h> // Read and set time on the RTC
#include "SparkFun_KX13X.h" // Configures and communicates data from the SparkFun KX13X accelerometer
#include <Adafruit_Sensor.h> // Required library for all Adafruit Unified Sensor libraries
#include <Adafruit_LIS3DH.h> // Configures and communicates data from Adafruit LIS3DH accelerometer (uses Unifed Sensor Library)
#include <SparkFun_MAX1704x_Fuel_Gauge_Arduino_Library.h>
#include <AES.h> // 128-bit CBC for encryption
#include <AESLib.h>
#include <CTR.h> // Part of the crypto libraries
#include <Crypto.h> // Rhys Weatherly's crypto library
#include "arduino_base64.hpp"
#include "FS.h" // ESP 32 File System library
#include "SD.h" // Reading and writing to SD cards using the SPI interface of a microcontroller
#include "SPI.h" // Part of the SPI library

//Pins
#define EVI 14 // Timestamp pin
#define R_LED 4 // Red LED pin
#define G_LED 13 // Green LED pin - changed from 16 to 13
#define B_LED 17 // Blue LED pin
#define BUTTON 25 // Button input pin

//variables
RV8803 rtc; // Real Time Clock variable - uses the class RV8803
Adafruit_LIS3DH lis = Adafruit_LIS3DH(); // LIS3DH Accelerometer variable - UPDATE 10/30/2023: looks used
SFE_MAX1704X battery;
const float gravity = 9.80665;  // Earth's gravity in m/s^2

// Reading the motion detections
float accel;
int detect = 0;
bool det = false;
float numReadings = 50.0;

// Hold the previous averaged readings for each axis on the accelerometer
float last_x;
float last_y;
float last_z;

// Hold the current averaged readings for each axis on the accelerometer
float x;
float y;
float z;

// Threshold of change in each axis to be considered a detected movement
float move_tholdX = 0.1;
float move_tholdY = 0.1;
float move_tholdZ = 0.1;
```

```
// Read state of the button press
int buttonState = 0;

// Create a battery object and battery percentage variable
double battery_percent;
int low_battery_threshold = 20;

// Idle Mode: variables that measure the time since the last detected motion
unsigned long stop_motion;
unsigned long current_time;
lis3dh_dataRate_t current_rate = lis.getDataRate();

// Encryption variable
AESLib aesLib;

void setup() {
  pinMode(R_LED, OUTPUT);
  pinMode(G_LED, OUTPUT);
  pinMode(B_LED, OUTPUT);
  pinMode(BUTTON, INPUT);
  pinMode(EVI, OUTPUT); // NEED INFORMATION: Why is this an output pin?
  Wire.begin();//I2C addresses begin
  Serial.begin(115200);//set baud rate

  //RTC initialization
  if (rtc.begin() == false) // If the RTC cannot be found or started
  {
    Serial.println("Device not found. Please check wiring. Freezing."); // Prints to the serial monitor that the RTC cannot be found
    while (1); // NEED INFORMATION: why are they using an infinite loop?
  }
  Serial.println("RTC online!"); // Prints to the serial monitor that the RTC was found

  if (rtc.setToCompilerTime() == false) {
    Serial.println("An error has occurred in setting the RTC to compiler time");
  }

  rtc.setEVIEventCapture(RV8803_ENABLE); //Enables the Timestamping function

  Serial.println("LIS3DH test!");
  if (! lis.begin(0x18)) { // If the LIS3DH accelerometer cannot be found or used, follow this condition
    Serial.println("Couldnt start"); // Prints to the serial monitor that the accelerometer cannot be found
    while (1) yield(); // NEED INFORMATION: why are they using an infinite loop AGAIN? What is yield?
  }
  Serial.println("LIS3DH found!"); // The LIS3DH accelerometer is found

  // Set up lis and init readings
  lis.setRange(LIS3DH_RANGE_4_G); // NEED INFORMATION: What does this mean?

  delay(10); // Delays by 10 milliseconds
  lis.read(); // Takes a reading from the accelerometer
```

```
//orientated on the back of the permobil
x = -lis.z; // Takes the x-axis reading, using a negated z-axis accelerometer reading
y = lis.y; // Takes the y-axis reading
z = -lis.x; // Takes the z-axis reading, using a negated x-axis accelerometer reading

// Check if SD is connected correctly
if (!SD.begin()) { // If the SD card cannot be found, follow this condition
  Serial.println("Card Mount Failed"); // Prints to the serial monitor that the SD card cannot be found
  // Removed: digitalWrite(LED, HIGH); while (1) {}
  return; // Returns without further action
}
uint8_t cardType = SD.cardType(); // Saves the type of SD card to an unsigned 8-bit integer

if (cardType == CARD_NONE) { // If there is no SD card, follow this condition
  Serial.println("No SD card attached"); // Prints that there is no SD card attached
  // Removed: digitalWrite(LED, HIGH); while (1) {}
  return; // Returns with no further action
}

Serial.print("SD Card Type: "); // Prints this statement to the serial monitor
if (cardType == CARD_MMC) { // If the card is a MultiMediaCard, follow this condition
  Serial.println("MMC"); // Prints that the card is a MultiMediaCard (MMC) to the serial monitor
}
else if (cardType == CARD_SD) { // If the card is a standard SD card, follow this condition
  Serial.println("SDSC"); // Prints that the card is a standard SD card to the serial monitor
}
else if (cardType == CARD_SDHC) { // If the card is a high capacity SD card, follow this condition
  Serial.println("SDHC"); // Prints that the card is a high capacity SD card to the serial monitor
}
else { // If the card is of another type, follow this condition
  Serial.println("UNKNOWN"); // Prints that the card is of an unknown type of the serial monitor
}

// Initialize the MAX17043
if (battery.begin() == false) {
  Serial.println("Can't find MAX1704X Battery");
}

battery.quickStart(); // Restarts the MAX1704X to createa. more accurate guess for the SOC
battery.setThreshold(low_battery_threshold); // An interrupte to alert when the battery reahes 20% and below

//axis zeroing to eliminate false positives
x = 0;
y = 0;
z = 0;

// Procedure at device start-up
String startTime = RTC(); //timestamp
Serial.println();
File file = SD.open("/accelerationdata.txt", FILE_APPEND); //open file.txt to write data
if (!file) { // If the file cannot be opened, follow this condition
  Serial.println("Could not open file(writing)."); // Prints that the accelerometer.txt file cannot be opened
}
```

```
  else { // If the file can be opened, follow this condition
    file.println(); // Adds a new line to the file
    file.print("Device start up at: "); // Writes this to the bottom of the file
    file.print(startTime); // Prints the start-up time to the bottom of the file
    file.println(); // Prints another new line to the bottom of the file
    file.close(); // Closes the file
  }
}



void loop() {
  /*
   * Condition 1: Bluetooth File Transfer
   * The user presses the button to send the file from the device to a supported computer or mobile device
  */

  // Records whether the button has been pressed
  buttonState = digitalRead(BUTTON);
  current_time = millis();

  // Gets the battery percent
  battery_percent = battery.getSOC();


  // Check for button press
  if (buttonState == 1) {
    setColor(0, 0, 255); // Set LED color to blue
    // If yes, then do the bluetooth transfer protocol
    // Make sure all protocol finish before returning to normal procedures
    // Reset state of the button to "not-pressed"
    delay(5000);
    buttonState = 0;
    setColor(0, 255, 0);
  }

  /* CHECK FOR IDLE MODE HERE */
  else if (current_time - stop_motion > 30000) {
    setColor(255, 30, 0);
    lis.setDataRate(LIS3DH_DATARATE_LOWPOWER_5KHZ);

    // Used to detect changes between datarates
    // Serial.println(LIS3DH_DATARATE_LOWPOWER_5KHZ);

    motionDetection();
  }
```

```
// Checks if battery is below 20 percent
else if (battery_percent < 20) {
  setColor(255, 0, 0);
  motionDetection();
  // Print the battery percentage
  Serial.print("Battery Percentage: ");
  Serial.print(battery_percent);
  Serial.println("%");
}

else {
  setColor(0, 255, 0);
  lis.setDataRate(LIS3DH_DATARATE_10_HZ);

  // Used to test changes between datarates
  // Serial.println(LIS3DH_DATARATE_10_HZ);

  motionDetection();
}
}
```

References

[1] Charlton, Haley. "Plummer, Permobil's Explorer Mini Recognized in TIME Magazine's Top 100 Best Inventions of 2021." Belmont Unviersity News & Media. Belmont University, April 8, 2022. https://news.belmont.edu/plummer-permobils-explorer-mini-recognized-in-time-magazines-top-100-best-inventions-of-2021/#:~:text=The%20Explorer%20Mini%20was%20listed,that%20positively%20impact%20the%20world.

[2]"Disability." World Health Organization. WHO, March 7, 2023. https://www.who.int/news-room/fact-sheets/detail/disability-and-health#:~:text=Key%20facts,earlier%20than%20those%20without%20disabilities.

[3] "Go Baby Go - Design Document (Ver. 1.0)." Microsoft Word. Microsoft, April 25, 2023. https://upedu-my.sharepoint.com/:w:/r/personal/petersot24_up_edu/_layouts/15/Doc.aspx?sourcedoc=%7BCEB0018C-C5F9-4FEC-A064-951111659539%7D&file=Go%20Baby%20Go%20-%20Design%20Document%20(ver.%201.0).docx&action=default&mobileredirect=true.

[4] "Go Baby Go." Go Baby Go Oregon. Go Baby Go, April 25, 2023. https://gobabygooregon.org/home.

[5] "Modified Ride-on Toy Car User's Manual." Google Docs. Google, Accessed September 28, 2023. https://docs.google.com/document/d/1YicK4_H787xEOGDYQX43jDBuXEcOHK2fsZFHY6uRAy8/edit.

[6] Nikitina, Dina. "Trexo Home Puts Kids on Their Feet and Helps Them Walk." Abilities. Trexo Robotics, Accessed September 25, 2023. https://www.abilities.com/community/trexo.html.

[7] "Pediatric Adaptive Equipment." Adaptive Specialties. Adaptive Specialties. https://www.adaptivespecialties.com/pediatric-adaptive-equipment.aspx.

[8] "Adafruit LIS3DH Triple-Axis Accelerometer (+2g/4g/8g/16g)." Adafruit Industries, Unique & Fun DIY Electronics and Kits. Adafruit, https://www.adafruit.com/product/2809.

[9] "SparkFun Triple Axis Accelerometer Breakout - KX134 (Qwiic)." SparkFun Electronics. SparkFun, Accessed October 5, 2023. https://www.sparkfun.com/products/17589.

[10] "SparkFun Real Time Clock Module - RV-8803 (Qwiic)." SparkFun Electronics. SparkFun, Accessed October 5, 2023. https://www.sparkfun.com/products/16281.

[11] "Lithium Ion Polymer Battery - 3.7v 2500mAh." Adafruit Industries, Unique & Fun DIY Electronics and Kits. Adafruit, Accessed October 5, 2023. https://www.adafruit.com/product/328.

[12] "Amazon.com: Tenergy 2 Pack, Fire Retardant Lipo Bags, Battery Bags for Charging and Storage, 5.5x3.5x2 inches Each, material tested to meet UL94 Standard." Amazon, Amazon.com. https://a.co/d/41Whqd9.

[13] "USB Lilon/LiPoly charger – v1.2." Adafruit Industries, Unique & Fun DIY Electronics and Kits. Adafruit, Accessed October 5, 2023. https://www.adafruit.com/product/259.

[14] "Amazon.com: Amazon Basics USB-A to Mini USB 2.0 Fast Charging Cable, 480Mbps Transfer Speed with Gold-Plated Plugs, 3 Foot, Black." Amazon, Amazon.com. Accessed October 5, 2023. https://a.co/d/aCNqv4V.

[15] "microSD Card – 1GB (Class 4)." SparkFun Electronics. SparkFun, Accessed October 5, 2023. http://sfe.io/p15107.

[16] "Amazon.com: YETLEBOX Waterproof Electrical Box with Mounting Plate 200x150x100mm, IP67 Junction Box Dustproof Clear Cover Plastic DIY Electric Project Enclosure Box Grey 7.9"x5.9"x3.9"." Amazon, Amazon.com. Accessed October 5, 2023. https://a.co/d/4wDrJ3R.

[17] "SparkFun IoT RedBoard – ES32 Development Board." SparkFun Electronics. SparkFun, Accessed October 5, 2023. http://sfe.io/p19177.

[18] "LED – RGB Addressable, PTH, 5mm Diffused (5 Pack)." SparkFun Electronics. SparkFun, Accessed October 5, 2023. https://www.sparkfun.com/products/12986.

[19] "LED – Assorted (20 pack)." SparkFun Electronics. SparkFun, Accessed October 5 2023. https://www.sparkfun.com/products/12062.

[20] "Amazon.com: TUOFENG 24 awg Wire Solid Core hookup Wires-6 Different Colored Jumper Wire 30ft or 9m Each, 24 Gauge Tinned Copper Wire PVC (OD: 1.46mm) Hook up Wire Kit." Amazon, Amazon.com. Accessed October 5, 2023. https://a.co/d/eGDl9JQ.

[21] "Qwiic Cable – Grove Adapter (100mm)." SparkFun Electronics. SparkFun. Accessed October 5, 2023. http://sfe.io/p15109.

[22] "Amazon.com: USB Plug, USB Wall Charger 3 Pack, GiGreen Dual Port Electrical Cube 5V 2.1A Charging Block USB Outlet Plugs Compatible iPhone 11 XS X 8 7, LG V30 G8, Samsung S20 S10+ S9 S8 Note 9 8, Moto G6." Amazon, Amazon.com. Accessed October 5, 2023. https://a.co/d/2o6K0pf.

[23] "Amazon.com: Gikfun Solder-able Breadoard Gold Plated Finish Proto Board PCB DIY Kit for Arduino (Pack of 5PCS) GK1007." Amazon, Amazon.com. Accessed October 5, 2023. https://a.co/d/hW9Bqlz.

[24] "Amazon.com: E-Projects 10EP5121K00 1k Ohm Resistors, ½ W, 5% (Pack of 10)." Amazon, Amazon.com. Accessed October 5, 2023. https://a.co/d/8MjtlmN.

[25] "Trexo Home Pricing." Trexo Robotics, October 5, 2023. https://www.trexorobotics.com/trexo-home-pricing/.

[26] Explorer Mini. Accessed October 6, 2023. https://www.permobil.com/en-us/products/power-wheelchairs/permobil-explorer-mini.

[27] “IOT Redboard ESP32 Development Board Hookup Guide.” IoT RedBoard ESP32 Development Board Hookup Guide - SparkFun Learn. Accessed October 6, 2023. https://learn.sparkfun.com/tutorials/iot-redboard-esp32-development-board-hookup-guide/all.

Glossary

Cart: The Permobil Explorer Mini provided by the Oregon Health & Safety University team.

Device: the hardware designed to track and record movement.

ESP32 Microcontroller: a small, specialized electronic component that computes and manages simple devices, making them work by following specific instructions.