MEASURING EARLY-CHILDHOOD POWER MOBILITY: DEVELOPMENT OF A GOBABYGO DATA LOGGING DEVICE

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ABSTRACT

Children with mobility impairments have difficulty interacting independently with their environments. There are no commercially-available powered mobility devices for very young children (e.g.: under three years of age). The GoBabyGo approach to powered mobility modifies commercial ride-on toy cars for use as powered mobility devices. GoBabyGo research is promising, but relies on parent logs of device use. If more rigorous research is to be conducted, we need objective methods for quantifying GoBabyGo device use. This paper describes the engineering design process behind an open-source data logging device to record GoBabyGo device usage. Simply put, this is a "black box" device to measure how children use their GoBabyGo cars. Bioengineering students, under the joint mentorship of faculty from Biolengineering and Occupational Therapy, underwent two semesters of design and prototyping. The result is a device that is capable of unobtrusively recording car usage, safety (kill switch) activation, and movement path, all without any effort on the part of children or parents. Experienced GoBabyGo builders can easily install the device in existing or future 12V GoBabyGo cars and retrieve data simply by removing an SD card. Two design iterations have been completed to date. Final designs will be released under an open source license to allow for distribution to other GoBabyGo sites. Widespread implementation of onboard logging systems will allow for more rigorous research into the efficacy and effectiveness of GoBabyGo powered mobility interventions.

INTRODUCTION

The ability to independently move around one's environment "provides a means for an individual to engage in everyday life activities including exploration and enjoyment of the world," (Logan, Feldner, Galloway, & Huang, 2016, p. 100). Children with mobility impairments deserve equitable opportunities to engage in those same life activities. Mobility impairments limit opportunities for children to independently interact with their surroundings, leading to delayed motor and social development as well as decreased activity participation and play (Huang, Ragonesi, Stoner, Peffley, & Galloway, 2014; Huang & Chen, 2017). Lynch, Agrawal, and Galloway (2009) suggest that the utilization of Early Childhood Powered Mobility (ECPM) as a means for exploration and learning may positively affect later perceptual, cognitive, social, and quality of life outcomes.

There are no commercially available powered mobility devices (i.e. motorized wheelchairs) for young children. The GoBabyGo approach modifies off-the-shelf, battery-operated ride-on toy cars (e.g.: PowerWheels) to serve as ECPM devices by installing an accessible activation switch and a customized seating system built of common off-the-shelf materials. Since 2012, 75 GoBabyGo sites across the U.S. have modified approximately 5,000 ride-on cars for children with mobility impairments.

Although GobabyGo efficacy research to date is overwhelmingly positive, it is of limited rigor. This is due in part to the reliance on car usage estimates reported by parents and caregivers. Parent reports are imprecise at best and unreliable or non-existent at worst. To better assess the efficacy of GoBabyGo ECPM devices, we need a non-intrusive, automatic, and reliable method for quantifying device use.

The purpose of this work was to create an open-source GoBabyGo ECPM data logging device that could provide non-intrusive, automatic, and reliable collection of precise, objective usage data from a ride-on toy car.

METHODS

This engineering design project occurred over the course of two academic semesters. Senior Bioengineering students completed the project under the joint supervision of faculty from the Departments of Bioengineering and Occupational Therapy.

DESIGN

Functions

The key functions of the device were to record: timestamp, momentary (activation) switch state, toggle (kill) switch state, battery level, and car velocity (speed and direction).

Requirements

The device was required to convert input signals from analog to digital, record events and measurements on a millisecond timescale, and store up to one month's worth of data.

Objectives

Among the many identified objectives, the device was expected to: collect data passively (i.e.: without family interaction), make assembly, installation, and data retrieval convenient for researchers, record precise and reliable data, not pose a safety risk, not impact car usage, consume minimal power, and withstand occasional exposure to the environment, including dust and rain.

Constraints

Additionally, the device was expected to: draw power from the existing 12V battery within the car, boot in less than one minute upon car power-up, reduce battery life by no more than 10%, maintain data storage on sudden power loss, achieve Ingress Protection (IP) 42 rating, and be physically mountable within the under-seat electrical compartment of the car.

Alternatives

Numerous microcontroller platforms were considered, including Raspberry Pi, BeagleBone, Arduino, and Adafruit feathers. Raspberry Pi and BeagleBone alternatives were eliminated from consideration because of the lack of an onboard real-time clock and team members' relative lack of experience with the platforms. Further, the Arduino and Adafruit platforms share the open-source Arduino software IDE, which features a robust support presence. In total, 9 Arduino feathers and 5 Adafruit feathers or shields were considered.

RESULTS

Initial Approach

The first iteration of the data logging device was a combination of the Arduino 101 microcontroller, Adafruit Data Logging shield, and stacking headers. In addition to a 32-bit processor, the Arduino 101 microcontroller provided analog and digital I/O pins as well as an accelerometer and gyroscope for position and velocity measurement. The Adafruit Data Logging shield provided the means to write data to an SD card as well as the necessary real-time clock (RTC).

A housing was 3D-printed from PLA filament.

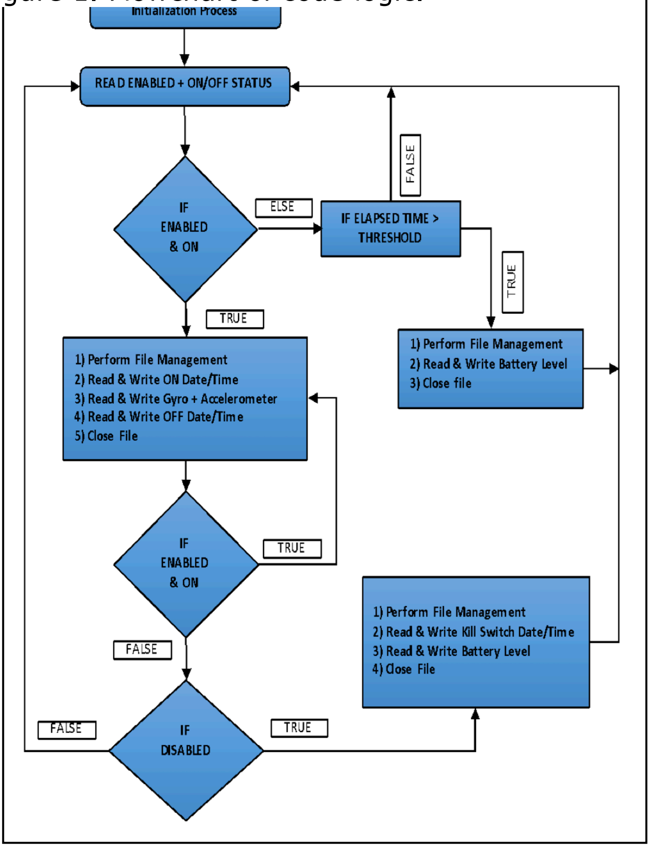
The initial device met most of the original design specifications. The device successfully read all switch states and battery level and wrote data to the SD card. An unknown error caused RTC time values to format incorrectly on write. Extensive testing with multiple microcontrollers, feathers, and code samples was unable to solve the problem. Time devoted to RTC troubleshooting precluded IP 42 testing.

A flow chart of the microcontroller code logic is provided in figure 1.

Final Approach

In light of the shortcomings of the initial approach, the team recruited the additional assistance of two electrical and computer engineering students and iterated on the design process. The result was an Arduino-compatible custom printed circuit board assembly (PCBA) with all necessary I/O pins, sensors, and SD read/write capability connected to a FONA 808 Microcontroller. (Because the core functions of the device were offloaded to the PCBA, any pincompatible Arduino microcontroller should work as a replacement for the FONA.)

Figure 1. Flowchart of code logic.

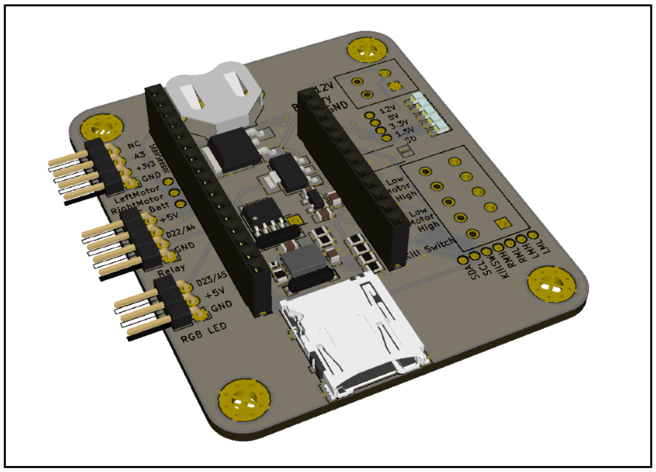


The PCBA replaced the separate gyroscope and accelerometer with a single Bosch Inertial measurement Unit (IMU) sensor. The IMU is a 9-axis absolute orientation fusion sensor with gyroscope, accelerometer, and compass built in. The PCBA also included onboard power regulation and clear markings for simplified connection to the car. Crucially, the RTC on the PCBA worked as expected, producing clearly timestamped data. A rendering of the PCBA is provided in figure 2.

Figure 1. CAD Rendering of custom PCBA.

DISCUSSION

The final result was a data logging device that met all of the original design features with the continued exception of ingress protection. Work is ongoing to design an IP 42 rated housing.



CONCLUSIONS

Through a collaborative, interdisciplinary design process, we have created a data logging device capable of measuring and recording objective GoBabyGo-style ECPM device use. The device is simple to install and data retrieval is as simple as removing an SD card. Data collection requires no effort on the part of the child or parents using the ECPM.

A follow-up feasibility and reliability study will be conducted in fall 2018, when ingress protection testing is completed. Should the device prove feasible and reliable, we will begin integrating the data logging device into all of our 12v GoBabyGo ECPM builds. The PCBA schematics, code, and housing CAD files will all be released under appropriate open source licensing agreements.

Additionally, we will modify the hardware design to run from a 6vdc power source, allowing it to be used with a much wider variety of GoBabyGo car platforms. Should the device prove reliable across platforms, it will provide much-needed quantitative data about GoBabyGo ECPM device use. Such data will allow for more robust studies of ECPM efficacy and comparative effectiveness, with the end goal of maximizing participation and development among children with complex mobility impairments.

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