SignalMe

UIUC ECE 445 - Spring 2019 - Project 21 Proposal

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Introduction

Objectives

Micromobility is a term referring to all forms of lightweight personal transportation, including, but not limited to, bicycles, skateboards, scooters, and rollerblades, along with electric variants. To be safe for use on the road, all of these modes of transportation require intuitive and standardized signaling and lighting. Unfortunately, this is currently not the case. While regulations for bicycles require certain forms of forward and rear illumination, signaling currently takes the form of arm based signals. Other modes of transport do not have similar regulations. As such, current micromobility signaling as a whole is fragmented and non standardized compared to equivalent systems on motor vehicles.

We propose to solve this with a universal signaling vest usable for all forms of micromobility. With movement based sensors and explicit button controls, the vest will give users intuitive and unified signaling with the ease of use found in the signal systems for motor vehicles. At the same time, the lighting used will be highly visible and understandable for others on the road using common signal conventions in the form of forward illumination on the chest, brake lighting on the back, and left and right turn signals around the shoulders. As an additional feature only possible with a motion aware wearable, the vest will also provide a high visibility flashing hazard operation that activates when a user has any incidents resulting in them falling to the ground.

Background

According to the NHTSA, "In 2016, there were 840 bicyclists killed in traffic crashes in the United States" with most deaths occurring during low light night hours. [7] Visibility and safe riding practices play a large role in reducing these kinds of incidents. To ride safely, riders should use cumbersome hand signals that many motorists should also be aware of. Anecdotally, however, very few (even seasoned) riders use these signals and few drivers know what they mean. During a time where many people are beginning to use ride-share programs such as Veoride, Bird, and Lime, the development of a safe intuitive signal system can be part of an effort to reduce the number of these incidents despite increasing utilization rates.

Currently, on the market, there do exist electronic signal systems for those on bikes in the form of backpacks, gloves, saddlebags, and more. These systems allow for signal initiation at the push of a button. However, the current solutions are in no sense of the word "smart." The turning off of a signal is based either on timers or manual user input which either risk a signal turning off in mid-turn, or requiring more effort than existing hand signals. Additionally, none of these systems are usable on modes of mobility other than bicycles. SignalMe aims to bring motion tracking to the area of micromobility signaling to make the act more like signaling in a car or other motor vehicle.

High-Level Requirements

1. **Requirement 1:** Automate bike signaling by the turning off of a remotely initiated turn signal after the user maintains a straight path for ten (10) feet after a right angle turn or lane change and signaling a brake light when the rider de-accelerates by more than 20% of the current speed in less than half a second.

2. **Requirement 2:** Provide street legal night lighting of all signals with all lighting visible from 500 or more feet away in clear night conditions.

3. **Requirement 3:** Remain functional for at least two (2) hours off of a single battery charge.

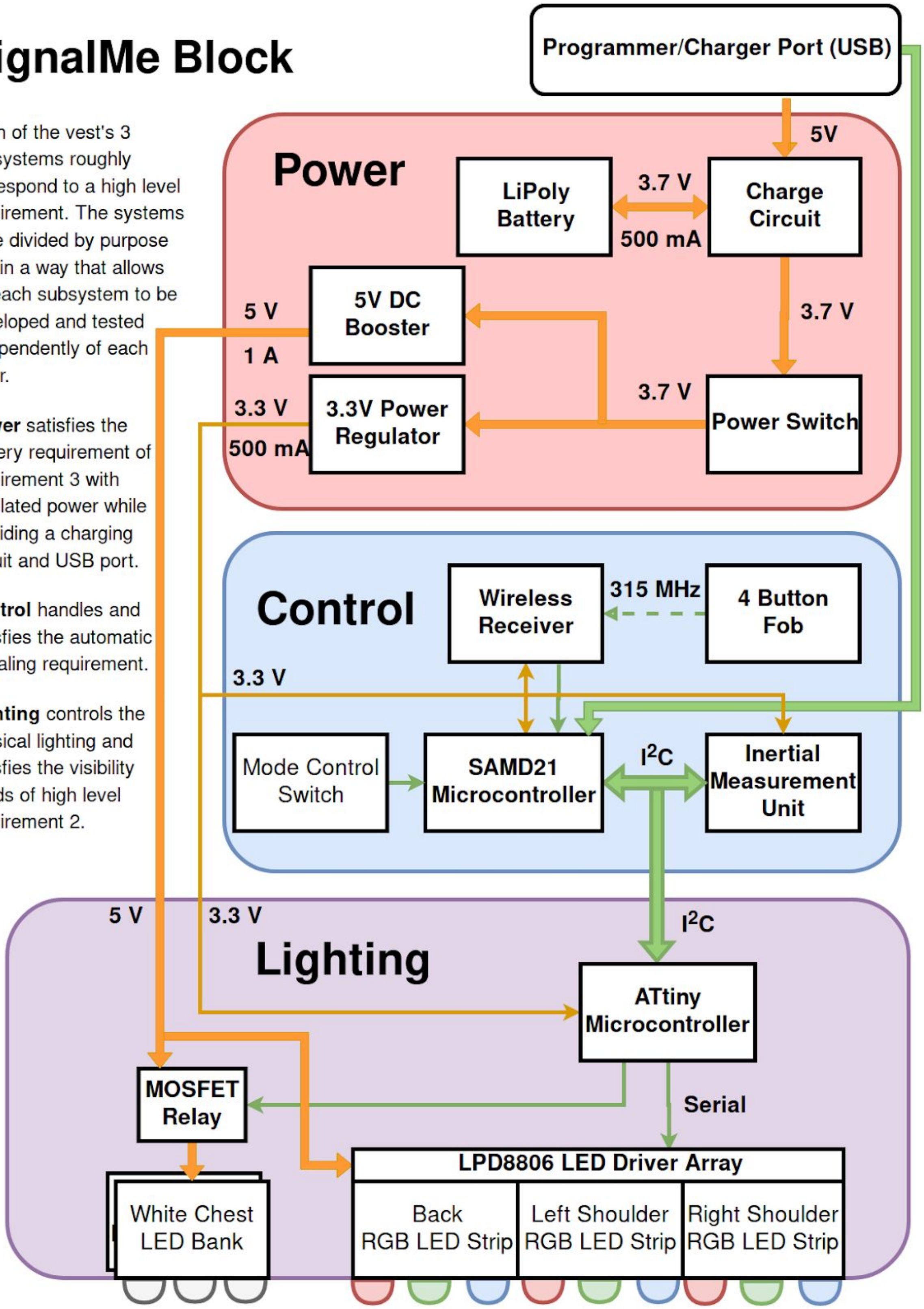
SignalMe Block

Each of the vest's 3 subsystems roughly correspond to a high level requirement. The systems were divided by purpose and in a way that allows for each subsystem to be developed and tested independently of each other.

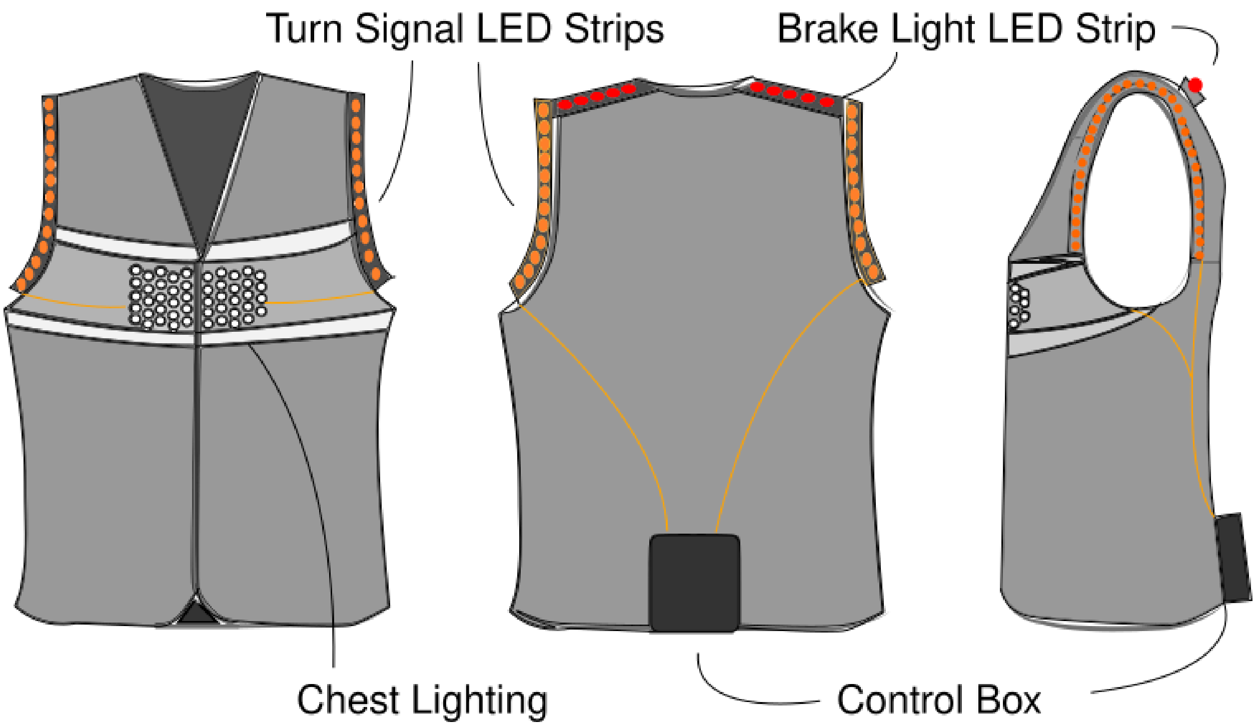
Power satisfies the battery requirement of requirement 3 with regulated power while providing a charging circuit and USB port.

Control handles and satisfies the automatic signaling requirement.

Lighting controls the physical lighting and satisfies the visibility needs of high level requirement 2.



Physical Design



The entire device is integrated into a one size fits all vest. Over the shoulders and along the upper back are RGB LED strips with each light individually controllable.

The upper back strip is primarily for brake signals and will usually be red while the shoulders when signaling a turn will blink an orangish yellow. On each side of the chest is a bank of white LEDs for forward lighting. All of these are wired to a control box on the lower back. This water resistant lightweight hard plastic box contains the sensors, microcontrollers, and battery system. To for user input, a 4 button keyfob is held in hand or affixed to handlebars to initiate turns, toggle hazard mode, and toggle the chest lighting.

Functional Overview

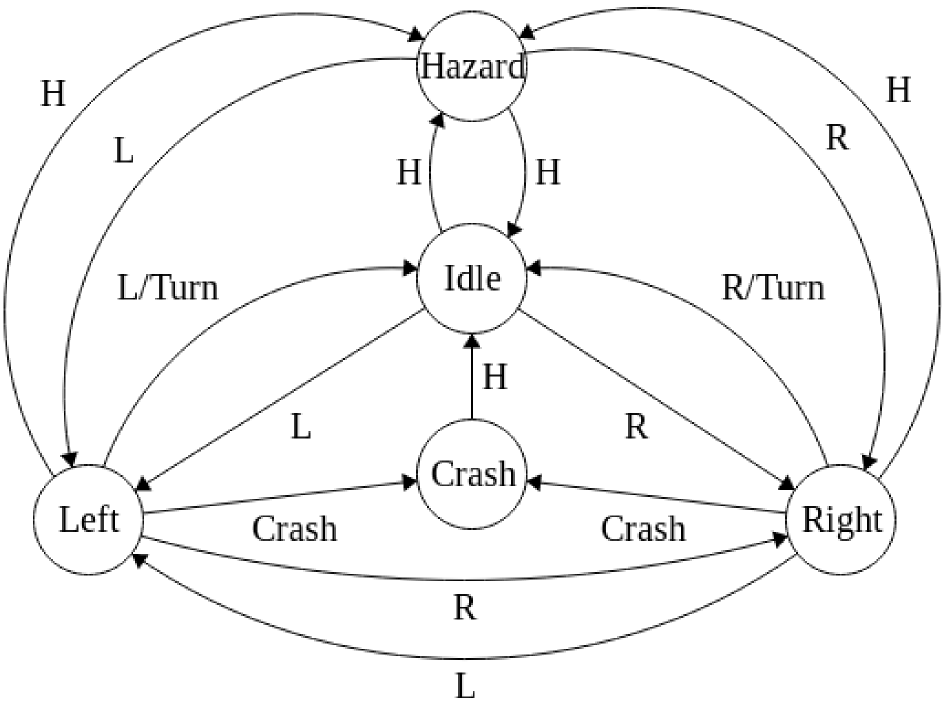
1. **Idle** - This is the main state the vest is in when not doing any signaling, it has an ambient dim rear red light that goes bright on brake detection and the chest lighting can be toggled with a button. The sensor controller constantly uses accelerometer data to dead reckon an approximate rider speed using poweron state as zero velocity. Otherwise the system waits for user input or a crash for any state changes.

2. **Left Signal** - This state corresponds to a left turn signal with a blinking yellow left shoulder. Upon triggering, the sensor controller will mark the current location as the origin of the turn. Using accelerometer and gyro data, rider displacement is tracked until the rider is laterally displaced by at least 10 feet (the lower end of standard lane width) to the left from the origin. From here the controller waits for a stabilization of riding direction for at least ten feet before automatically transitioning back to idle. The user may of course move back to idle manually by pressing the left signal button again.

3. **Right Signal** - Equivalent to the Left Signal but using the right shoulder for signal and mirroring detection along the sagittal plane.

4. **Hazards** - Equivalent to a motor vehicle's hazard lights. Shoulders and back both so a slow bright blink. Useful if a rider is off on the shoulder of the road or otherwise in traffic while not actively riding.

5. **Crash** - In the case the sensors detect a vertical drop greater than 2 feet followed by very sudden stop, it is likely the rider had an incident and is now on the ground. The vest will go into a flashing mode similar to the Hazard state but with more rapid flashing including flashing chest lighting. The only way to return from this state to idle is by holding the hazard button down for more than 1 second.



Key	
H	Hazard Button
R	Right Button
L	Left Button
L/Turn	Left button or Turn
R/Turn	Right Button or Turn
Crash	Crash Detected

States to Lights	Back Light	Left Shoulder	Right Shoulder	Chest
Idle	Dim Red[1]	Off	Off	Toggleable White[2]
Left Signal	Dim Red[1]	Blinking Yellow	Off	Toggleable White[2]
Right Signal	Dim Red[1]	Off	Blinking Yellow	Toggleable White[2]
Hazards	Blinking Bright Red	Blinking Yellow	Blinking Yellow	Toggleable White[2]
Crash	Rapid Red and Yellow	Rapid Red and Yellow	Rapid Red and Yellow	Rapid White

[1] Becomes steady bright red upon detection of a brake.

[2] Holds toggle state between non crash state transitions.

Control Subsystem Block Requirements

The control subsystem processes button and sensor input to produce control messages for the lighting subsystem. A microcontroller and inertial measurement unit are used to determine a user's positional, velocity, and acceleration vectors. In conjunction with button inputs from the user, control messages are sent to the lighting controller over I^2C when the controller determines a change in signal state.

Sensor Microcontroller

The main microcontroller, decided to be an Atmel SAM D21, is connected to the IMU and Light Controller over a common I^2C bus and to four (4) momentary button control signals. This controller will process IMU data to determine a user's movement path after button initiated signals. Simultaneously, acceleration and velocity are tracked to notice and signal any significant de-accelerations. In the event of any signal state changes, I^2C commands are sent to the lighting controller to request a change in lighting. It lastly uses a mode controlling switch to change between different modes for different forms of transportation (i.e. Sideways oriented modes such as Skateboards vs. forward oriented modes such as bikes and scooters).

Requirement: Track at least 1 minute of location/IMU data.

Inertial Measurement Unit (IMU)

A 9 Degrees of Freedom Inertial Measurement Unit (IMU) consists of an accelerometer, gyroscope, and magnetometer in a single package. Read and controlled by the sensor microcontroller over I^2C, the IMU package will provide rotational data from the gyroscope, linear data from the accelerometer, and cardinal directional data from the magnetometer to be further processed by the microcontroller. As micromobility movements are relatively slow, low full-scale range sensors will allow for precise readings over small movement ranges.

Requirement: Gyroscope Range of ±250-500°/sec and accelerometer Range of ±1.5-2g

Requirement: Operating Current below 5 mA

Button Controls

Four (4) momentary button controls allow the user to initiate signals for **hazard**, **left**, and **right** turn signals as well as **toggling the chest lights**. These button controls are needed as, legally, turn signals need to be initiated ~100 feet before the location of the turn itself. A receiver wired to the sensor controller over general purpose digital I/O. To send signal, a 4 button transmitter akin to an automotive key fob will be used.

Requirement: Sensor MCU acknowledges a button press within half a second.

Lighting Subsystem Block Requirements

The lighting subsystem takes commands from the sensor controller over I^2C to produce appropriate light patterns on the shoulders, back, and chest. Chest lighting gives street legal forward white light while the back and shoulders produce different lighting patterns based on the current signal state.[1]

Light Microcontroller

A low power microcontroller, decided to be an 8-bit AVR controller from the ATtiny line, is interfaced to the main sensor controller over I^2C to take commands for producing various lighting patterns. It is interfaced to the signal lighting over LPD8806 drivers with a clock and data line for each strip. It is interfaced to chest lighting via a pair of MOSFET relays.

Requirement: Under 1 mA during signal operation.

Shoulder Light Strips

LPD8806 based Weatherproof RGB LED strips allow for individual LEDs to be separately addressed and controlled by the light microcontroller. The shoulder light strips specifically are for signaling turns with a blinking yellow light common in motor vehicles.

Requirement: Yellow blinking light is visible at least 100 feet away in a 270 degree cone centered in the direction of that signal's side under clear night conditions.

Back Light Strip

Using the same LPD8806 based RGB LED technology as the shoulders, the back light strip provides both rear ambient red lighting and bright red lighting in the case a brake level de-acceleration is detected by the sensor controller.

Requirement: Red light is visible from at least 100 feet away from the rear when the brake signal is engaged under clear night conditions.

Chest Lights

To be a comprehensive lighting solution, forward illumination is provided by bright white LEDs. The operation of these lights are controlled by MOSFET relays controlled by the lighting controller.

Requirement: White light is visible from the front at at least 500 feet away in clear night conditions.

Power Subsystem Block Requirements

The power subsystem allows for battery operation of the vest, charging of the on board battery, and distribution of power to the appropriate subsystems in the form of direct battery potential and regulated 3.3V for the microcontrollers and sensors.

Battery

While the exact battery storage value is unknown, the system will require at minimum 3.3 V at running current for at least 2 hours to maintain the microcontrollers. A single-cell Lithium-Polymer (LiPo or LiPoly) has a nominal voltage of 3.7 V, and safe and easy to charge while connected to the device, and is common for wearables of this scope.

Requirement: A Full charge provides at least 2 hours of functionality.

Power Distribution

Consisting of a power switch a 5V booster, and 3.3 V regulator, the power distribution system provides a regulated 3.3 V for the microcontrollers and sensors while providing a safe 5V potential for the rest of the lighting.

Requirement: Provide at least 500 mA over the regulated 3.3V rail.

Requirement: Provide at least 1 A over the regulated 5V rail.

Battery Charger

LiPo cells are fairly particular about their charge circuits. Dedicated LiPo charge controllers (such as the MCP73831) exist that can take an input voltage and provide system power while charging a wired up battery. This charging port will take the form of a small form factor USB connector.

Requirement: Provide a charge current of at least 500 mA.

Risk Analysis

We believe biggest risk of our project comes from the sensor subsystem. Since our project depends heavily on information of gyroscope, accelerometer, and magnetometer, having precise sensor readings will determine success on our project. For example, if we have too sensitive of a gyroscope, using the raw data can erroneously trigger a state change in the sensor microcontroller. On the other hand, if we filter too aggressive or have too low resolution of a sensor, there may not be enough information to accurately respond to what should be a change in signal state.

Additionally, as a wearable, there will be a level of introduced noise in the form of rider motion which differs both between modes of transport and between riders. In all of these cases, this unwanted noise provides either false or scant IMU information and may result in incorrect turning on/off of LED light negating the core purpose of this project. If this happens in the middle of a turn, this could turn out to be quite dangerous.

Because, all three sensor devices, gyroscope, accelerometer and magnetometer provide various result depending on how we eliminate noise, the key approach of our project would be setting filtering value. To adapt for various riders and personal transportation, numerous experimental results must be collected and processed to find useful signal range of our sensors in addition to determining an appropriate dynamical model for various modes of transportation..

Safety and Ethics

There are handful of safety concerns within our project. Usage of a Lithium polymer battery is one of them. We chose the Lithium polymer battery as a mobile power source due to its high energy density and discharge rate. With such features, the LiPo cells have a distinct risk of fire. There are two common causes of fire; when the battery is overcharged, and when it is exposed to too much heat such as from its own discharge. LiPo batteries are also quite soft making puncture and associated fires a very real risk. To avoid these incidents, we will ensure our charge circuit has a cutoff point and instruct users to not charge unattended. To protect the user and vest we will create an enclosure for the control and power systems that will protect battery from heat exposure and puncture [6].

As we are billing ourselves as a “comprehensive micromobility signaling system”, it is our responsibility to follow part 3 of the IEEE code of ethics, and 1.3 of the ACM Code by providing a system that fulfills the common sense requirement of such a project. To do so the project will allow users to follow state regulation for bicycle lighting on the road.[2][3] The regulation states that bicycle safety equipment should compose of red rear reflector visible from 100 to 600 ft, horn or bell that can be heard up to 100 ft, and front light visible at least 500 ft[5]. All of these lights should point down to not distract any drivers from driving on the road. Since we are making vest with LED lights, we need to account that extreme brightness and darkness can distract drivers more, and find valid range of brightness that will suit both state regulation and driver’s comfort.

As an outdoor device that uses electricity, we must acknowledge and follow IP67 guidelines to avoid potential safety hazard. According to IP67, the device needs to be protected from total dust ingress, and water immersion between 15 cm to 1m depth[4] which the enclosure would also satisfy. Another concern is failure of the device in the middle of the ride, particularly in the middle of turn signals along with erroneous brake lights. This problem could be crucial since it can guide to a false communication between rider and other drivers leading potential accident. To solve this problem, we will have a remote controller that can override any signals between sensor and the vest to ensure rider to manually signal their desired turn.

References

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[2] “IEEE Code of Ethics”, *IEEE.org* [Online] https://www.ieee.org/about/corporate/governance/p7-8.html

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