ECE 445

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Mock Design Document

Conductive Fabric Gesture-Controlled Sleeve

Team 56

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1 Introduction

1.1 Objective

Bicyclists encounter many distractions as they travel. Between using their arms to indicate turns and navigating, cyclists must also focus their attention on the road to ensure their safety. As the number of riders in big cities has exploded over the years, so have concerns regarding rider safety. In Boston, where ridership has grown by more than 100% since 2007, nearly a third of riders demonstrate distracted bicycling (Wolfe). As a consequence, these safety concerns have created a need for a wearable solution that enables connectivity on the go and optimizes the rider experience, while preventing against the possibility of an accident.

Our goal is to integrate gesture control into a fabric sleeve that can be worn by bicyclists. This sleeve will be equipped with a capacitive touch sensor system designed on fabric using conductive thread. It will be responsible for detecting simple gestures, which in turn will be routed through an RF module to a receiver capable of performing certain actions depending on the gesture pattern. For the purposes of this project, the external interface will be an LED array setup that will represent the potential use cases of this conductive sleeve technology. As an added (optional) level of complexity, we will also enable this sleeve to control simple functions (i.e. volume control) on a smartphone.

1.2 Background

Efforts to create a wearable device for bicyclists that can effectively interface with a smartphone have thus far been limited. While smartwatches enable connectivity, they present yet another visual distraction to bicyclists. Project Jacquard, a commuter jacket designed by Google and Levi's, is perhaps the closest comparable consumer product to our design [3]. While advertised as keeping riders connected on the move, its rather large ($350) price tag has kept it from finding mainstream adoption. Our sleeve is expected to be a significantly cheaper alternative that maintains a strong degree of functionality.

1.2 High-Level Requirements List

- The sleeve, located on the arm, will be able to wirelessly communicate with the LED array display.
- This product will be able to detect four different hand gestures on the sleeve: swipe up, swipe down, single tap, and double tap.
- The LED array will be used to demonstrate the sensitivity of the gesture-control on the sleeve.

2 System Design

2.1 Block Diagram

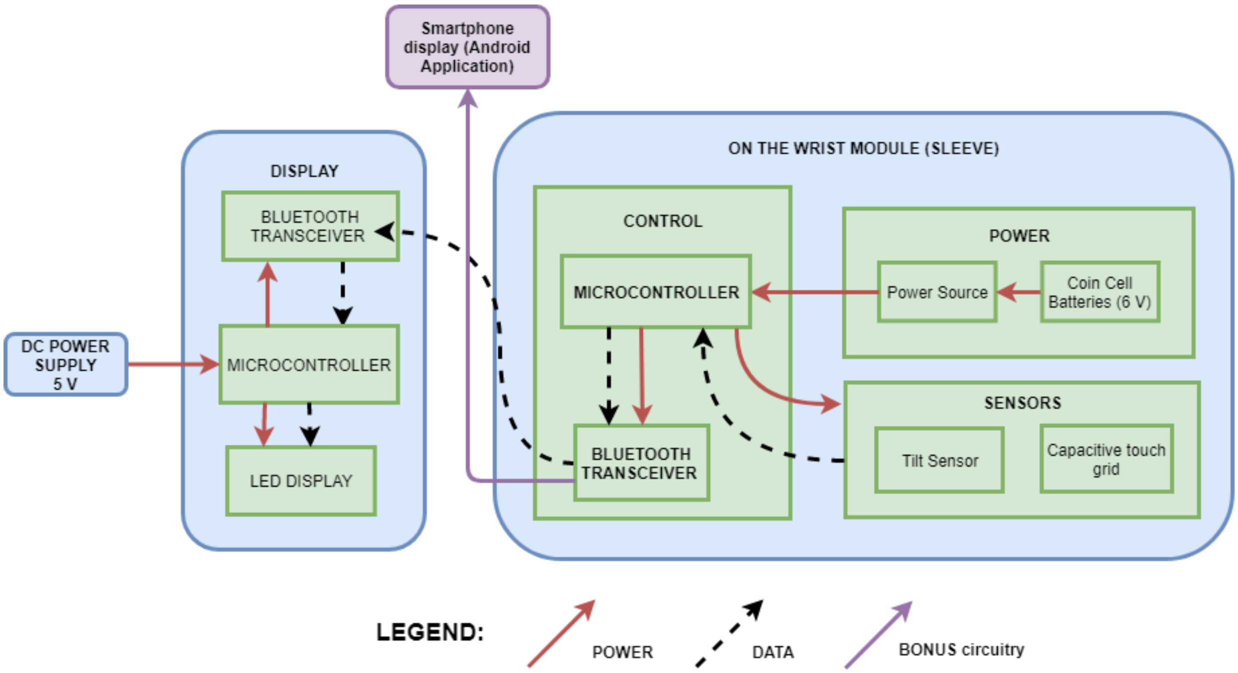

Figure 1. Block diagram overview of system.

2.2 Description of Block

Conductive Thread Capacitive Touch Grid

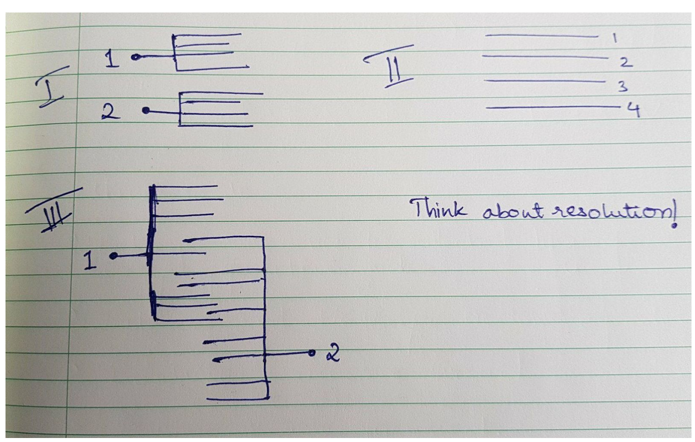

Figure 2. Potential Capacitive Grid Designs

This capacitive touch will be used to detect the gestures made by the biker on the sleeve. It will consist of a conductive thread pattern and will be powered by the microcontroller. It will be capable of detecting four gestures - swipe up, swipe down, single tap and double tap. The capacitive grid will be made of conductive thread weaved into straight lines oblique to sleeve and will be connected directly to the microcontroller.

Microcontrollers

For this project, we have chosen to use the low-cost Atmel MEGA328P microcontroller (MCU) for its simplicity yet ability to support our desired project goals. It supports the generic driver for capacitive touch and has 23 general I/O pins that will be sufficient to communicate all input and output information from the sensors to the Bluetooth module.

There will be two MCUs located on the sleeve and LED demo submodules respectively. The microcontroller on the sleeve submodule will handle collecting and processing the input from the capacitive touch sensor. It will determine which gesture the user performed and what action should be performed next. Then, it will provide the output signals to the RF transmitter. A second microcontroller will be used to support the LED display demo. This one will collect the signal from the RF receiver. It will process it to these inputs to determine which LEDs and what color should be displayed, corresponding to the gesture made.

Requirements: Must be able to transmit/receive data using programmable UART.
Requirements: Must be able to operate in normal mode on 3 V input with +/- 5% tolerance.

Bluetooth Module

The Bluetooth module will establish communication between the sleeve module and the LED array display module. Wireless connectivity is important for wearable technology, like this gesture-controlled sleeve, in order to communicate with other devices preserve ease of accessibility for users [ref].

Sleeve Bluetooth Transmitter

The purpose of the Bluetooth transmitter module is to receive signals sent by the MCU, with both devices mounted on the sleeve module to capture appropriate sensor data.

LED Demo Bluetooth Receiver

The purpose of the Bluetooth receiver module is to pick up on signals sent by the corresponding transmitter module. The receiver will be connected to the demo display. For demo purposes, commands sent through to the Bluetooth receiver will be decoded by the MCU to appropriately control the LED array display.

Requirements:

- Effective range: 0-5m
- Data rate: ~250 kbps
- Receiver sensitivity: -92 dBm
- Voltage: 3.0V +/- 5%
- Successfully pair with receiver and transmitter devices

Verification:

- Monitor Bluetooth serial transmit cycles in code portion of the microcontroller

LED Array Display

The LED block will be used to demonstrate the sensitivity of the sleeve and the state associated with the gesture pattern. A 2D array of LEDs will model the gesture performed by the user on the capacitive touch grid. For instance, swiping down on the sleeve will prompt the LED matrix to simulate colors travelling downwards, while swiping up will result in colors travelling in the opposite direction. This block will receive its inputs from the second microcontroller that is connected to the RF receiver.

The LED array we intend on using in this lab is a 1.2” Adafruit Bi-Color 8x8 Matrix, equipped with 64 Green and 64 Red LEDs. The 8x8 matrix will also be paired with 2 MAX7219 LED drivers. The requirements for each device are as listed below:

Requirements

1.2” Bi-Color 8x8 Matrix:

- Operating Voltage: 2.2-2.5 V
- Current: 20 mA
- Will require 2 LED drivers to perform multiplexing operations

Maxim MAX7219 LED Drivers (4 pin SPI Interface):

- Must have a minimum clock period of 100ns
- Will require the use of 2 additional capacitors and 1 resistor to suppress noise and regulate current through the LEDs

Verifications:

- Cycle through multiple colors by displaying each upon initialization.
- Be able to effectively interface the two LED drivers with the LED matrix and Arduino
    - Connect pins on drivers to Arduino, perform data transfer and monitor for correct output

Power

Power calculations for components:

Component voltage specs						
	Voltage (V) min	Voltage (V) max	Typ Current (mA)	Max Current (mA)	Power (mW)	Max Power (mW)
Bluetooth module	2.8	3.4		50	170	
Tilt Sensor	2	3.6				
MCU	3	5				
		3	1.7	2.5	5.1	7.5
		5	5.2	9	26	45
LED Array	2.5					
LED driver						
	3.6	5		61.5	201.1	52.5

* Voltage levels for MCU determine processing speed - 4 MHz vs. 8 MHz for 3 and 5 V respectively

Power Source components:

- 2x Lithium button batteries (3V each)
- 2x Linear voltage regulator (with linear dropout of 2 V) for MCU & Bluetooth

Requirement: Battery must be able to provide power for xx hours.
Verification: With battery at full charge, apply a load calculated to induce current flow and measure time until current or voltage output decreases by 10%.

Requirement: Physical requirements: a) Battery size must not exceed standard wrist size
b) Battery weight must not exceed 60% of standard wrist watch weight (~50-90g)
Verification: a) Battery dimensions will be measured using calipers and compared with standard
b) Battery weight will be measured using a digital scale and compared against standard

Requirement: Voltage regulator: Must be able to provide 3V with +/- 5% tolerance.
Verification: Measured using signal generator

Requirement: Voltage regulator: Must be able to provide 70 mA of current at all times
Verification: Measured using signal general with a resistor on breadboard set up

Android Interface
Currently, the Android interface module is expected to be out of scope of the project timeline and will be a stretch goal, as the main demo will be the LED array display. The overall interface of the Android application would be simple and minimal for the purposes of the project. It would primarily consist of a home screen with various options.
All functions would be programmed and implemented with the standard Android Studio and Android SDK and targeted for Android API Level 26 (Oreo 8.0.0).

Requirements:

- Native connectivity to Bluetooth module through Android interface. Must have standard pairing protocols.
- Must run on Android API Level 26 (Oreo 8.0.0).
- Successfully display gesture patterns.

Verification:

- Verify successful pairing to Bluetooth module by monitoring data transfer using serial monitor for microcontroller and app for smartphone.

Cost Analysis

Part	Part Number	Unit Cost	Quantity	Total

Conductive Thread		$14.95	2	$29.90
Microcontroller	Atmel ATMEGA328P-PU	$2.20	2	$4.40
Arduino Uno OR Raspberry Pi	-	$0 (acquired from previous personal project)	1	$0
Testing Breadboard	-	$0 (acquired from previous coursework)	1	$0
Various MST / Through-Hole Passive Componenets	-	$10.00	-	$10.00
Bluetooth Antennas	Digi XBee S1 Low-Power Module w/ PCB Antenna	$15.50	1	$15.50
LED Array	Adafruit Bicolor LED Square Pixel Matrix	$15.95	1	$15.95
Coin Cell Battery				
Total Cost				

Table x. Expected component pricing information.

Schedule (our Gantt Chart)

Week	Mrunmayi Deshmukh	Guneev Singh	Stephanie Wang
2/11/18			
2/19/18			
2/26/18			
3/5/18			

3/12/18			
3/19/18 **Spring Break**			

Table x. Progress schedule split by team member.

Risk Analysis

We believe the biggest risk of our project will be the sensors block. Our design depends on the sensitivity of the capacitive touch sensor to provide accurate information to the microcontroller. Information from the touch will be input signals to the microcontroller to determine the action that should be performed next. In particular, one design challenge for the touch sensor will be to determine the adequate levels of gesture sensitivity. Different users will make swiping or tapping gestures at varying rates, so to avoid false positives, thorough testing must be performed to achieve the optimal pattern design and gesture tolerances.

As a result, our project will also be dependent on the microcontroller's clock speed. For both sensors, we will need to be mindful that they are not too sensitive, otherwise the system will perform actions when they are not needed. If they are not sensitive enough, the system will not receive enough data. Another challenge will be implementing low-level code for bluetooth module driver.

Ethics & Safety

As we continue to work towards finalizing the design of our sleeve, we hope to eliminate the possibility of any electric shock to a potential rider. Given that the bicyclist is interfacing directly with conductive fabric and is also wearing the sleeve, we want to ensure that we incorporate some type of electrical insulating fabric to avoid direct skin to sleeve contact and afford the rider greater protection. One of the ways we hope to minimize this risk and also protect the sleeve from the environment is by applying a water resistant epoxy. While this is a later-stage design consideration, if pursued, we would need to consider the impact of the epoxy on the sensitivity of the conductive thread and ensure that the overall performance of the sleeve is not compromised.

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