Intuitive and Ergonomic Gesture-Based Drone Controller

ECE445 Design Document Spring 2019

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Team 22 (TA: Channing Philbrick)
1 Introduction

1.1 Objective

Recreational drones are more popular than ever before with roughly 1.4 million UAVs (Unmanned Aerial Vehicles) operated in the United States in 2018 [1]. Though the Federal Aviation Administration (FAA) projects this number will double to 2.4 million by 2021, this forecast is several million fewer than last year’s prediction. Analysts at the FAA suggest that “market saturation and shifting consumer tastes” are negatively impacting growth. Accordingly, entering this market can be difficult for new products and older products can be easily overlooked.

Our project aims to provide a means of distinction for numerous commercially available recreational drones. We plan to create an ergonomic and intuitive gesture-based controller. Serving as both a novelty and a simpler means of control, compatibility with our device would raise the profile of compatible products. Additionally, the glove stands out on its own as a cool new way to fly. Users would use wrist and hand movements to control the drone’s pitch, roll, and yaw by mimicking the desired movement. Thrust would be controlled by a trigger-like mechanism actuated by the user’s index finger. Ideally, the entire package would be low-profile and cost effective while allowing for effective control.

1.2 Background

While attempts to make a similar product already exist on the market, they tend to be clunky and only work with one specific drone model [2, 3]. Our product would be slim and have compatibility with a wide variety of devices. This would attract current and new drone owners to purchase our product as an add-on to their drone or collection of drones. The product could also be included with partner companies products. Our product could be especially convenient for users with multiple drones as removes the need for having a separate controller for each drone.

1.3 High-level requirements list

- The glove must be able to measure user hand movements greater than 1 m s$^{-2}$ and user hand orientation within 5° by reading and processing sensor data from multiple inertial measurement units.
- The glove must be able to transmit control signals to the drone within a latency of less than 50 ms.

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*See Appendix A for compatible products.*
2 Design

2.1 Block Diagram

The design for this controller consists of four subsystems for proper operation: an array of sensors and buttons; a micro-controller, a power supply, and a transmitter. The array of sensors will collect data about the movement of hand when in the glove. The micro-controller will collect the data from the sensor array via I²C connections and convert it to a transmittable form. The transmitter will then take the output of the micro-controller and transmit the data stream to the drone. The power supply, through a battery and a collection of voltage regulators, will supply 3-5V depending on the component.

Figure 1: Block Diagram

Red - Power; Blue - I²C; Black - Data; Double Black - Wireless
2.2 Physical Design

Figure 2 below is a qualitative sketch [4] of the glove with approximate positions where the sensors, battery, and micro-controller will be placed. The whole surface of the glove is used from the placement of the sensors on top of the glove for accuracy of capturing movement to the battery being placed on the underside of the forearm just below the wrist to reduce the strain from battery weight.

Figure 2: Approximate placement of sensors and buttons
2.3 Functional Overview

The various sensors in the palm and on the back of the hand will relay information to the microcontroller which will in turn translates those signals into control commands for the drone. The control commands will then be sent to the drone via a 2.4GHz transmitter. The combined electronics will be powered by a rechargeable Lithium-Ion battery.

2.3.1 Sensors

The sensor system of the glove is meant to collect all necessary control inputs from the user. Each sensor will be powered by the microprocessor and send their data to it.

2.3.1.1 Digital Buttons

The digital buttons will be used to signal different modes and features of the drone. They will be mapped almost directly to the existing controller buttons.

Requirement: The digital buttons must be the appropriate size (2cm²) to fit on the bottom corner of the glove.

2.3.1.2 Inertial Measurement Units

These IMUs will create sensor data along 3-axis from movement of the hand. These movements will control the roll, pitch, and yaw of the drone. They will also take into account lateral movements in the form of an accelerometer on the X, Y, and Z-axis. The accelerometer portion will also act as a kill switch.

Requirement 1: The IMU must consume under 12mW.

Requirement 2: The IMU must be less than 1cm² so multiple IMUs can fit on the glove.

Requirement 3: The IMU must be sensitive enough to generate the signal in 4ms or less.

2.3.1.3 Analog Trigger

The analog trigger will control the thrust level of the drone through a voltage divider with a potentiometer.

Requirement: The trigger should be easy to press, but still provide a moderate level of resistance in order to more easily control the thrust.

2.3.2 Micro-controller

This micro-controller will be a ATmega328 boot-loaded with Arduino compatibility so it can be programmed with Arduino. It will collect sensor data, organize it, and transmit it to the drone through the transmitter.

Requirement 1: The micro-controller needs to process and transmit the data in less than 100ms in order to help minimize latency.
Requirement 2: The micro-controller must take in at least 3 $I^2C$ signals from the IMUs, one for each of the IMUs on the glove.

Requirement 3: The micro-controller must convert the signals into transmission packets that the drone read and react accordingly.

2.3.3 Battery Pack

The battery pack will power the microprocessor which in turn powers the sensors and transmitter.

Requirement 1: The battery pack must supply voltage (3-5V) and current over the length of several flight periods about 60 minutes. This is around 500mAh.

Requirement 2: The battery pack must be small and/or low profile meaning under 1.5cm in height.

2.3.4 Transmitter

The transmitter will be an XBee Pro S1. Its role is to communicate the sensor data from the glove to the drone.

Requirement 1: The transmitter must function with a latency of less than 100ms.

Requirement 2: The transmitter must function at least up to 100m indoors.

3 Requirements and Verification

3.1 Digital Buttons

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The buttons must be less 2 cm</td>
<td>A. Using a ruler measure the length and width of the button and calculate area.</td>
</tr>
</tbody>
</table>
### 3.2 Sensors

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification</th>
</tr>
</thead>
</table>
| 1. The IMU must consume under 12mW.                                        | A. create a small circuit on a breadboard according to the datasheet for the IMU and using a power supply at the suggested operating voltage of 3.3V.  
B. Using an ammeter measure the current and record the value.  
C. Calculate power consumption.                                             |
| 2. The IMU must be less than 1cm².                                          | A. Using a ruler measure the length and width of the button and calculate area. |
| 3. The IMU generates the signal in 4ms or less.                             | A. Create a basic circuit connected to an AuDrino.  
B. Code AuDrino to read values from the IMU through the I²C SDA and SCL lines.  
C. Use a timer to verify the signals are being read by AuDrino in less than 4ms |

### 3.3 Micro-controller

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification</th>
</tr>
</thead>
</table>
| 1. The micro-controller needs to process and transmit the data in less than 100ms | A. Code the micro-controller with software to process the data  
B. Use a timer to verify timing from acquiring data to creating transmission packet is less than 100ms |
| 2. The micro-controller must take in at least 3 I²C signals                | A. Read datasheet  
B. Code and assign addresses according to datasheet |
3.4 Power System

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The battery must supply 100mA to a combined load of 12V.</td>
<td>A. Build complete sensor and micro-controller circuit.</td>
</tr>
<tr>
<td></td>
<td>B. Connect battery and using volt and ammeters measure to ensure all components are getting the recommended voltage and operating at typical currents as specified in the datasheet of the components within +/-5%</td>
</tr>
<tr>
<td>2. The battery must be under 1.5cm in height</td>
<td>A. Take a ruler and measure the battery to ensure it is under 1.5cm</td>
</tr>
</tbody>
</table>

3.5 Transmitter

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The transmitter must function with a latency of less than 100ms.</td>
<td>A. Using two audrinos set one up to send a signal and the other receive.</td>
</tr>
<tr>
<td></td>
<td>B. Using a timer measure the time it takes for the signals to transmit.</td>
</tr>
<tr>
<td>2. The transmitter must function at least up to 100m indoors.</td>
<td>A. Using the same set up with two audrinos stand 100m apart.</td>
</tr>
<tr>
<td></td>
<td>B. Send a transmission packet and verify it is received by the receiver in less than 100ms.</td>
</tr>
</tbody>
</table>
4 Schematics

4.1 IMU

This circuit will be implemented three times, one for each IMU being used. They will be connected to the ATMega328 via the I²C bus connection. Adapted from the schematics available for an arduino compatible breakout board[5]. VDD is received from the voltage regulators in the power subsystem, and ground is the common ground for the circuit.
4.2 Power Subsystem

Figure 4: Power Subsystem

GND and VDD will be supplied from the battery not shown in the diagram
5 Risk Analysis

The main risk for this project is shorts caused in the wiring on the glove. Shorts and/or exposed wires in the wires pose a risk for minor electrocution to the user. The plan to mitigate this risk is to have as few long exposed wires as possible and contain most of the main circuitry to the PCB. To minimize shorts sealing visible wires between layers of fabric will prevent wires from touching thus preventing shorts. It will also protect the user from electrocution risks. This approach does, however, slightly increase the bulk of the glove by having more fabric layers.
6 Cost and Schedule

6.1 Cost

6.1.1 Labor

<table>
<thead>
<tr>
<th>Rate</th>
<th>Hours</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>$40/hr</td>
<td>120</td>
<td>$4800</td>
</tr>
</tbody>
</table>

This is the calculation of labor for one person since there are two people on this team the total cost of labor will be $9600.

6.1.2 Parts

<table>
<thead>
<tr>
<th>Part</th>
<th>Cost</th>
<th>Number Needed</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPU-6050</td>
<td>$8.31</td>
<td>3</td>
<td>$24.93</td>
</tr>
<tr>
<td>ATMega328</td>
<td>$1.46</td>
<td>1</td>
<td>$1.46</td>
</tr>
<tr>
<td>XBee Pro X1</td>
<td>$7.99</td>
<td>1</td>
<td>$7.99</td>
</tr>
<tr>
<td>Resistors</td>
<td>$0.10</td>
<td>30</td>
<td>$3.00</td>
</tr>
<tr>
<td>Capacitors</td>
<td>$0.50</td>
<td>20</td>
<td>$10.00</td>
</tr>
<tr>
<td>Custom PCB</td>
<td>$8.00</td>
<td>1</td>
<td>$8.00</td>
</tr>
<tr>
<td>Battery</td>
<td>$9.95</td>
<td>1</td>
<td>$9.95</td>
</tr>
<tr>
<td>Physical Glove</td>
<td>$5</td>
<td>1</td>
<td>$5</td>
</tr>
<tr>
<td>Potentiometer</td>
<td>$0.95</td>
<td>1</td>
<td>$0.95</td>
</tr>
<tr>
<td>3D Printed Trigger</td>
<td>$4</td>
<td>1</td>
<td>$4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>$75.28</strong></td>
</tr>
</tbody>
</table>

Total cost (Labor + Parts): $9675.28

6.2 Schedule

<table>
<thead>
<tr>
<th>Dates</th>
<th>Targets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1: Feb. 18 - 24</td>
<td>Test all parts for verification</td>
</tr>
<tr>
<td>Week 2: Feb. 25 - Mar. 3</td>
<td>prototype circuit on breadboards and verify it works as intended.</td>
</tr>
<tr>
<td>Week 3: Mar. 4 - Mar. 10</td>
<td>Design PCB and analog trigger housing</td>
</tr>
<tr>
<td>Week 4: Mar. 11 - Mar. 17</td>
<td>Obtain glove determine final placement of battery, trigger, and any exposed wires</td>
</tr>
<tr>
<td>Week 5: Mar. 31 - Apr. 7</td>
<td>Solder, place all components, and attached to glove</td>
</tr>
<tr>
<td>Week 6: Apr. 8 - Apr 14</td>
<td>final design and verification testing.</td>
</tr>
<tr>
<td>Week 7: Apr. 15 - Apr 21</td>
<td>mock demos and presentation writing.</td>
</tr>
</tbody>
</table>
7 Ethics and Safety

A possible ethical concern is someone using this product to control a drone that could be used in a non-personal use scenario. If this scenario were to happen it could violate the IEEE code of ethics in terms of potentially harming the public, environment, and/or hurting groups of people. Full statements of these ethics are IEEE Policies 7.8.1 and 7.8.9. [6] To alleviate this concern our controller will only control one hobbyist type drone. As part of the Federal Aviation Administration’s (FAA) policies on drone flying for hobbyist users we must ensure the drones altitude remains under 400ft in uncontrolled airspace. There are also regulations at the campus level where before flying a drone on or inside campus property we must obtain approval from various campus safety groups including the Division of Public Safety and Code Compliance & Fire Safety.

We also must be aware of the voltages and currents across various areas of the glove to make sure no part becomes unstable where it would be dangerous for the user to wear on their hand.
References


Appendix A  Compatible Products

Attop YD-822/YD-829/YD-829C
BayangToys X6/X7/X9
BWhoop B03
Cheerson CX-10/CX11/CX12/CX205/CX30/SH6057/SH6043/SH6044/SH6046/SH6047
EAchine CG023/CG031/3D X4/E010/H7/H8 mini/H8 mini 3D/JJRC H20/JJRC H22
Floureon FX10/H101
FQ-777-124 Pocket Drone
FY326Q7
HiSky RXs/HFP80/HCP80/HCP100/FBL70/FBL80/FBL90/FBL100/FF120/HMX120
JJRC DHD D1/H36 mini/H6C/JJ850
JXD 385/388/389/391/393
MJX X600
NiHui NH-010
Syma X5C/X5C-1/X11/X11C/X12/X2
WLToys V202/252/252 Pro/272/343/930/931/939/966/977/988/933/944/955
XinXun X28/X30/X33/X39/X40
Yizhan Tarantula X6