

ECE 445
Senior Design Laboratory
Project Proposal

Camera Gimbal

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Abstract

For our senior design project, we are creating a camera gimbal system that allows the user to film stable video footage by stabilizing the camera on the X and Y axes while allowing the user to control the Z axis. This document is a more detailed description of our project as compared to our RFA. This document will contain high-level details on our implementation, requirements for our project to be considered a success, as well as safety and ethical considerations.

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1. Introduction

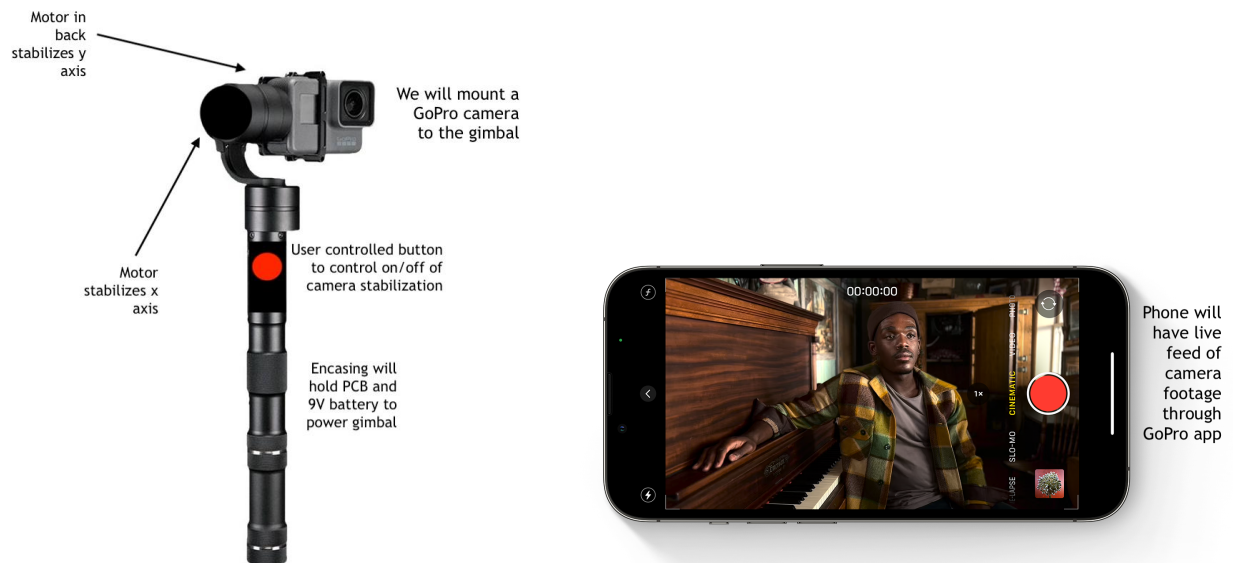
1.1 Problem

A major problem in video processing is footage that is shaky. If you take the forward direction as +y, right direction as +x, and up direction as +z; Shaky video footage is a result of the camera rotating around the +y and +x axes at minute steps. For example, if you take out your hand with your palm facing forward and pretend that it is a camera. Wave your hand as if you are waving hello. Moving your hand left and right is the camera rotating around the y axis also known as roll. If you move your hand up and down, bending at the wrist, it is the camera rotating about the x axis also known as pitch.

1.2 Solution

Camera stabilization, countering the shift in pitch and roll, is the key to solving this issue. To do this, we want to make a camera gimbal. This will allow for stability in camera footage given an initial starting orientation of the camera. Once a button is pressed, the camera gimbal will take in an initial orientation from a gyroscope sensor. This reading will go to an encoder to the microcontroller. Two servo motors, controlled by the microcontroller, will be used to maintain the initial orientation by opposing the shift in pitch and roll, keeping the camera stable.

1.3 Visual Aid



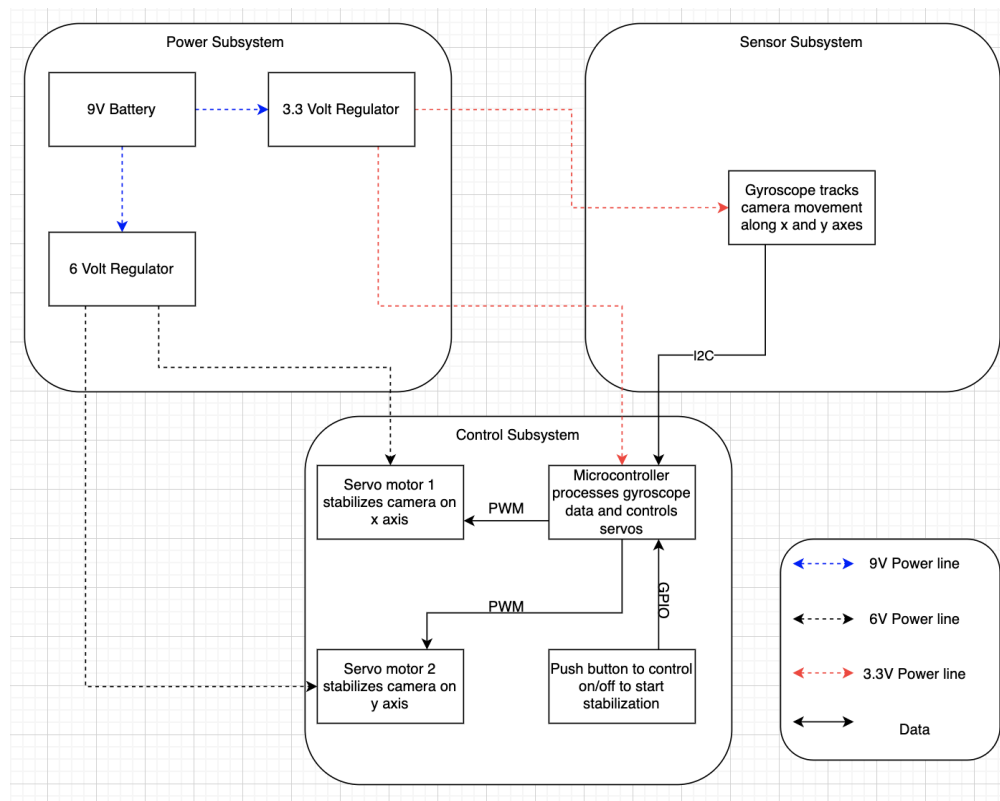
1.4 High Level Requirements

For our project to be considered successful, we will need to meet the following requirements:

- i. Camera is stabilized on +x axis (Pitch)
This can be tested by isolating one of the servo motors and seeing how they oscillate as the gyroscope/gimbal is moving around. After researching industry standards [5] for gimbal slew rates (speed at which the gimbal can rotate in a given direction), we will try to achieve a minimum slew rate on the x axis of 100 degrees/second.
- ii. Camera is stabilized on +y axis (Roll)
This can be tested by isolating one of the servo motors and seeing how they oscillate as the gyroscope/gimbal is moving around. We will try to achieve a minimum slew rate on the y axis of 100 degrees/second.
- iii. User interface (button) works
 - First button press turns on and starts reading from the gyroscope sensor.
 - Second button press locks the camera orientation by saving gyroscope reading and turns the gimbal mode on.
 - Third button press turns the system off.

2 Design

2.1 Block Diagram



2.2 Subsystem Overview

Our modular design is divided into 3 subsystems:

2.2.1 Power Subsystem

The purpose of this subsystem is to pull power from our 9-volt battery and route the required amounts to our other components: servo motors, gyroscope, and the microcontroller.

Components: 9V battery EN22, 9V battery mount 1294, +6 Volt Regulator MC7806CTG, +3 Volt Regulator LM317T

2.2.2 Control Subsystem

The purpose of this system is to actuate our motors in order to mimic a gyroscopic gimbal. We will use a microcontroller which interprets data from a gyroscopic sensor to set control inputs to motors.

Components: Microcontroller ATmega328p, 2x Servo Motor HS-311, Push Button MPB-43

2.2.3 Sensor Subsystem

To understand the purpose of this subsystem, we need to first understand the mechanics of the device. We will have a user controlled handle where the control end of the handle will house our Pitch movement, and directly above that another motor will control the Roll movement. The gyroscope will be attached at the base of these motors so that the far end of the handle will be the modular platform (refer to the visual aid). Our gyroscopic sensor will read positional data to tell us how the gimbal is oriented. We will continuously read these output values in order to simultaneously control servo positions.⁶

Components: Gyroscope GY-521 MPU6050

2.3 Subsystem Requirements

2.3.1 Power Subsystem

1. In order to protect the rest of the circuit, we need to account for variable voltage and current outputs
2. Route the 9-volt ~500 mAh battery to two regulators where the 6 volt regulator can support up to 1A output (need a minimum of 800 mA to support servo stall). The 3 volt regulator can support up to 1.5 A of current, well surpassing the amount needed to support both the microcontroller and the gyroscope

2.3.2 Control Subsystem

1. The microcontroller will read data from the gyroscope, calculate necessary signals for both motors individually and update the motors input signal all in real time
2. Each motor must be able to accurately hold and alter a position all while bearing the load of anything it supports
 - a. The first motor must be able to support the second motor as well as the camera mount and camera
 - b. The second motor must be able to support the camera mount and the camera

2.3.3 Sensor Subsystem

1. The gyroscope must be able to obtain accurate readings from the moment the gimbal is turned on and until it is turned off.

2.4 Tolerance Analysis

The most critical portion of our Gimbal is ensuring that the gimbal is able to react to changes in movements in a small enough time frame that there is very minimal to no visual shake in the camera feed. As there is no real metric to measure the shakiness of a camera feed in either mechanics or the digital output, our standard we want to achieve is at a minimum, an emulation of the industry standard camera gimbal [5]. This gimbal setup achieves a slew rate of 100°/sec which is the minimum for our project, but since this is for a much larger camera load than our intentions, we plan to perform at a rate of 200°/sec. In order to achieve this, we needed to first ensure that our data protocols could run at a sufficient speed in order for this to work.

In our testing and application, the GoPro HERO Session can record 1080p footage up to 60 fps. Since our HS-311 performs at a rate of 400°/sec with no load at 6.0 Volts.

$$0.15 \text{ sec}/60^\circ \Rightarrow (60^\circ/0.15 \text{ sec}) * \frac{3}{20} \Rightarrow 400^\circ/\text{sec}$$

This maximized strength of the motor means that we are able to perform well above the required speed in order to maintain stable footage.

60 fps and a motor speed of 400°/sec allows us to complete a full servo rotation in between each frame in the video.

The data signals to control this movement originate from the gyroscope which has an output data rate of 8 KHz [2]. This data is then sent to the microcontroller with an internal clock of 1 MHz [2] and processing speed of about 12 MHz at 3.3 Volts [1].

The ATmega328P is configured to use Timer/Counter 1 for both PWM signals, and a prescaler value of 64 is used with a TOP value of 255 (8-bit resolution) [1], the total number of clock cycles required for one PWM cycle for each motor would be:

$(1 / (12 \text{ MHz} / 64)) * (256 \text{ cycles} + 1 \text{ cycle for overflow}) = 0.00136533 \text{ seconds} = 1365 \text{ clock cycles.}$

Since we are only doing a simple read of the gyroscope, this will add another 200 clock cycles. This plus the amount of time to send PWM signals to both motors, we are at 2930 clock cycles total to get positional data from the gyroscope, process data in the microcontroller, then send PWM signals to the motors. With a 12 MHz clock, we are able to constantly update our motor positions through PWM signals more than 4000 times a second. This many updates within each frame means that we will have steady footage even after the physical movement time of the HS-311 motors.

3 Ethics and Safety

Our group will follow the IEEE Code of Ethics and will hold all team members accountable to the highest ethical standards which will include, but is not limited to:

1. To uphold the highest standards of integrity, responsible behavior, and ethical conduct in professional activities. [4]

We will make sure that our design will not put any users into harm's way and will disclose anything that may be deemed unsafe or can put people or the environment at risk. We will seek and accept honest criticism of our work by going to the professor or our TA often for feedback on our designs. We will also make sure that we are technically competent in what we do which includes the completion of Lab Safety Certification, CAD assignment, and soldering assignment.

2. To treat all persons fairly and with respect, to not engage in harassment or discrimination, and to avoid injuring others. [4]

Our group will ensure that everyone in our team as well as the rest of our class is treated with respect regardless of age, gender, race, etc. Harassment and bullying will not be tolerated and will be reported. Everyone in the group will have access to all files and work done by members of the group. All group members are also roommates so there will be ample communication throughout the group. When working in the lab, the group members will avoid injuring others physically and emotionally.

3. To strive to ensure this code is upheld by colleagues and co-workers. [4]

We will support each other in upholding the highest ethical standards and to speak up if someone is not following these standards.

In regards to the safety and regulations for our project:

1. We will enclose our motors and electronics in plastic boxes to ensure that nothing can pop out and harm the user.
2. We will ensure that our project follows relevant licensing terms and follow the terms of service for the software components used in our camera gimbal system.

4 References

- [1] “Atmega328p,” *Microchip ATMega328p*. [Online]. Available: <https://www.microchip.com/en-us/product/ATmega328p>. [Accessed: 09-Feb-2023].
- [2] “Haoyu Electronics : MPU-6000 and MPU-6050 Product Specification Revision 3.3.” [Online]. Available: <https://www.haoyuelectronics.com/Attachment/GY-521/mpu6050.pdf>. [Accessed: 09-Feb-2023].
- [3] “HS-311 Standard Economy Servo,” *HiTec*. [Online]. Available: <https://hitecrcd.com/products/servos/analog/sport-2/hs-311/product>. [Accessed: 08-Feb-2023].
- [4] “IEEE code of Ethics,” *IEEE*. [Online]. Available: <https://www.ieee.org/about/corporate/governance/p7-8.html>. [Accessed: 08-Feb-2023].
- [5] “Shotover G1 a lightweight, weather resistant, gyro-stabilized gimbal platform,” *Shotover*. [Online]. Available: <https://shotover.com/products/g1>. [Accessed: 02-Mar-2023].