Senior Design I Project Proposal

Single-Axis Camera Stabilizer

Project sponsored by Professor Michael F. Young, *George Mason University*

Team 3 – Spring/Summer 2014:

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Executive Summary

This project design proposal is for a hand-held single-axis camera stabilizer intended for videography in personal aircraft, included is the need, description, target specifications, documentation requirements, research plan, possible designs, test and experimentation plan, schedule and tasks.

Problem Statement

At times, many people find themselves piloting personal aircraft and can't help but be amazed at the surreal beauty and engulfing scenery. Whether it be a nice sunrise, birds flying in a pattern, or the way the sun hits the clouds, one would want to be able to take video recordings of these memorable sights. However, it has come to our attention that due to turbulence found at such altitudes, passengers and pilots experience violent and unpredictable vertical shaking motion of the craft, causing poor conditions and quality for videography.

If there could be a way to prevent the recording from shaking with a stability device, this device would lead to a much higher video recording quality. The proposal brought forth is to design a single-axis camera stabilizer (SCS) that would have a response time quick enough to prevent any vertical movement caused by the aircraft's disturbances and thus the user would no longer have to fret with altered or unviewable video capture.

Device Description

The SCS to be researched, designed, prototyped, and tested will be a single hand-held device which will have a standard camera. The device itself is reasonably sized and will have a vertical transient that travels quickly with considerable range to stabilize the camera as needed. One will expect to be able to use this device for most small point-and-shoot cameras that are comparable to the Nikon 1 series.

The SCS will also be expected to be efficient on power consumption. It will be tailored to run on a single rechargeable battery system, lasting a minimum of 30 minutes. The user will have a LED output to let them know when the SCS is powered and when the battery is running low. The SCS will also have an external power switch.

Target Specifications

The following specifications and goals for the SCS were determined by Professor Michael F. Young, *George Mason University*.

- Single hand-held device.
- Hold a vertical position within ⅛” with vertical transients up to at least 6”.
- Response time must be quick enough so as to eliminate all vertical movement as seen by the camera.
- Must have a standard camera mount.
- Supports the weight of a Nikon 1 series camera as well as smaller cameras.
- Runs on a single rechargeable battery.
- Must weigh less than 9 oz.
- Operates for at least 30 minutes on a single charge with light to moderate turbulence.
- Power on/off switch.
- Green Power-On LED flashes once every three seconds for about 0.1 seconds.
- LED flashes red when the battery is low.
- Circuit must be delivered on double-sided PCB with surface mount components.

Documentation Requirements

The following documentation specifications for the SCS were determined by Professor Michael F. Young, *George Mason University*.

- Design schematics.
- Mechanical and fabrication drawings.
- Bill of Material (BOM) with vendor part numbers and Digi-Key or Mouser part number.
- PCB artwork with Gerber Files.
- Production Test Plan and procedure.
- User manual.

Budget

A budget of $XXX is sponsored by Professor Michael F. Young, *George Mason University*.

Similar camera stability systems have a BOM ranging $300-500.

Possible Device Designs

Arm Cuff SCS

The design for the SCS must be compact, lightweight, rugged, safe, and effective. Given these constraints, the following SCS idea puts heavy emphasis on compact dimensions and simplicity. The SCS base frame housing was inspired by cuffed crutches, using the forearm and torque of the heavy camera to ensure an easy-to-hold and snug fit for the user. Below is a rough illustration of the design (*Figure 1*).

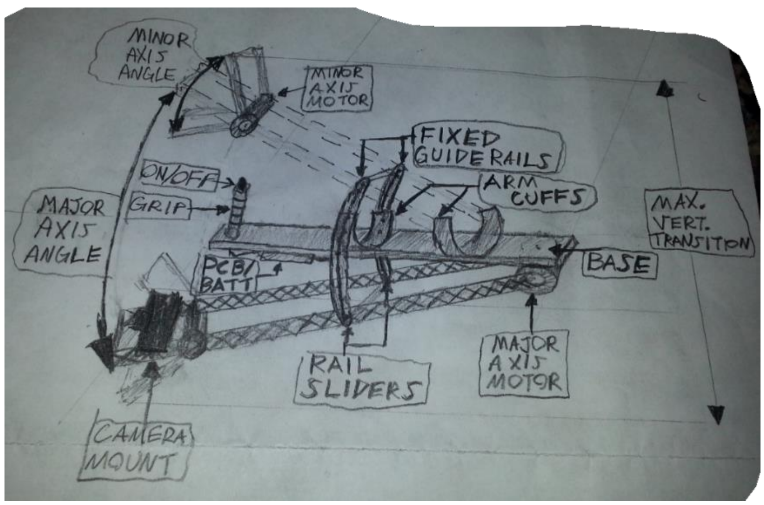

Figure 1: Arm Cuff SCS Illustration

The structural materials of the base and arms will be constructed of carbon fiber sheeting; due to carbon fiber's light weight, extreme rigidity, lack of flex, availability, and each of crafting. Carbon fiber sheets come in various thicknesses, weaves, and sizes. The main body of the Arm Cuff SCS (AC-SCS) is a simple carbon fiber base with arm cuffs, grip, and grip-mounted ON/OFF button. Attached below the base will be the PCB and rechargeable battery. There are two control arms, of adjustable length, are attached to the base by the major-axis motor (found on the right side of *Figure 1*), and guided by fixed rails attached to one of the arm cuffs. The major-axis motor will provide the majority of vertical translation for the camera mount. The major-axis motor will be brushless due to sparking concerns, lightweight, quiet, and have very fine control parameters such as torque, radial velocity and acceleration, and variation of motion. On the far ends of control arms is the camera stage where the camera mount is located. The camera stage will have another degree of angular motion, called the minor-axis angle. The minor-axis angle will be manipulated with either another brushless motor or a gimbal for contortion of the minor-axis

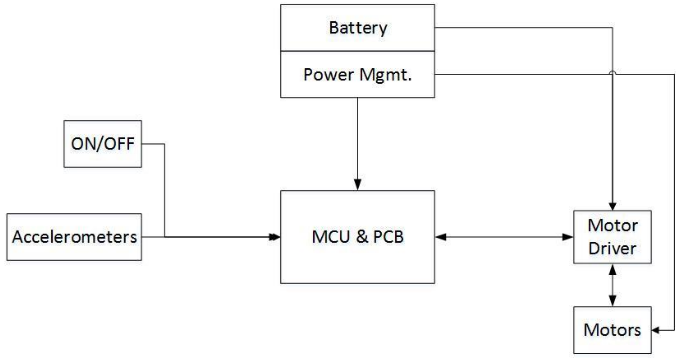

Figure 2: AC-SCS Hardware Diagram

Above is a functional diagram of the possible hardware system. To control the AC-SCS there will be accelerometers placed in various places with feedback to a microcontroller unit (MCU). Most likely there will be two accelerometers placed on the camera stage, one on a control arm, and one or two placed on the base. The MCU will take the accelerometer information, use methods currently unknown, and try to maintain minimum and equal acceleration on the two accelerometers found on the camera stage. There will also be a maximum swing allowance to ensure that the AC-SCS does not go beyond the maximum vertical translation range to ensure that the arms do not accidently injure the user in case of extreme aircraft climb/fall.

The key to this design being comfortable and easy-to-use is maintaining the axis of torque (center of gravity?) of the device near/around the arm cuffs. This will take very careful design and attention to component placement. Luckily, placement of the battery can be used to "balance" the SCS. Other design considerations include protecting the arm, hand, and fingers from getting pinched or crushed from the control arm moving past the base; most likely some sort of covering or guard (similar to an archery wrist guard) may be implemented.

The major hurtle of this design is to keep the weight under 9 oz. This may be a problem since there are many structural components.

D-Grip Camera Stabilizer

The implementation of this idea is a rolling camera along a D-shaped frame. Below is a rough illustration of this design (*Figure 3*).

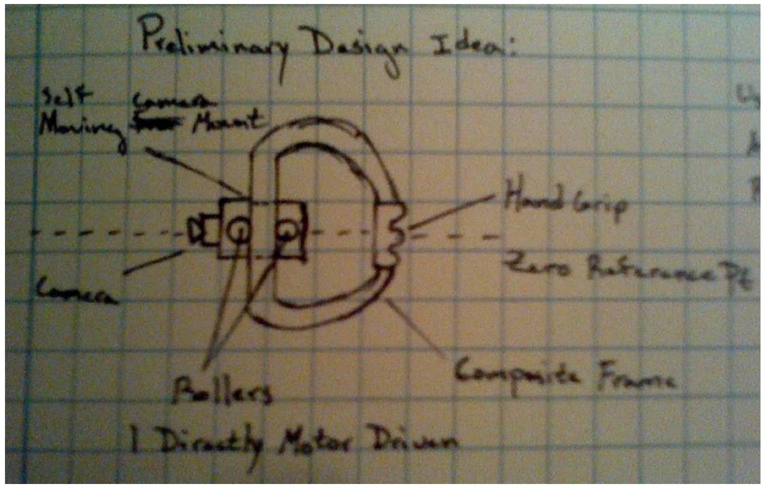

Figure 3: D-Grip Camera Stabilizer Illustration

The user would hold a lightweight channel frame with a center grip. The frame is made of composite materials and acts as a guide track for the camera to roll vertically. The camera would be attached to a movable mounting bracket. The bracket system would be self-automated to align itself to the center of the vertical section. Upon initiation, the center would be used as a zero reference point. The movable bracket system would contain two guide wheels on either side of the vertical section. One of the wheels would be directly connected to a drive motor. Using a system similar to a monorail, the wheels would roll up and down on the vertical section of the frame. When the wheels roll along the frame, the entire bracket and camera would move in the corresponding direction. Using an accelerometer embedded in the grip of the frame, the bracket would use a control system to detect the change in position of the channel frame. Using this information, the bracket would move in the opposite direction to compensate for the change in vertical position of the system. By doing this repeatedly, the moving bracket would try to always return to the zero reference point. As a result, camera stabilization would be achieved. In addition to the accelerometer within the grip, an accelerometer in the moving bracket system would be required, and limit switches on each end of the vertical section. The bracket's accelerometer would be used to help with calculations required to smoothly maintain a zero reference point. The limit switches would prevent the moving bracket from damaging itself.

Gyro-Based Servo Stabilizer

The Gyro-Based Servo Stabilizer (GSS), is a hand-held device designed to stabilize the vertical position of a camera. Below is a rough illustration of this design (*Figure 4*):

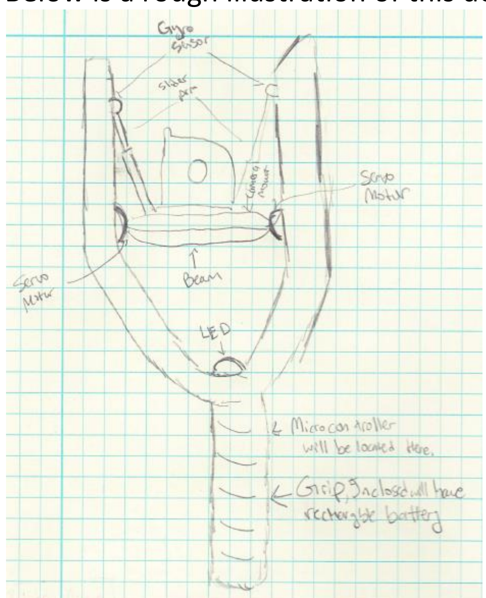

Figure 4: Gyro-Based Servo Stabilizer Illustration

GSS will have a light weight carbon fiber frame designed in a shape similar to that of a goal post in football. The GSS will have servo motors that can go up and down the upper sides of the frames. Both servo motors will be connected using a beam that will also have the camera mount on the center of the beam. The GSS will have two MEMs-based gyro sensors located on each top end of the device. Also there will be two slider arms, each connected between the gyro sensors and the camera mount. GSS will have a rechargeable battery contently located within the compartment in the lower part of the device that will also serve as the grip. This same location will also house the microcontroller needed to control all the different features in the GSS. Right above the grip, there will be an LED light that will either light green to indicate that the GSS is charged or flash a red light indicating that the battery is low.

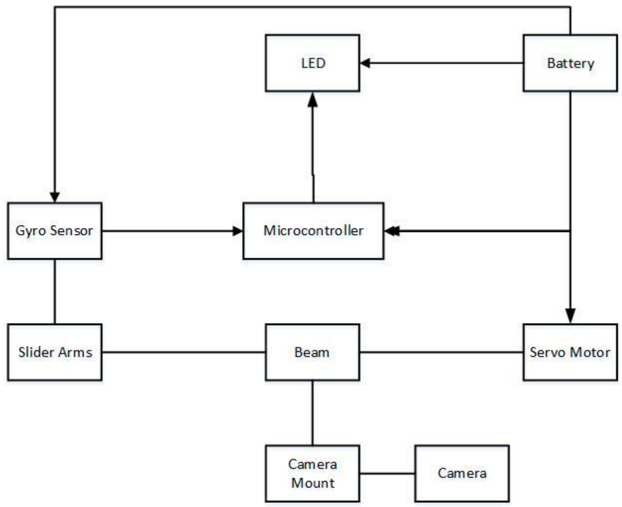

Figure 5: Gyro-Based Servo Stabilizer Hardware Diagram

Above is a function diagram of the possible hardware (*Figure 5*). The GSS will have a microcontroller that can be used to initially program an appropriate angle of reference for the slider arms used to balance the device. The gyro sensor will measure the angular rate of the rotation of slider arms and send signals to the microcontroller, letting it know when there are changes to angle of the slider arms. Once the microcontroller receives these signals it can then send instructions to the servo motors. The servo motors will either move up or down, causing the beam that has the camera mounted onto it to move as well. The servo motors will continue to move in a direction until the angle of the slider arms have been adjusted to the appropriate angle. Thus the result will be the camera constantly being stabilized in the y-axis and leading to a much higher result in video quality.

Initial Experimentation Plan

1. Create a method of reliably recording acceleration and jerk using an accelerometer and data-saving device (such as an Arduino or MEM-based).
2. Simulate rough flying conditions by driving slowly of a rough dirt road while recording acceleration and jerk. Other simulations may include free fall, off-road cycling, and driving over various speed bumps.
3. Once confidence in the accelerometer is achieved through simulation and accelerometer development, a mild-turbulence flight test in a personal aircraft will be implemented. This test will determine the forces and considerations for design of the SCS.
4. See attached spreadsheet for Systems Experimentation Plan

Schedule

See attached spreadsheet for Spring and Summer Schedules

Task Assignments

During the early research phase task assignments may change.

Member:	*Posititon:*	*Tasks:*
Thomas Mizell	Project Manager	Frame Design Logic
Alex Pennock	Documentation Editor	Measurement Systems Instrumentation
Ahmed Salih	Testing Supervisor	Motor Systems Battery & Power