Android Enabled Programmable Camera Positioning System

Sponsor: Air Force Research Laboratory

Pre-Proposal

Facilitator: Dr. Karim Oweiss
Team Members:
Austin Fletcher
Jeremy Iamurri
Ryan Popa
Yan Sidronio
Christopher Sigler

Michigan State University
ECE 480 Design Team 3

February 2, 2012

Executive Summary

The purpose of this project is to design and construct an automated infrared camera positioning system utilizing a commercial Android smartphone. The system must be able to sense its current location and orientation, and slew between GPS designated targets based on a pre-programmed script. A smartphone is used for its multitude of sensors, processing power, and low cost.

Table of Contents

Introduction

Background
Design Specification
Conceptual Design Descriptions
Risk Analysis
Project Management Plan
Budget
References

Introduction

Design Team 3 has been tasked with developing an Android enabled GPS-based camera positioning system for the Air Force Research Laboratory (AFRL). This entails constructing a motorized camera mount for an approximately 19lb infrared camera, provided by AFRL, that is controlled by an Android smartphone. This system should be able to point at any target GPS coordinate (latitude, longitude, and altitude) on a pre-programmed script to a high degree of accuracy (as high as a smartphone's sensors permit) and reliability. In order to do this, the system must be able to detect its own location and orientation, calculate the necessary orientation so that the infrared camera focuses on its target location, and control the motors in the mount to rotate to that orientation. The phone must then signal the camera to capture an image, and take one itself as context imagery. Thus, the phone's camera must be oriented in the same direction as the infrared camera. A typical electrical grid connection will be available to connect the device to, so conserving battery charge is not a primary concern. This project is highly experimental, so the exact requirements are highly variable and based on the phone's capabilities.

Background

The AFRL will use this system to automate the positioning of an infrared camera to perform field testing of infrared imaging technology and processing algorithms. Such devices already exist, but the purpose of this project is to develop one at a reduced cost using the sensing and processing power from a smartphone (specifically, we will be using an Android smartphone). The exact details of these pre-existing systems have not been given to the team. Automated motorized mounts similar to this can be used for surveillance cameras or telescope systems.

Preliminary research into the Android SDK has shown that an Android smartphone should provide the necessary sensors and predefined functions for calculating the system's exact location and orientation. An accelerometer can be used to calculate the direction of gravity, in order to obtain the pitch of the phone. A magnetometer obtains the Earth's magnetic field, and in conjunction with the accelerometer the phone is able to calculate the azimuthal angle. The GPS receiver on a phone will provide the latitude, longitude, and altitude of the system. The Android SDK can provide the necessary calculations for obtaining the target orientation, and a phone should provide the necessary channels for communicating with the motor controllers and the infrared camera, while still being able to obtain power to stay charged. Additionally it has been shown that an audio jack can be used for data communication and for powering a small circuit. This research reinforced the idea that the motors can be controlled by the audio jack thus saving our very limited wired I/O capabilities.

Design Specification

Sponsor's Requirements

For this project, the AFRL requires our team to fully develop and implement an automated camera position system. The capabilities of the system along with a rating of importance (on a scale of 1 to 5, five being the most important) are given below.:

1. Positioning - Slewing between target points defined by GPS coordinates at various times according to a pre-programmed test script
    - Azimuthal rotation range of at least 0 to 360 degrees (one full rotation). **(5)**
    - Polar elevation range of 0 to 90 degrees. **(2)**
    - Capable of securely rotating and managing a 30 lbs load **(5)**
    - Capable of being securely mounted above and below the horizon. **(4)**
2. Coordinate sensing and calculation -Automatically sensing the camera's own position and orientation in order to calculate the required target acquisition geometry.
    - GPS, compass heading, and elevation is to be detected using an Android based smart-phone. **(5)**
    - Taking as much advantage as possible of the computing power available to commercial Android smart-phones **(3)**
3. Imaging - Generating an image acquisition command signal to the attached infra-

red camera.

- (Suggested) Using the phone’s camera to acquire context imagery in the visual spectrum. **(1)**

4. Optimizing cost vs. performance. **(5)**

Team 3 - Goals

The team takes the above as minimum requirements to be achieved and if time allows, make the following addendum's.

1-b. Polar rotation range that exceeds 90 degrees; possibly eliminating the need to physically re-mount the camera to acquire data both above and bellow the horizontal. **(3)**

1-d. Producing a mount sturdy enough not only for the camera and it’s weight, but the environment as well (ie. rain and wind). This will required a design that can be self-contained or easily covered by a plastic shell (plastic would be for future implementation since it is outside the scope of the equipment available to us). **(4)**

1-e. (Added requirement) - Produce a positioning mechanism sturdy enough to keep the camera at a designated position, allowing for video acquisition. **(5)**

2-b. Avoid, if possible, the use of additional micro-controllers and rely as much as possible on the electronics of the android phone for signal generation and handling. This does not include controllers necessary for motor operation. **(3)**

3-a. Complete suggested requirement. **(4)**

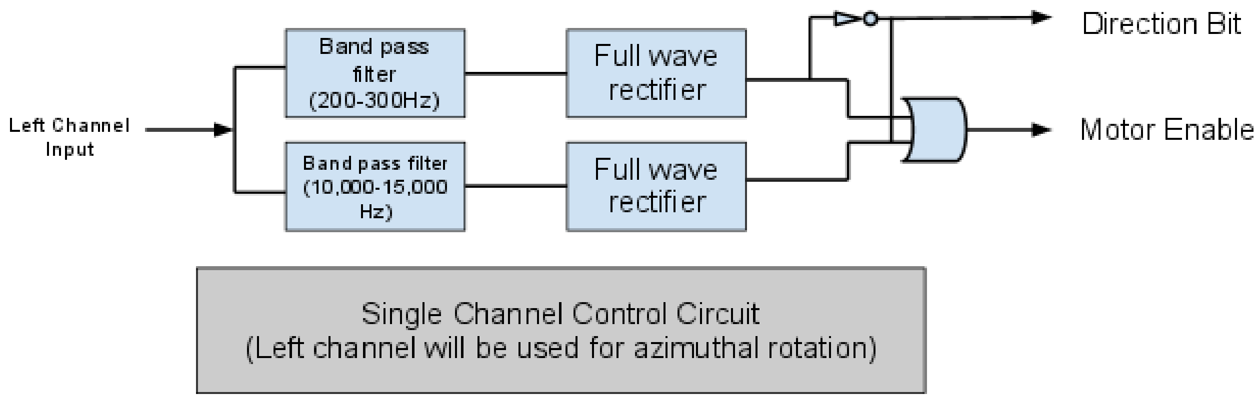
4. Completing the aforementioned goals within a $500 budget **(5)** including:

- Android smart-phone
- Electric - amplifier components, band-filter components, motors and their control boards (if necessary), transformers
- Mechanical components - gears, bearings, metal-supports.
- Misc. materials - wood, sheet-metal, screws/bolts/washers/etc., wires

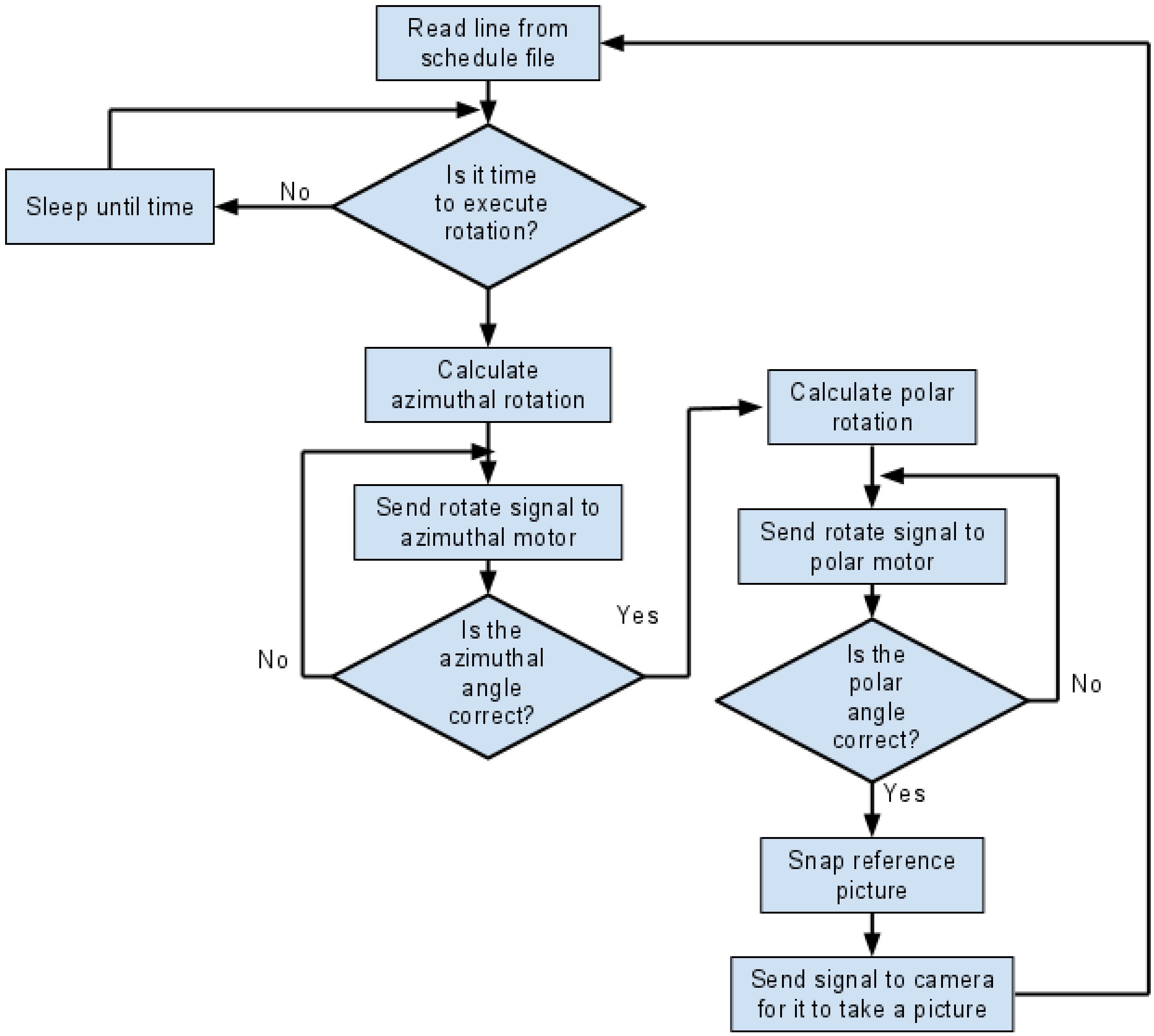
Conceptual Design Description

The project is split up into three distinct design sections. The first is the mount assembly. This section consists of the components needed to hold the camera in place and allow it to rotate both up and down, as well as side to side. The initial design for the assembly can be seen in the following CAD render.

The next design section is the motor circuitry. This section consists of the motors we choose, the motor controllers necessary to control them, any processing circuitry required to transfer input signals to the motor controllers, and the interface for communicating with the Android phone. We initially intend on trying to control the motors through the headphone jack on the phone and use the frequency and amplitude of the AC wave to control the motor's movement and direction. A block diagram of our proposed circuit can be seen below.



The final section in our design is the software for the Android phone. The phone will first need to read from a supplied schedule of coordinates and wait until the time the first scheduled point arrives. When the first scheduled event is ready it will need to calculate the angles of rotation required to point the camera at the desired coordinate. Once the rotation is complete the phone will need to send a signal to the camera telling it to take a picture. The phone will then take a picture with its own built in camera and store it to the SD card for reference. The phone will then go to sleep until it is time for the next scheduled event. A flowchart demonstrating our proposed program operation is below.



Risk Analysis

While considering various design options several potential pitfalls have been made apparent. One such problem is that data communication with a laptop and battery charging both utilize the mini-usb port on the phone. Since there are very few wired I/O ports to use, the usb must be capable of switching between communication and charging. This would not be a concern if wireless communications, such as Bluetooth, were to be used for communication between the laptop and Android phone. However, wireless communication could be a major security risk and requires more advanced programming on both of the connected platforms. Additionally wireless technologies are susceptible to interference, which could lower reliability.

Along with the Android phone there are concerns caused by the camera and the mechanics involved with moving it. One challenge it causes is due to the camera's weight. At 25 pounds the camera requires both a robust mount as well as high torque motors to attain the desired speed and stability of the system. While this is important, it is also crucial to note that if the camera's rotational movement is exceptionally fast, the phone's sensors might be too slow or inaccurate to obtain usable data. Additionally, the cost of the camera, $40,000, demands that care be taken as to the stability and robustness of the platform and its components.

Project Management Plan

In order to make quick progress on this project the team will have frequent meetings and will be using collaborative tools to help share contributions. The collaborative tools being used include shared Google documents, as well as an SVN so that it is easier to see the latest contribution that each member has made, as well as track the changes. Additionally, we have divided the work amongst the group, giving different individuals different areas to work on.

Austin is the project manager and is working on the motor and motor controller interfaces. He will be handling the Audio jack signal and interfacing it with the motor controller. As time allows he will also be assisting in the Android development.

Ryan is the Webmaster and is working on the motor and motor controller interfaces. He will be taking the signal from an audio jack interface circuit and using it to interface with the motor controller. He will also be assisting in the Android development as time and work permits.

Yan is the Presentation prep and is working on the camera and motor mounts and design. He is responsible for the CAD drawings of our camera mount, the placement of the camera and motors, and the physical assembly of the platform. He will also be involved in the Android programming as time and work allows.

Chris is the Document prep and is working on the development of the location calculations for the Android device. He is responsible for determining the phone's current position and orientation and using this data to calculate the correct bearing between the target location and current location and for outputting a signal to the audio jack.

Jeremy is the lab coordinator and is working on the development of the file input and parsing for the Android device. He is responsible for the development of a standard for the scheduling file format, reading in and validating target points and coordinates, and parsing of this data.

The team's Facilitator is Dr. Oweiss, with whom we will have scheduled meetings designed to mentor and guide us in the right direction with the development of the project.

The team's Sponsor is Dr. LeMaster, with whom we will have frequent teleconferences so that he may be updated on our progress as well as help us achieve our objectives.

Budget

Total budget - $500
Android smart-phone - $200
Electrical positioning system- $100

- Amplifier and band-filter components
- micro-controllers (if necessary) and it's necessary development boards/kits
- power circuit components, transformer & misc. power.

Mechanical positioning system - $200

- Motor (and required control board if necessary) for positioning
- All gears, bearings, bushings

- All wood, sheet-metal, metal support rods/pipes
- Bolts, screws, washers, etc.

References

http://www.eecs.umich.edu/~prabal/pubs/papers/kuo10hijack.pdf
http://www.creativedistraction.com/demos/sensor-data-to-iphone-through-the-headphone-jack-using-arduino/
http://developer.android.com/sdk/index.html