Autonomous Motorized Mount for PATHS Sensor

ECE 445 Project Proposal

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Project #23

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1 Introduction

1.1 Objective

Existing commercially available motorized mounts for astronomical instruments are designed to be directly used by a human, either by going to a point keyed in by the human, or tracking an object specified by a human. In most use cases, this is sufficient, as the primary market is amateur astronomers who want to personally look at specific objects in space. This is insufficient for some types of tasks, such as observing in a set pattern for multiple nights, moving in a custom path, or functioning in concert with other instruments.

In addition, most astronomers would use an equatorial mount to track celestial objects. The issue with an equatorial mount is that, outside of celestial objects, their movements can be difficult to calibrate between arbitrary spherical coordinates since it was built to track objects moving along a diurnal motion. Most motorized equatorial mounts would also move at a set pace compensating for the earth’s movement and offer no actual control over the speed for the user. For this project, the mount will be a manual altazimuth mount which we will attach stepper motors, sensors, and a microcontroller to create the control scheme behind the autonomous, custom paths required to track the object of interest, which will be located in the upper atmosphere.

Our objective is to create an automatable motorized mount for an existing sensor, to be used by the PATHS project. This mount should be able to turn the sensor as needed and also move between two arbitrary locations in the sky over a given period. These motions will be specified by an external device.

1.2 Background

One of the current challenges in atmospheric research has been the ability to study atmospheric density, spatial distribution, and temporal variability. Therefore, the PATHS project has been proposed to implement remote sensing and controls theory to capture the airglow emission of Hydrogen for computing its density. This project will allow to overcome single-line-of-sight viewing geometry by allowing multi-angle viewing through a common volume to enable tomographic formulation for solving an inverse problem which will yield accurate H density.

The PATHS instrument used in this project is a novel ground-based photometer that will capture the brightness of H airglow along multiple lines-of-sight in an array configuration. The sensors used in the array are ~20x40 cm binocular optical assemblies, one of which must move over the course of the night.

The PATHS sensor needs to be pointed very precisely, within a fraction of a degree. It also needs to act semi-autonomously given a set of spherical coordinates, as it is grossly impractical to have a human attempt to directly control it.

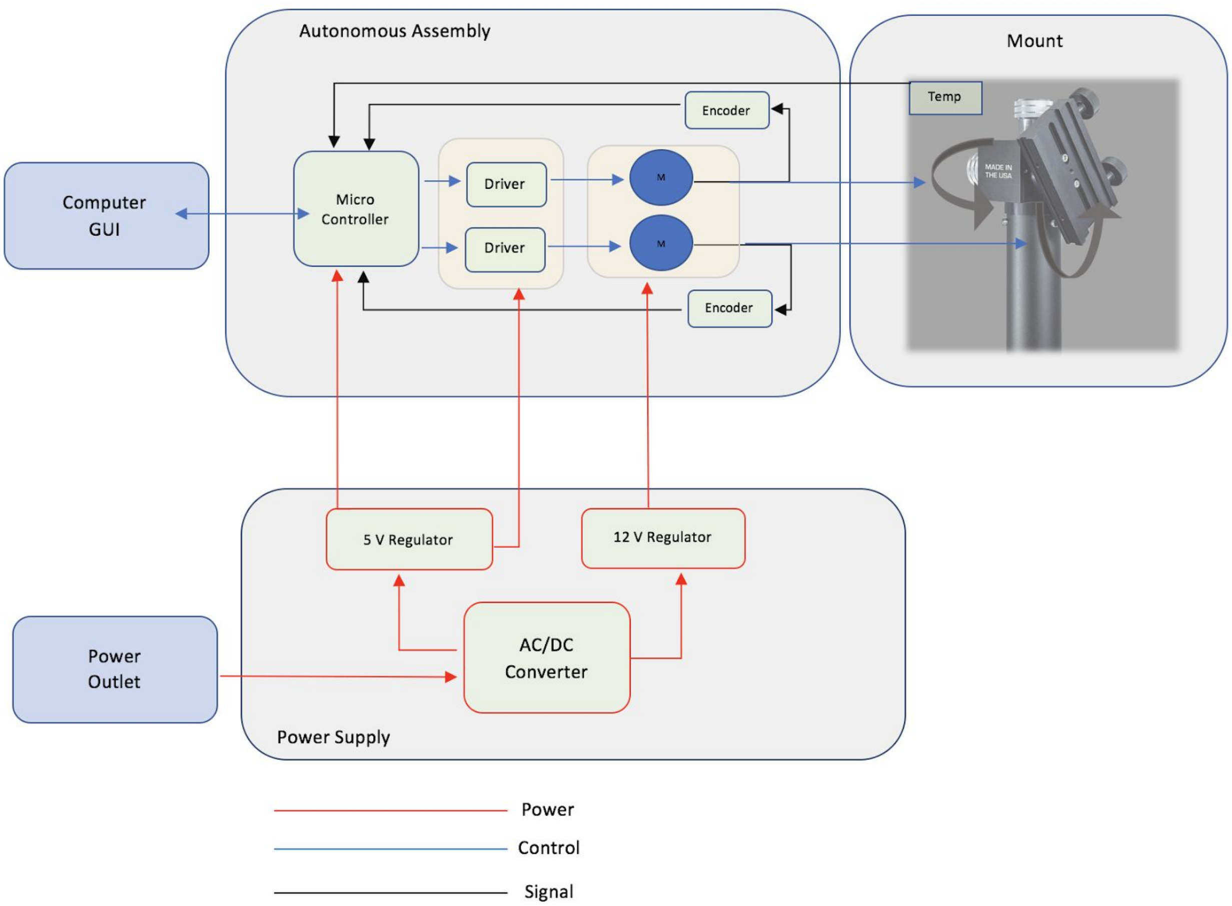
1.3 High-Level Requirements List

The autonomous assembly for the PATHS sensors will provide 2 degrees of freedom along the altitude and azimuth angles. The mount must have 2 rotary joints which will provide the two degrees of freedom, and 2 stepper motors to provide accurate motion to each base and feedback to the micro controller. Also, the bases must be able to freely rotate in any direction with no limit of rotation, allowing a smooth navigation of the spherical coordinates. The base must be rigid and strong enough to hold and provide motion to the PATH sensor as well as the two step motors, and the additional controls providing the motion. The microcontroller must be able to command the stepper motors using two drivers, one for each motor. Calibration feedback shall be implemented using a temperature sensor. The temperature sensor will serve as data feedback which depends on the sensor temperatures. The autonomous assembly must have an appropriate to configure desired parameters and modes of operations, as well as for reporting data and diagnostics.

- Accurate and precise pointing and tracking of target.
- The mount must be able to move autonomously based on external commands.
- Movement between tracking points must be smooth.

2 Design

There are three main elements to the project: the hardware assembly, the feedback control, and the autonomous tracking. The assembly is built around a commercially available altitude-azimuthal astronomy mount. This mount comes manually operated so we will be coupling it with off-the-shelf bipolar stepper motors which will be built right onto the mount. For our controls scheme, the stepper motor will have a rotary encoder attached which will be feed back into the microcontroller. Commands to the microcontroller will come from a remote computer via a serial cable. We will implement a simple intuitive GUI for the user to relay commands such as go to a point, calibrate the position, etc.



2.1 Autonomous Assembly

The assembly is in charge of moving the manually operated mount. It will move the mount through gears. Specifically, the mount will have gear teeth essentially wrapped around the base with the motor attach to its side.

2.1.1 Microcontroller

The microcontroller is responsible for providing appropriate control values for the motor drivers, tracking motor movement via the encoders, and interfacing with an external device via USB to receive commands.
We are currently considering the PIC16F1459.
Requirement 1: *It must have an integrated USB or UART controller (UART will necessitate a second microchip).*
Requirement 2: *It must have at least 10 I/O pins to interface with all other components.*
Requirement 3: *It must have sufficient computing speed to execute all of the above tasks.*

2.1.2 Motor

We plan to use the a bipolar stepper motor with less than a 1 degree step angle at 5% accuracy. The motor needs to be a stepper motor because we need to be able to hold specific angle positions as well as have better control over the precision of its movements.
Requirement 1: *The motor must have the minimum holding torque to hold the sensor in place*
Requirement 2: *The power supply must have at least 12V but ideally 24V with a 0.8A (0.4A x 2 motors) draw.*
Requirement 3: *Dual shaft for the rotary encoder attachment*

2.1.3 Driver

The driver we need to use has to be compatible with our bipolar stepper motor, which means it needs an H-bridge, as well as an output capacity of at least 24V and 2A. We want full, half,

quarter, eighth, and even sixteenth-step modes so we can match the precision required for celestial measurements. In addition, the chip should have safety features such as thermal shutdown protection and shorted load protection. The DRV8825 is our current consideration.
Requirement 1: *Must be compatible with our stepper motor shaft.*
Requirement 2: *Must be able to control stepper to within 0.5°.*

2.1.4 Encoder

The HKT22 optical rotary encoder will be attached to the rear shaft of the NEMA 17 stepper motor. It will allow us to have more accuracy over the motor's movements through a closed-loop feedback scheme.
Requirement 1: *Must have at least 1 step per 0.5° of resultant mount rotation.*

2.1.5 Temperature Sensor

The temperature sensor will be used as a feedback for optical sensor calibration since optical performance varies for changes in about ~1 degrees Celsius.
Requirement 1: *A tolerance of 0.1 degrees Celsius*

2.2 Power Supply

The mount will be tracking volumes in the upper atmosphere and will need to stay powered over extended periods of time. In addition, it might also need to be controlled remotely. Due to this, we chose a wall outlet over a battery since the battery would have to be replaced and if it can't deliver enough power, the instrument will not move correctly.

2.2.1 AC/DC Converter

The AC/DC converter will take the 120V alternating current at 60 Hz to a 24 V direct current for our motors.
Requirement 1: Converts to within +/- 1% of the 24V output

2.2.2 5 Volt Regulator

The 5V regulator will lower the 24V DC coming from the AC/DC converter to power the microcontroller and the drivers.
Requirement 1: The regulator needs to output 5V at 1.5A within a 5% tolerance

2.2.3 12 Volt Regulator

We will initially be using a 12V regulator to feed to the motor to see how well the steppers move before testing the motors with 24V. Higher voltages for stepper motors should allow it to run better.
Requirement 1: 12V regulator needs to output 12V at 2A within 5% tolerance

3 Ethics and Safety

Our assembly always requires a continuous current flow in order to hold a given position with our stepper motors, unlike a DC motor for example, and this must be done over prolonged periods. This means that we must pay close attention to the heat dissipation and possibly implement a shutoff mechanism using our temperature sensors.

Since our design has both low-voltage components and higher-voltage components that will be drawing from the same source, there is a chance we will experience some crosstalk which will negatively affect our accuracy. Crosstalk could also harm our low-voltage components so we need to be aware of the layout of our wiring. In addition, working with these high voltage components will require significant care to ensure that appropriate safety standards are met.

Our design will be holding and continuously moving an expensive and possibly delicate sensor for a long period of time without any direct supervision. If this sensor is damaged, it could also potentially produce erroneous results, resulting in lost time or even possibly erroneous conclusions. Thus, significant care should be taken to eliminate control errors that could cause damage, such as rapid vibration around a set point or rapid acceleration.

In addition to material damage, personal damage is also a risk in this project. Since this project is powered by mains voltage and mains voltage presents a significant risk of serious injury due to electrical shock, we should use existing power components where possible in order to minimize the risk to ourselves and the user. This course of action is heavily supported by parts 1 and 6 of the IEE code of ethics[5].

4 References

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