University at Buffalo
The State University of New York
CURCA CENTER FOR UNDERGRADUATE RESEARCH AND CREATIVE ACTIVITIES

Development of a Low-Cost Sky Imager

University Honors College

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Overview/Abstract

Sky imaging is a very useful tool for predicting cloud cover and thus solar energy availability. With this technology, it is possible to decipher when conditions are optimal for harnessing the sun's energy at solar power plants. Information collected from a sky imager can be used to increase a solar power plant's efficiency or evaluate its efficacy at given moments in time.

A sky imager is a relatively small, weatherproof device equipped with a camera used outdoors in an area with few visual obstructions. In the most basic sense, a sky imager generally consists of three elements: a camera used to record a direct or reflected image of the sky, an arm or band used to block direct sunlight, and a digital video recorder coupled with image processing software [1].

This project is specifically being conducted to see if an inexpensive sky imager can be constructed and used to collect data necessary for forecasting the motion of clouds, and available sunlight.

Initial Design

Originally, one of the project goals was to compare two different sky imager models. One model would have a large arm with a camera attached to it. In this model, the camera would record a reflected image on a convex mirror, and the arm would move to block the sun. The second model would have a camera beneath a dome capable of reducing the intense sunlight (like a polarized lens). Unfortunately, each one of these models had obvious flaws upon further inspection, and the expected costs for building both models exceeded our budget. Thus, the best components of each model were combined to form the model we decided to construct.

The major considerations that needed to be made when designing the sky imager were image quality and weather resistance. These considerations are delineated below.

Image Quality

Field of View:
- Maximize area of sky covered

Blocking Direct sunlight:
- Protect camera lens from direct sunlight
- Be able to predict and account for the sun's motion

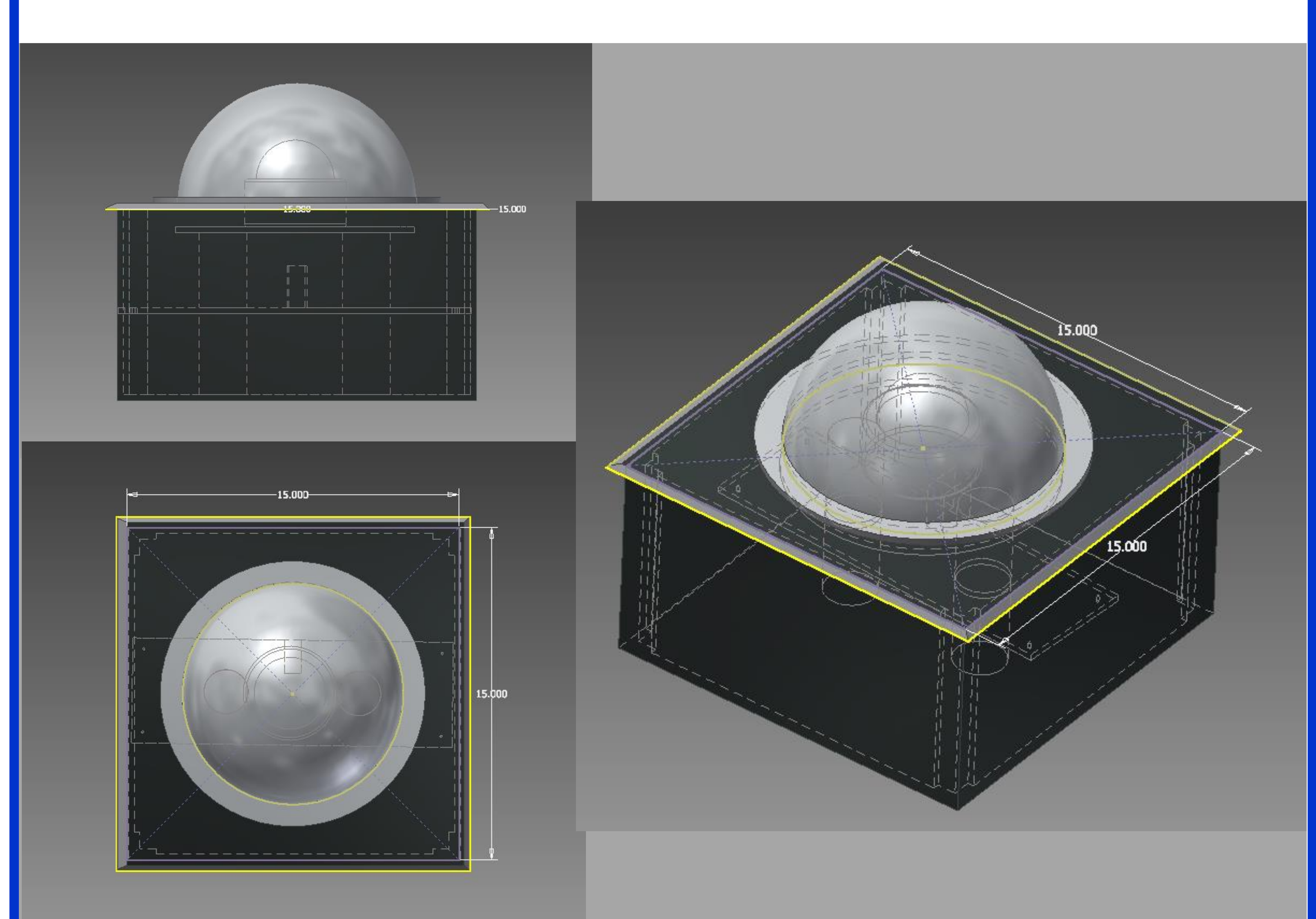
Adverse Environmental Conditions:
- Ensure that the weather/elements do not obstruct the camera image

Device Durability

Weather Conditions:
- Reduce moisture buildup
- Protect the sky imager from weather elements such as rain and snow

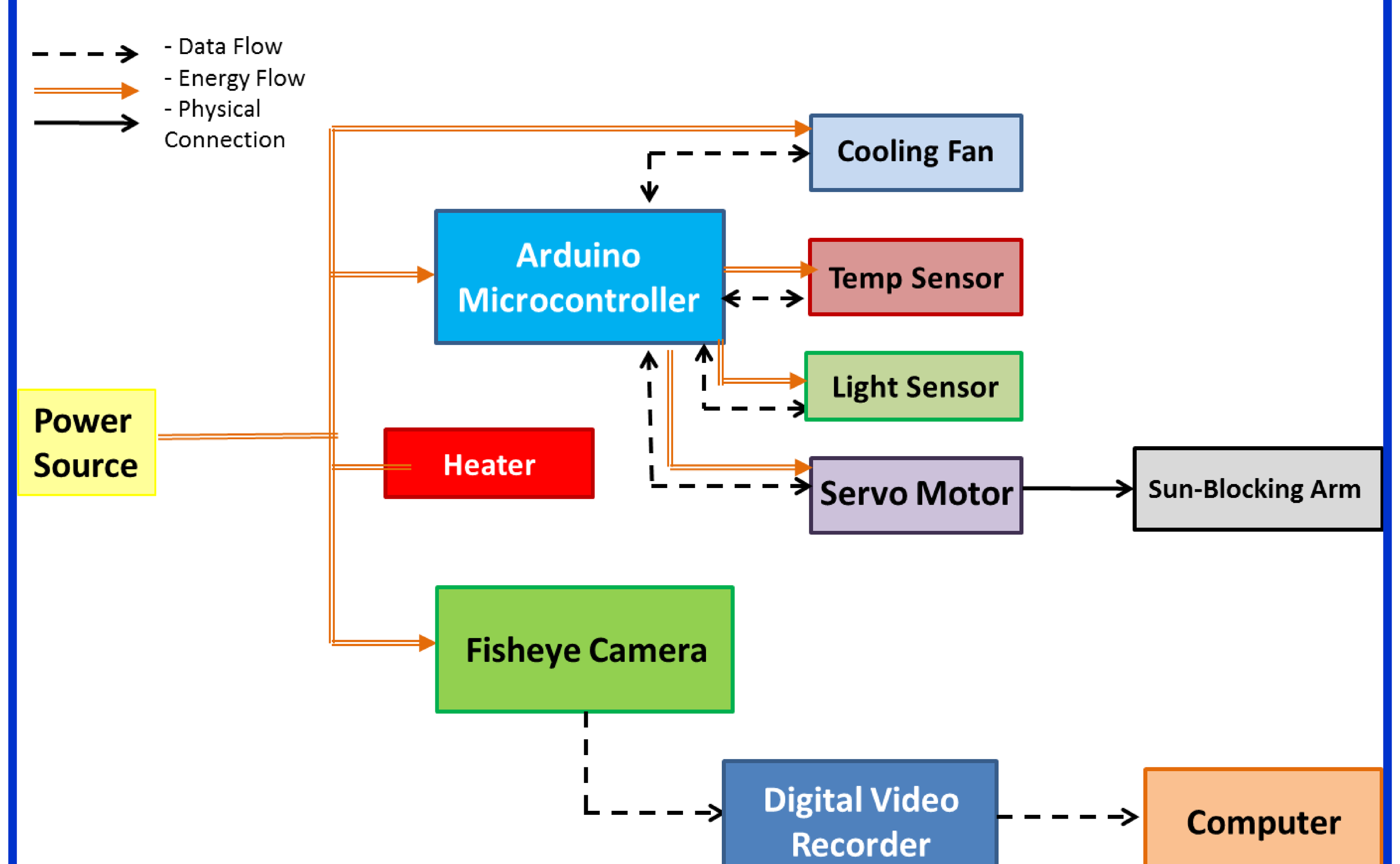
Temperature Concerns:
- Ensure that electronics do not freeze or overheat
- Structural integrity must be maintained with temperature changes
- Material choice for the casing must be made carefully to fulfil the outlined requirements

3-D Model



Conceptual Model

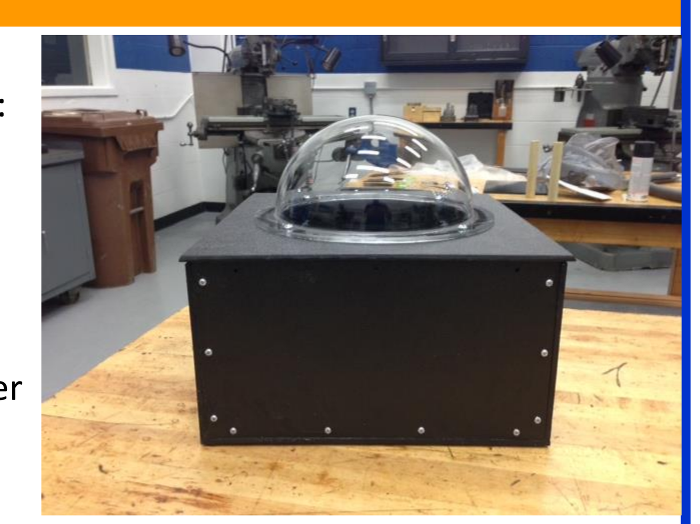
Below is a simple model of our sky imager in terms of data, energy, and physical flows.

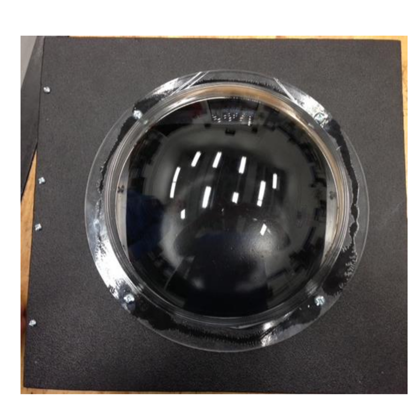


Development

Weather Protection:
ABS plastic was chosen for the housing because ABS is:
- Easy to cut and construct with
- Impact resistant
- Rigid
- Waterproof

The box was also lined with a silicon adhesive to further waterproof and protect the electronic components within.





An acrylic dome was chosen for the dome because it's:
- Completely transparent
- Rigid
- Fairly durable
- Inexpensive compared to other plastics

Sun Blocking: Tracking the Sun's Motion in Buffalo

Blocking out direct sunlight was a major concern when designing the sky imager. Sunlight is powerful, and exposure to intense light for an extended period of time would be damaging for the camera. Furthermore, even if the camera was able to withstand this sunlight, the image quality would be greatly reduced from glare, reflection, and other forms of distortion. Thus, a mechanical arm is needed to block the direct sunlight.

Mechanical arm:
- Rotates from 0° to 180° via a servo motor
- Extends from edge of camera image to the middle of the lens
- Servo motor is controlled by a light sensor capable of discerning shade from intense light

Computer generated image of camera view.

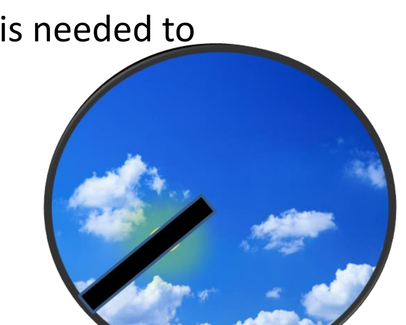
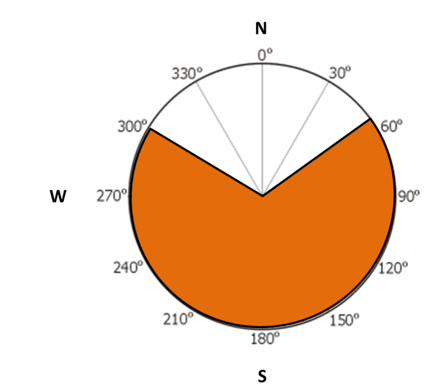


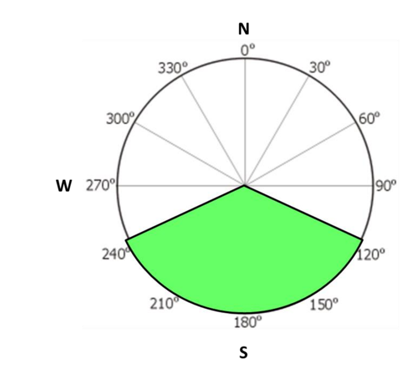
Table A1 shows useful data points for the sun's position in Buffalo

Table A1 [2]

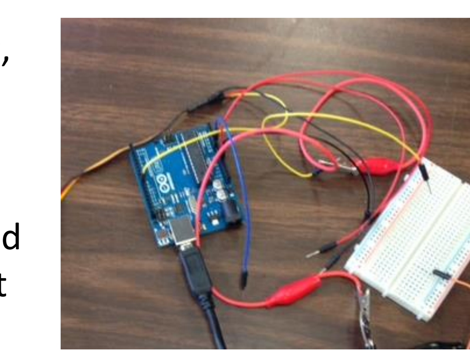
Sun's Motion in Buffalo, NY [2]		
	Height (Relative to Horizon)	Azimuth Span (In Horizontal Plane)
Maximum	70.6°	248°
Minimum	23.7°	116°

A quick visualization of the sun's maximum and minimum sweep can be seen below.





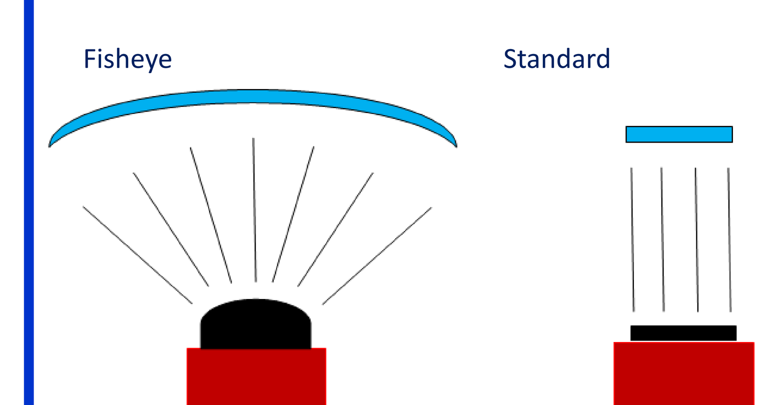
Temperature Regulation: To avoid overheating, a fan was installed inside the box to regulate temperature. Much like the previously mentioned light sensor, a temperature sensor was also programmed to activate the fan should the temperature approach the upper heat limit of the sky imager's internal operating range. A small, self-regulating heater will also be installed to reduce moisture buildup and prevent freezing.

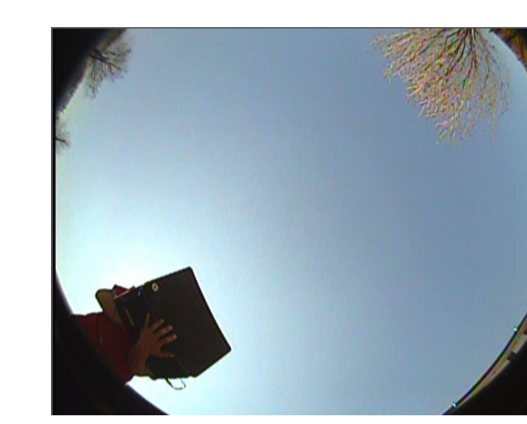


Control board for temperature sensing , light sensing, fan control, and servo control

Sky Image/ Field of View: To maximize the amount of sky recorded by the sky imager, a camera with a 180° fisheye lens was chosen. This way, a much larger portion of the sky can be recorded in a single camera frame than if a camera with a standard lens was used.

Visualization of camera sight area





Actual camera view

Conclusions/ Future Considerations

So far, the project has been successful. The weatherproof case is constructed and the electronics are configured. The project is not quite finished yet, and is not expected to be finished until the semester's end. The sky imager still needs to be fully assembled, and tested and debugged to ensure smooth operation.

One future adaptation that could be made is the addition of a cloud tracking algorithm. This would process the images collected from the sky imager, and actively calculate where the clouds are expected to be in the next time interval. This would make the sky imager a more advanced tool for predicting cloud cover, but would also require much future development regarding this software and hardware integration.

References

1.) "TSI-880 Automatic Total Sky Imager." *Yankee Environmental Systems, Inc.* N.p., n.d. Web. 3 Apr. 2014.

2.) Timeanddate.com. "Sunrise and Sunset in Buffalo." *Timeanddate.com*. N.p., n.d. Web. 5 Apr. 2014.

3.) Circle with degree marks. Digital image. *Richard Harwood's Courses: Physical Geography 101: Longitude and Latitude*. N.p., n.d. Web. 5 Apr. 2014. <http://facweb.bhc.edu/academics/science/harwoodr/geog101/study/LongLat.htm>