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Celestial Tracking and Imaging

Abstract

The Celestial Tracking and Imaging project will focus on creating a device to improve photographers' ability to perform high quality astrophotography easily and at a low cost. The device will consist of three parts. The first part will be a physical tracking device, able to connect to a DSLR camera and tripod. The device will be able to easily move the weight of a camera and lens, with mobility to point to any location in the sky. The second part will be the backend programming of tracking. Instead of using conventional tracking methods (calculating the speed of the object, or using the velocity of Earth's rotation), this project will use image processing to locate the object of interest on the sensor and constantly refresh to keep the target centered. The last part is an automatic finder in the form of a phone application. Not only will this app be able to control the entire device's tracking, it will also allow users to input coordinates or the name of a celestial object. The app will then communicate with the physical device and automatically find the object with the camera.

Fundamental Problems

Astrophotography is becoming more and more accessible for photographers without a physics or math background. As camera lenses and sensors grow in power and low light capability, it is even easier to create these images. However, there are still some limits that need to be overcome in order to take these photos.

The main issue is cost of equipment. Long exposure photography of the night sky needs a tracking device to eliminate star trails. Tracking devices are historically and generally made for telescopes. Most are unable to adapt to a DSLR camera. This adds to the total cost as both a tracking device, mount, and telescope. In the few cases where a tracking device and mount are adapted for a DSLR camera, the price can shoot up to hundreds of dollars.

The second issue is ease of use. Most tracking devices themselves are difficult to set up and use without help. The main difficulty is trying to find objects to photograph. This step normally requires help from an outside source (a star chart). Moving and centering the telescope itself and making sure the tracking device is aligned correctly can prove difficult.

Historical Work

Tracking devices are used in modern day telescope set-ups, both professional and amateur. Tracking devices are centered on the North Star and track by using the direction of motion and speed of Earth's rotation. For objects with different speeds (planets and asteroids) a tracking device will allow to user to change the speed.

Automatic finders historically were in the form of star charts. Archeologists have found ancient versions of star charts that can date back to 30,000 years ago. These star charts are very crude, they are usually used to predict the position of large celestial objects such as the Sun, Moon, and planets. More modern interpretations of star charts date back to 1500 BC in ancient Egypt. Physical paper star charts are still used today, although digital versions are becoming more common.

Current Approaches

When speaking about tracking devices, the current approaches for amateur set-ups are very common. In general, a tracking device will attach onto a telescope mount. The telescope is centered on the North Star to begin accurate tracking. Some tracking devices and mounts are adapted to DSLR camera. These will track much in the same way as the former.

Automatic finders, however, vary greatly. In some form star charts are used. There have been apps created to transpose a star chart on the night sky. This augmented reality will allow the user to move their phone across the sky to find objects. More advanced apps will allow the user to input an object and will show basic directions to find it.

When it comes to a project like this, which will connect these two devices, there are only a few products on the market. These products are considered "GoTo" telescopes. These have a telescope permanently attached to a tracking device and mount. There is a handheld control allowing the user to choose from a bank of celestial objects to find and track. Then the telescope will point towards the object. Some of these telescopes have the option of attaching a sensor for imaging, but none are adaptable for a DSLR camera.

Project Goals

A multitude of steps need to be completed to create this project. Each step will have specific goals which need to be met before it can be considered complete. The following list outlines each step in detail with the goals.

Section 1: The Tracking Device

- Design a tracking device able to hold and move a camera freely
  - Begin by drawing up prototypes
  - Assemble a basic device using inexpensive parts
  - When design is finalized, 3-D print the parts
  - Goals of this section
    - Device must hold the weight of a DSLR camera and lens
    - Device must be attachable to a standard tripod
    - Device must have the mobility needed to access the entirety of the night sky
- Combine tracking device with a system to move and connect it to software
  - Use servos and motors to allow the device to move
  - Connect system with an Arduino and/or Raspberry Pi to control it
  - Goals of this section
    - Device must be able to smoothly and accurately control a camera
    - Device must be able to move in small increments for tracking

Section 2: Software

- Create a program to run the tracking device
    - Must be compatible with astronomical coordinates (declination and right ascension)
    - Test the accuracy of the movements
    - Goals of this section
        - A program that is able to use digital inputs to move the camera
- Create tracking program
    - Must be able to read images from the camera
    - Program should use the image to find the area of interest and center in the object in the frame
    - Must refresh to continuously calculate any shift in the image
    - When image shifts, program should physically more camera until centered on object
    - Goals of this section
        - Image should be kept in frame and centered without movement
- Create an automatic finder
    - Software should connect to an online database to retrieve coordinates of objects in the night sky
    - Program must be able to translate these coordinates to inputs for the tracking device
    - Goals of this section
        - Program must be able to find a specified object in the night sky

Section 3: App

- Create an easy-to-use phone app to control the tracking device
    - Phone app should allow users to input their location and time (or be able to pull that data automatically)
    - App should allow users to choose from a bank of objects to find in the night sky
    - App should allow users to control small movements of the camera (for fine tuning)
    - Goals of this section
        - A working app that is easy to use and available on smartphones
        - App allows user input and control

Section 4: Final Goals

- Paper detailing the methods used to create the project
- Time lapse video
    - First video should show the accuracy of the tracking device
    - Second video will show an artistic application of the system
        - Subjects include the Moon and a large constellation
    - Third video will be a pseudo-time lapse
        - Subject will be the Moon transitioning through its phases
- Still images
    - Moon phases
    - Constellations

- Long exposures without star trails

Section 5: Reach Goals

- Distribute device to photographers to test and give feedback
- Work with graphic designers to create a well laid out, professional app
- Create a case to hold the motors and wires of the tracking device

Challenges

The challenges of this project revolve around time, money, and weather. The device itself will need to be engineered, therefore supplies will have to be purchased. The supplies will include a Raspberry Pi3, an Arduino, servos, stepping motors, the materials to fabricate the device, and a case to hold all of it. Every other portion of this project will be digital. With access to the RIT Photo Cage, the use of camera gear will not be an issue.

The time issue can be solved by creating and sticking to a strict schedule. This schedule will span from the current date, 10-20-2016, until the end of the academic year. By keeping this updated and accurate, it should be possible to complete the project on time.

The last issue that can be encountered is the weather. The winter in Rochester will make it almost impossible to test out the imaging device. Therefore, field testing will have to wait until the spring. With that, one of the project's goals is to take images and videos of the Moon through all of its phases. This could be an issue if clouds are present one night. To combat this, a large amount of time will be made available for actual image capture.

References

Current Approaches

Telescope mounts/tracking devices

- https://www.astronomics.com/celestron-2-axis-dc-drive-cg-4-mount-telescopes_p3328.aspx
- https://www.astronomics.com/celestron-omni-cg-4-german-equatorial-mount_p19034.aspx
- :https://www.astronomics.com/celestron-6-newtonian-advanced-vx-mount_p20046.aspx
- http://www.telescope.com/Orion-EQ-1-Equatorial-Telescope-Mount/p/9011.uts?keyword=eq-1
- http://www.telescope.com/Orion-AstroTrack-Drive-for-EQ-1-Equatorial-Telescope-Mount/p/99600.uts?keyword=eq-1

Mounts and tracking devices for DSLR cameras

- https://www.bhphotovideo.com/c/product/843972-REG/Vixen_Optics_35505_Polarie_Star_Tracker.html
- https://www.amazon.com/Vixen-Optics-35505-Polarie-Tracker/dp/B006ZSRHKC
- http://www.ioptron.com/product-p/3400w.htm

- https://www.amazon.com/iOptron-3400W-SkyTracker-Camera-Package/dp/B00EFRN1BY/ref=pd_lpo_421_tr_t_3?ie=UTF8&psc=1&refRID=BBFD1NBDGDRFWJVA13HE

Digital star charts

- https://play.google.com/store/apps/details?id=com.google.android.stardroid&hl=en
- https://itunes.apple.com/gb/app/skyview-free-explore-universe/id413936865?mt=8
- https://play.google.com/store/apps/details?id=com.google.android.stardroid&hl=en

GoTo Telescopes

- http://www.target.com/p/ioptron-smartstar-e-r80-8502b-computerized-telescope-astro-blue/-/A-11283014?ref=tgt_adv_XS000000&AFID=google_pla_df&CPNG=&adgroup=&LID=700000001170770pgs&network=g&device=c&location=9005672&gclid=CjwKEAjw1qHABRDU9qaXs4rtiS0SJADNzJislz9OIhe2JcQPPM1cSF3EGRwRKYPwkeAna8FdI_N4yRoC8Hjw_wcB&gclsrc=aw.ds
- http://www.telescope.com/catalog/product.jsp?productId=102026&utm_source=google&utm_medium=comparisonshopping&utm_campaign=US-googlemerchant&gclid=CjwKEAjw1qHABRDU9qaXs4rtiS0SJADNzJiskOGyAAtF_Su2VN8NXxXv8dgDJEu_gq9XOlxBimO6NxoCMFzw_wcB

Historical work

- http://www.moses-egypt.net/star-map/senmut1-mapdate_en.asp
- http://irfu.cea.fr/Sap/Phocea/Vie_des_labos/Ast/ast.php?t=actu&id_ast=2615

Mentor Choices

1. Nanette Salvaggio
2. Bob Rose
3. Ted Kinsman