TEAM B1

Asterism

Smart Astrophotography Mount

Kenny Ramos, Joy Gu, and Yuyi Shen

Use Case

Jones, Trevor. Photograph of nebula w/ and w/o star tracking. *AstroBackyard*, 9 Sept. 2019, https://astrobackyard.com/wp-content/uploads/2019/10/how-to-use-star-tracker.jpg.

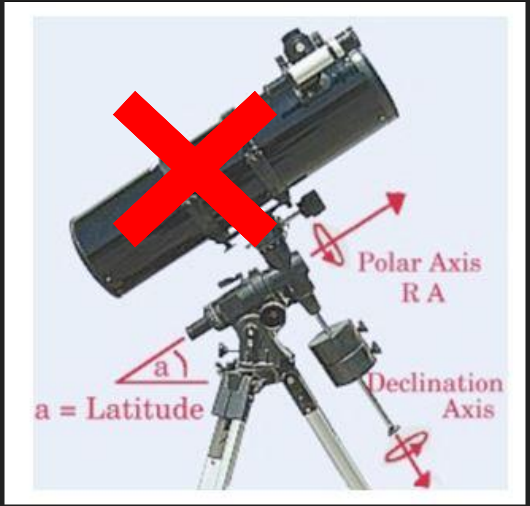
Use Case

- Additional compensation is required for “non-stationary” objects (the moon, planets, comets, etc.) [Not commercially offered]

Tevel, Tunc. Photograph of planetary movement. *NASA Earth Observatory*, 2007, https://earthobservatory.nasa.gov/ContentFeature/OrbitsHistory/images/retrograde_mars_tezel_2007-2008.jpg.

Scope

- In-scope:
  - EQ mount construction
  - Polar alignment and object tracking
  - Motor control
  - Computer vision
  - User interface
- Out-of-scope:
  - Camera connection, tripod
  - Camera driver (libgphoto2)
  - Embedded controller board
- **Areas: Software Systems, Circuits**



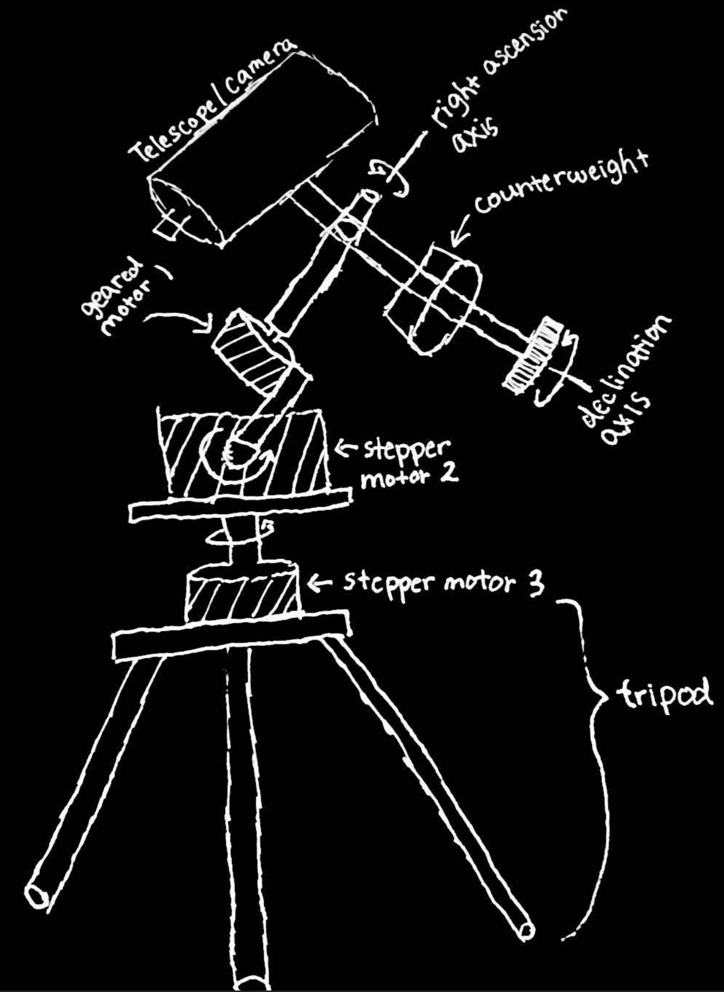
Ventrudo, Brian. Photograph of German equatorial mount. *One-Minute Astronomer*, 29 Aug. 2014, https://astronomer-wpengine.netdna-ssl.com/wp-content/uploads/2014/04/german-equatorial-mount.jpg.

General Requirements

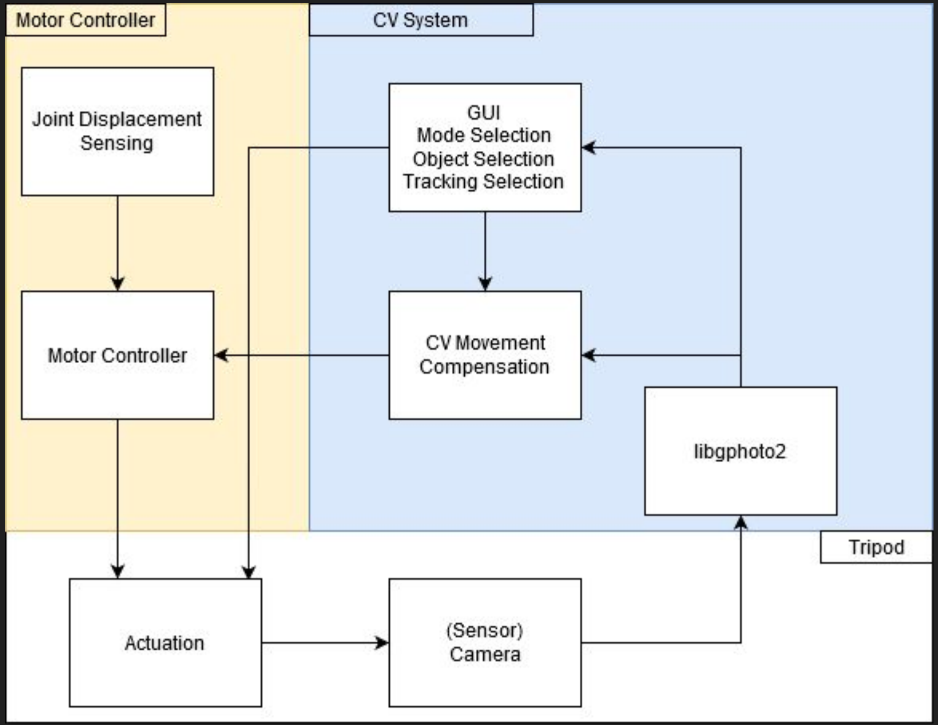
Criterion	Requirement	Justification
Polar alignment accuracy	~0.5 deg from celestial pole	Produces a 5% Error on a 60 sec Jupiter Capture
Polar alignment time	<15 minutes	Optimistic time estimate for setting up a mid range telescope by hand.
Endurance	8 hours	Typical for commercial telescope batteries under normal conditions
Power consumption	8.75 W	Typical capacities of commercial telescope batteries
Supply voltage	12 V	Typical for commercial batteries
Object-tracking accuracy	~0.5 deg in a minute	Produces a 5% Error on a 60 sec Moon capture

Our Solution

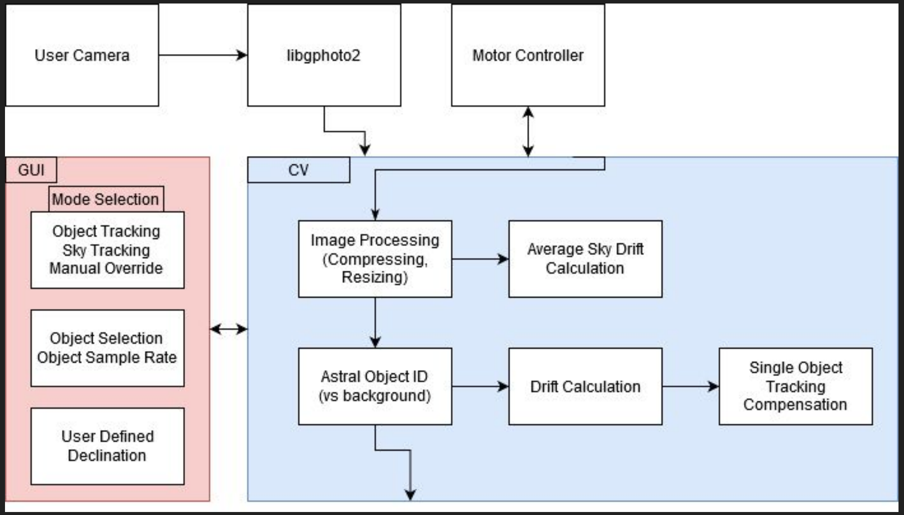
- 4-axis camera mount (1 free, 3 motorized)
- CV interface between mount and camera
  - Components: gphoto2, OpenCV
  - Raspberry Pi 4
- Polar axis alignment w/ gyroscope + geared stepper motors (Pololu hybrid motors)
- Bipolar stepper motor controller board for interface w/ Raspberry Pi (gate drivers + PCB + H-bridge MOSFETs)
- Interface between user and Pi



General System Diagram



CV+GUI Block Diagram



Requirements: Subsystem

Criterion for component	Requirement	Justification
Nominal load	1.9 kg	Average DSLR camera mass + 200mm telephoto lens
Maximum loaded linear deflection of polar axis shaft	0.0051L (L = shaft length)	Derived from polar alignment accuracy and cantilever deflection equation
Polar axis shaft rotation speed	4.178 mdeg / sec	360 degrees / sidereal day
Required polar axis shaft torque	1.8 x 10^(-5) kg*cm	Derived from required rotation speed
Required polar axis alignment torque	0.23 kg*cm	Derived from nominal load and estimated polar axis shaft length

Challenges

- Mechanical construction of the mount and gearboxes
- Fine-grained motor control
- Power distribution tree
- Software challenges
  - Working around image transfer latency
  - CV accuracy and ability to detect target objects
  - Translation between image distance in CV and rotation correction
  - Translation between rotation correction and motor control
- Integration

Testing and Verification

- Testing polar alignment
  - Testing Antipodal Alignment (Align to reference, Rotate RA 180°, Measure Offset from Axis)
- Testing sky-tracking
  - Laser Pointers that can be positioned on a rotating spherical grid
  - Compare still image of “dots” with long exposure
- Testing object-tracking
  - To aforementioned setup add another light with variable speed
  - Track object and compare smearing effect of object with other “sphere tied” objects
- Power consumption tests
  - 2 ADCs connected between current sensing resistor
  - Outputs logged by Raspberry Pi, integrated for average power calculation

Tasks and Division of Labor

Yuyi Shen	Kenny Ramos	Joy Gu
Motor controller and gyroscope boards	Gearing design and fabrication, some of mount construction	Mount construction and CAD of gearing and mount
User interface board	Polar alignment algorithm	Motor control (software component)
Test environment construction	User interface	Object tracking algorithm
Code convention verification	Testing	Testing

Schedule

TASK TITLE	TASK OWNER	Week 4 2/3	5 2/10	6 2/17	7 2/24	8 3/2	SB 3/9	9 3/16	10 3/23	11 3/30	12 4/6	13 4/13	14 4/20	15 4/27
Fabrication and Mechanical														
CAD Mechanical Parts	JG													
Motor Driver+Gyroscope Circuit Design	YS													
Motor Driver+Gyroscope Board Layout + Fab	YS													
User interface board layout + Fab	YS													
Constructing Equatorial Mount	JG + KR + YS													
Obtain Camera Adapter + Tripod	JG + KR + YS													
CV System and Interface														
Polar alignment algorithm	KR													
Interface PA with mount circuitry	JG + YS													
Object Mapping	JG													
Object tracking prototype (with video)	JG													
Integrate with Mount Movement	JG + KR													
Calibrate for mount and camera zoom	JG + KR													
GUI														
Software implementation	KR													
Obtain and install peripherals	JG + KR + YS													
Testing of software implementation	KR													
Verification														
Skychart laser array circuit design	YS + KR													
Skychart laser array board layout+fab	YS													
Assembly of Skychart laser array	YS + KR													
Sky tracking and object tracking tests	JG + KR + YS													
Integration and Additional Testing	JG + KR + YS													
Course Logistics														
1st Status Report	JG + KR + YS													
Design Presentation	JG + KR + YS													
Design Document	JG + KR + YS													
Final Presentation	JG + KR + YS													
Final Report	JG + KR + YS													