Asterism

Design Review Presentation

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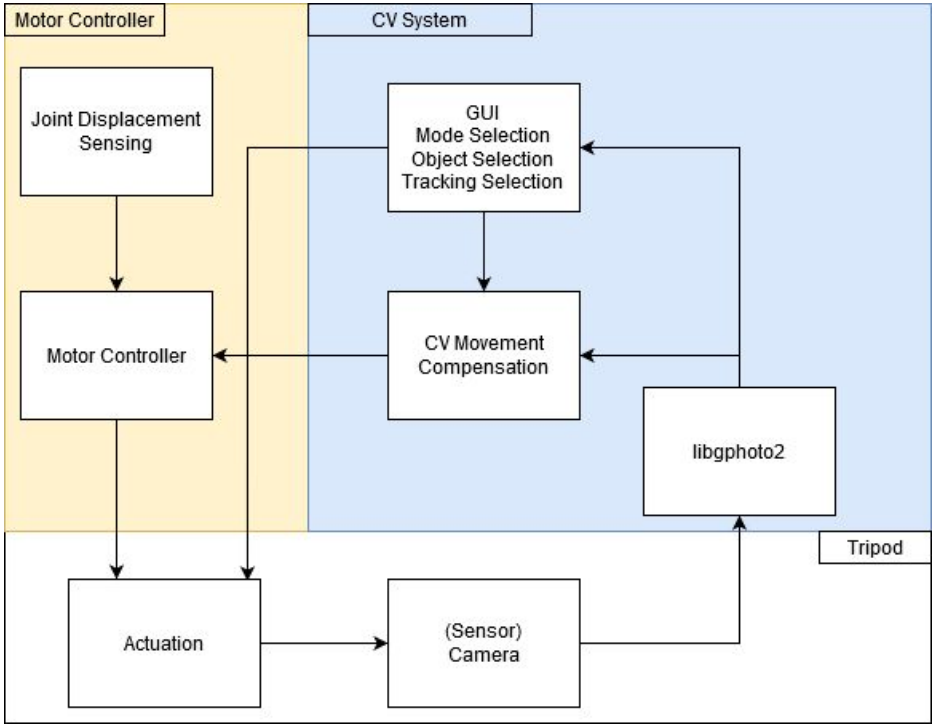
Application Area and Solution Approach

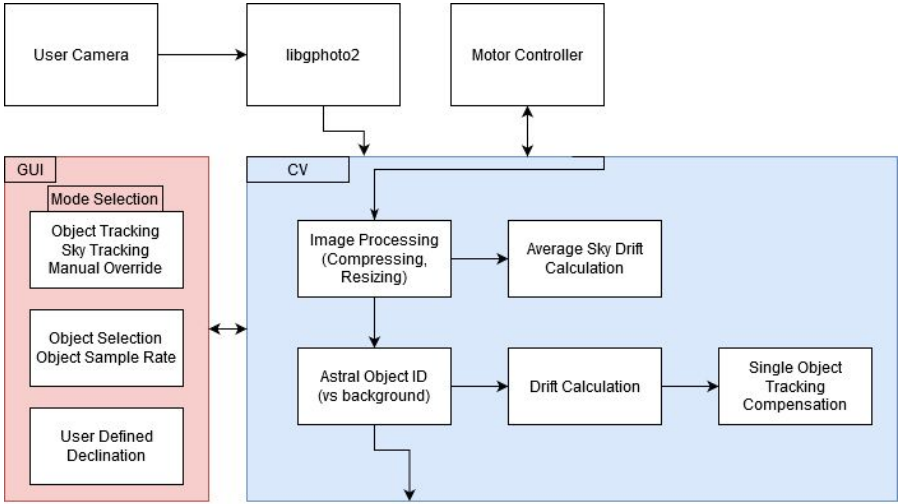
- Smart astrophotography mount
- Motor control, 3 motorized axes
  - Turn the camera on one axis to compensate for the motion of the sky
  - Other two axes for automated polar alignment and object tracking
- Mechanical fabrication
  - Difficult to integrate motor control into most existing mounts for all three axes
  - Existing mounts prohibitively expensive
- Object tracking with computer vision
  - In order to track a particular object

System Specification

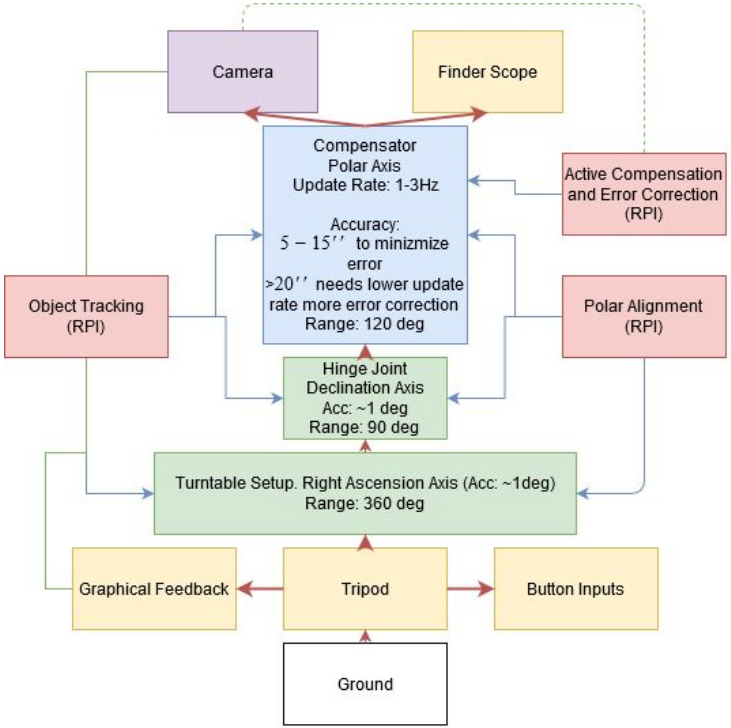
General System Diagram

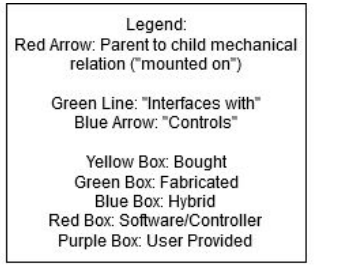


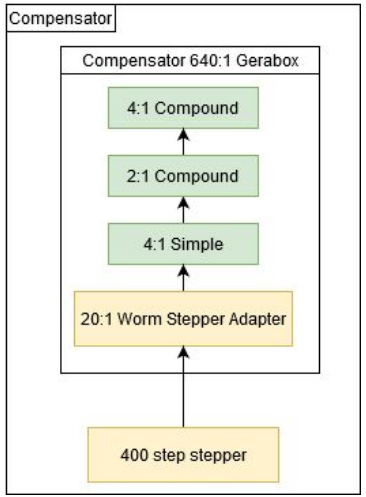
CV+GUI Block Diagram

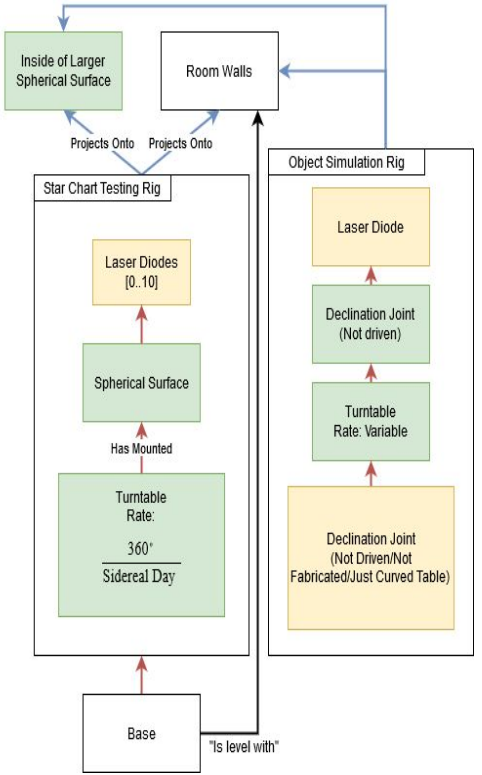


Mechanical Systems









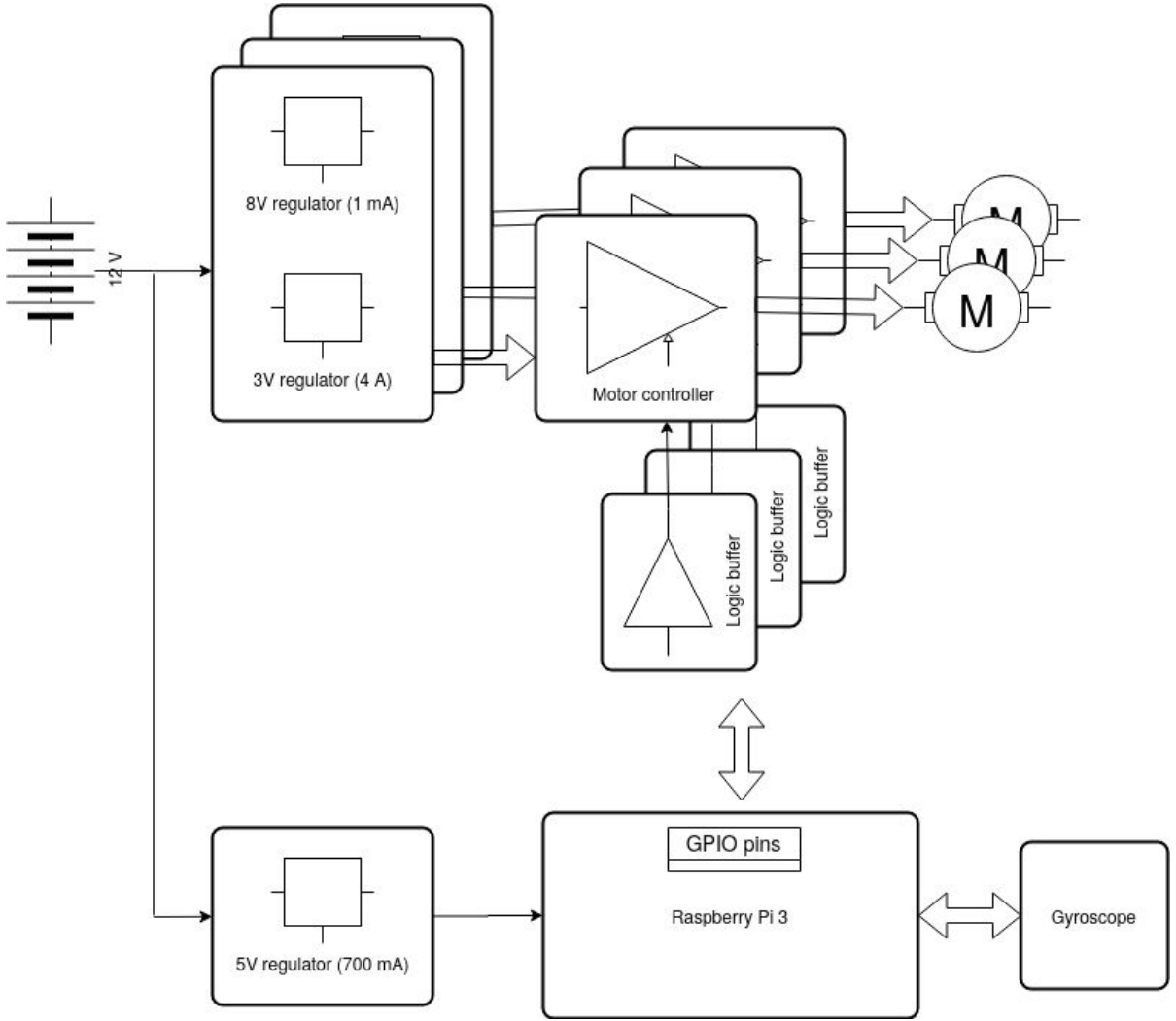
Electronic Block Diagram

Pi - to - Motor Controller Interface:

- GPIO pins (2 PWMs, 2 enables per motor)
- Logic buffers require 3.3V power from Pi
- Propagation delays:
  - PWM_tphl: 1.11 ms
  - PWM_tplh: 1.13 ms
  - EN_tphl: 0.41 ms
  - EN_tplh: 1.12 ms

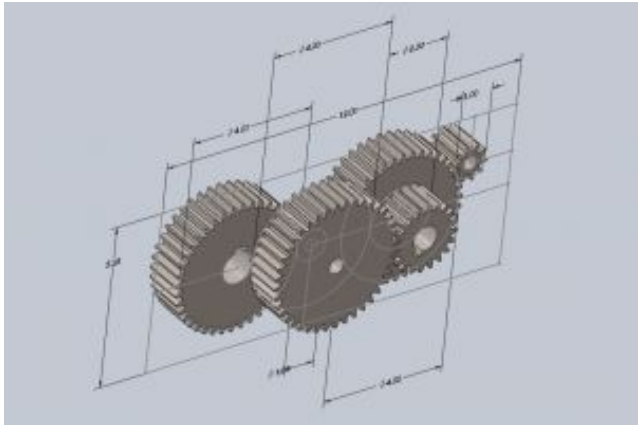
Pi - to - Gyroscope Interface

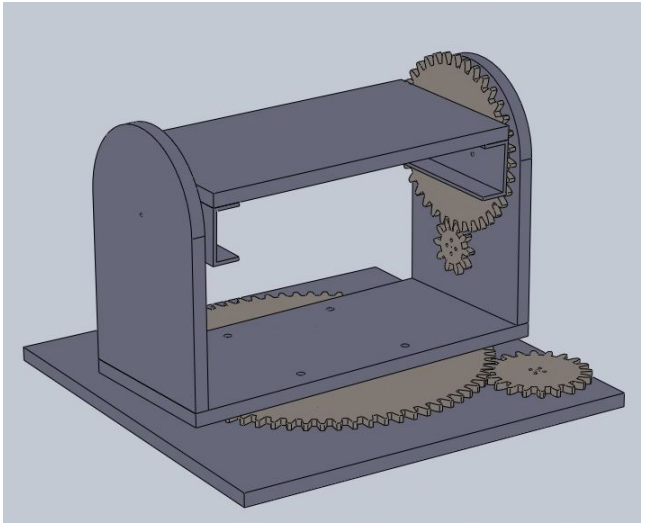
- SPI interface (MOSI, MISO, SCLK, SS)
- on-board SPI bus



Implementation Plan

- Assembly of the mount
  - Laser-cutting some gears, 3D printing others
  - Gearbox for compensator
- Integration of motors with the mount
  - Stepper motors
- Software
  - libgphoto2 to interface with a camera
  - OpenCV for object tracking and object mapping
    - Figuring out our minimal resolution
    - Testing with videos of objects
  - Motor control
  - Gluing these together





Note: Some components omitted for clarity

Component Management

Components to Purchase	Project Subsystem
3x 400-step stepper motors	Mechanical control
Gyroscope sensor	Mechanical feedback sensor
Camera tripod	Equatorial mount body
Tripod camera holder	Equatorial mount body
Telescope finder scope	Mechanical alignment
Pi-compatible display	Object tracking interface

Components to borrow	Project Subsystem
Raspberry Pi 3	Mount electronics
Arduino Uno Rev. 3	Test setup electronics

Components to Design/Develop	Project Subsystem
Power distribution boards	Mount electronics
Stepper motor controllers/logic buffers	Mount/test setup electronics
Laser diode drivers	Test setup electronics
Mount frame and gearing	Mount body

Components to Download	Project Subsystem
OpenCV	Object tracking software
libgphoto2	Camera-software interface

Metrics and Validation

- Testing polar alignment with the mount
  - Testing Antipodal Alignment (Align to reference, rotate RA 180°, measure offsets from axes)
  - Offsets must be <1 degree on both axes
- Testing sky-tracking with the mount
  - Lights positioned on a spherical surface rotating at a known rate
  - Compare a long exposure with compensation with moving lights with an image of the still lights with varying manually applied amounts of blur (qualitative)
- Testing object-tracking with the mount
  - To aforementioned setup add another light with variable speed
  - Track object and compare smearing effect of object with other “sphere tied” objects
  - Similar to the above test
- Testing position tracking for compensator
  - Position feedback error for compensator is within 40% of offset accrued over long exposure (~0.1 degree over 60 seconds).

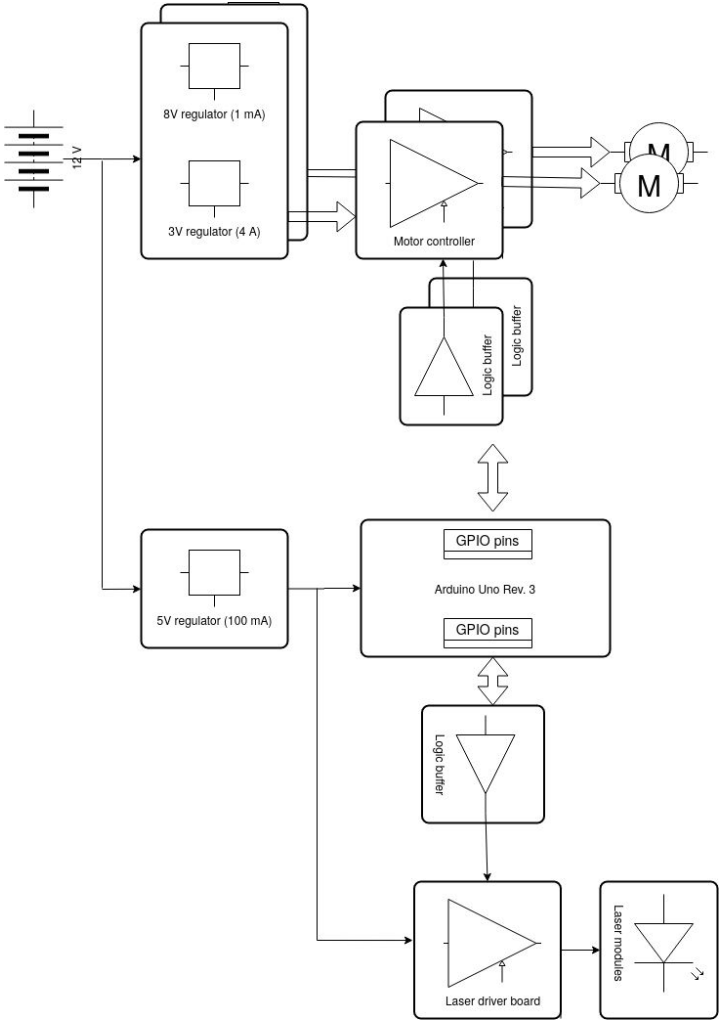
Subsystem Testing and Validation

Subsystem	Test Purpose	Pass Condition
Motor controller	Endurance	The Arduino records 216 revolutions of the paper disk through the phototransistor.
Motor controller	Voltage spike survival	The motor controller must pass the endurance test after going through this test sequence.
Computer Vision (Object tracking)	Computer vision accuracy	The test correctly identifies single object movement within 40% accuracy and cluster movement with 20% accuracy.

Test Setup Electronic Diagram

Arduino - to - Motor Controller Interface:

- GPIO pins (1 PWM, 1 enable per motor)
- Logic buffers require 3.3V power from Arduino
- Propagation delays (same as before):
  - PWM_tphl: 1.11 ms
  - PWM_tplh: 1.13 ms
  - EN_tphl: 0.41 ms
  - EN_tplh: 1.12 ms
- Arduino - to - Laser Driver Interface:
- GPIO pins (1 enable per laser module)



Risk Mitigation

- Motor controller test failure:
  - Purchase a stepper motor driver module with enable inputs as a replacement part.
    - Cons: Requires modification to power distribution.
- Gearbox/Compensator Failure:
  - An alternative design has been proposed to combine a (simple to fabricate and precise within a small range) “barn door mount” with a less precise but larger range turntable setup.
    - Pros: Easier and faster to fabricate in case of failure, does not rely on complex gearing.
    - Cons: Error accumulates and must be compensated for, small range
- Computer Vision (Object tracking) Failure:
  - By maintaining a database of known objects and their positions over time the mount could blind track objects after proper alignment has been done.

		Week												
		4	5	6	7	8	SB	9	10	11	12	13	14	15
TASK TITLE	TASK OWNER	2/3	2/10	2/17	2/24	3/2	3/9	3/16	3/23	3/30	4/6	4/13	4/20	4/27
Fabrication and Mechanical														
CAD Mount (not including gearing)	JG													
CAD Mount with gearing	JG													
Design compensator gearing	KR													
Order parts and supplies for mount	JG													
Constructing Equatorial Mount	JG + KR + YS													
Obtain Camera Adapter + Tripod	JG + KR + YS													
Circuitry														
Motor Driver+Gyroscope Circuit Design	YS													
Motor Driver+Gyroscope Board Layout + Fab	YS													
User interface board layout + Fab	YS													
CV System and Interface														
Polar alignment algorithm	KR													
Interface PA with mount circuitry	JG + YS													
Object Mapping	JG + KR													
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	JG + 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													