High Precision Sunphotometer using Wide Dynamic Range (WDR) Camera Tracking

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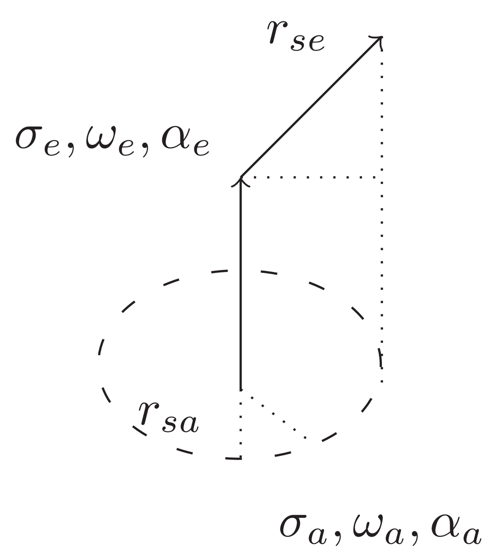
Objectives

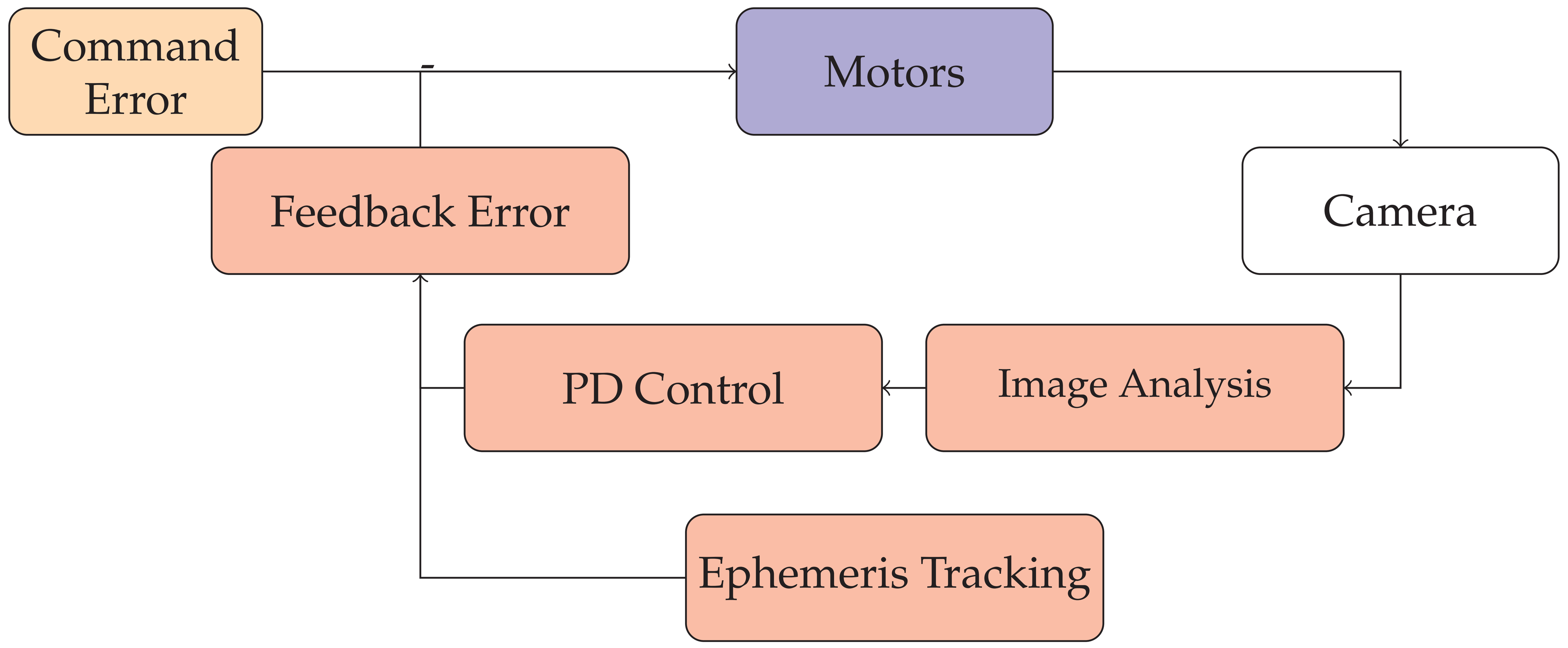
Develop Camtracking Sunphotometer using HD camera for sun tracking at similar or improved accuracy to photodiode quadrant detector tracking sensor while simultaneously obtaining real-time sky imagery for error processing during Direct Sun Tracking, Sky Scanning and Zenith Viewing.

System Dynamics

The CamTracker dynamics:



Device Architecture



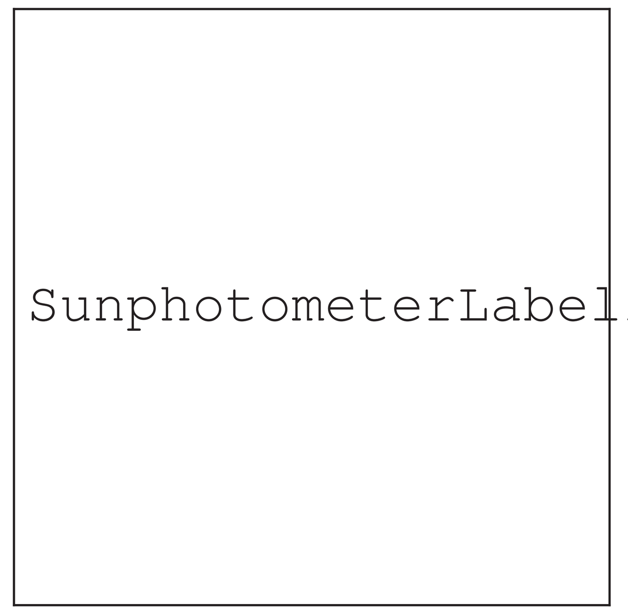


Figure 1: Camtracker on Aircraft Simulator Table

1. Determine the centroid of optical source despite some cloud obstructions using Python OpenCV.
2. Inner control loop to perform micro adjustments for sun following within +/-0.1 degrees.
3. Outer control loop using calculated Ephemeris sun tracking values for macro adjustments of within +/- 1 degrees).
4. Use sun and sky imagery for flagging cloud effects impacting atmospheric data quality.

1. Stepper motors with built-in encoders. (36,000 Elevation steps and 18,000 azimuth steps) [a].
2. IDS wide dynamic range camera with linear piecewise autoexposure.
3. Modbus ommunication protocol to network to both motors and read their encoders.
4. Prevent signal cable and fiber optic tearing through mechanical and software constraints.

[a] Oriental Motors DGM85R-AZAC

System Dynamics

$$\sigma_a = \omega_{a-1}\Delta t + \sigma_{a-1}$$
$$\omega_a = \frac{\tau \Delta t}{I_a} + \omega_{a-1}$$
$$I_a = 1/2 M_{sa}(r_{sa}^2)$$
$$\tau = \frac{K d_a r_{sa} M_{sa}}{\Delta t^2}$$

$$\sigma_e = \omega_{e-1}\Delta t + \sigma_{e-1}$$
$$\omega_e = \frac{\tau \Delta t}{I_e} - \frac{m_c \gamma r_{se}}{I_E} sin(\sigma_{e-1})\Delta t + \omega_{e-1}$$
$$I_e = 1/12 M_{sa}(a^2 + b^2) + M_{se}(r_{se} + a/2)^2$$
$$\tau = \frac{K d_e r_e M_s}{\Delta t^2}$$

Conclusions

- Created sunphotometry platform for testing computer vision and controls algorithms.
- Created Labview Modbus driver and encoder modules.
- Created more compact computer rack.
- Created Labview real-time camera imagery feedback for operators and scientists.
- Currently stable up to 6 deg/sec of yaw with roll and pitch perturbations of 1-2 Hz.

References

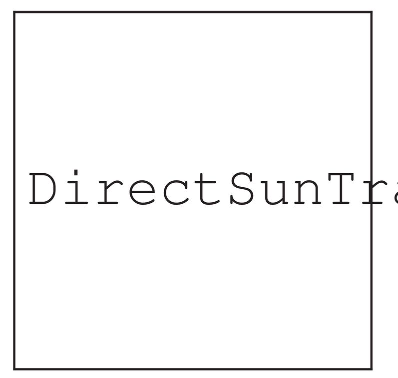
[1] Franklin, Gene F., J. David Powell, and Abbas Emami-Naeini. *Feedback Control of Dynamic Systems. 7th ed. Boston: Pearson, 2015. Print.*

[2] Dunagan, Stephen, Roy Johnson *"Spectrometer for Sky-Scanning Sun-Tracking Atmospheric Research (4STAR): Instrument Technology." MDPI. Remote Sensing, 2013. Web. 31 May 2016.*

Future Research

- Add logarithmic response tracking camera.
- Add advanced image detection algorithm for additional data quality flagging.
- Add autonomous radiometric calibration.
- Utilize FPGA or GPU for speedup.
- Be robust for spinal climb maneveurs.
- Create turn-key Matlab module to simulate nonlinear control for similar 2-axis sunphotometers.

Contact Information



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