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Automated Solar Tracking System

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What we plan to do: We are planning to develop an automated solar tracking system to adjust the orientation of solar panels for optimal sunlight exposure. The system will use two main axes for adjustment: altitude and azimuth. A clearer description of these terms is provided below in Figure 1. To monitor the sun's position, the system will use four light-dependent resistors (LDRs) arranged in a 2x2 array, which will measure the sunlight intensity from different angles. The LDR readings will be processed by the ADC on our Arduino Uno microcontroller. Based on the data from the sensors, the system will control two servo motors keeping the solar panel aligned with the sun's position throughout the day. The system will implement a feedback loop designed to minimize unnecessary motor movement and tracking error.. The system will be time-triggered to operate once every 30 minutes, preventing motor overuse and energy waste during the night.

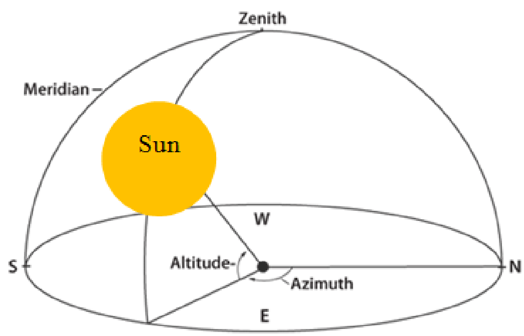
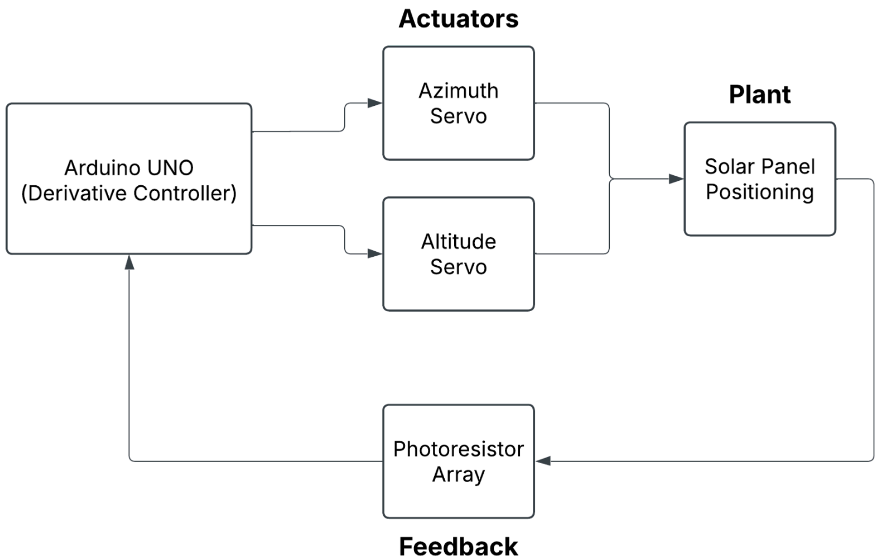


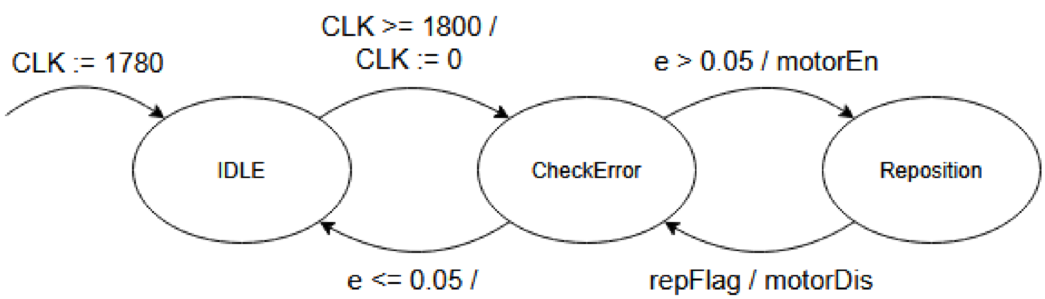
Figure 1: Solar Navigation Directions

Why: Solar systems are critical for renewable energy generation, but their efficiency heavily depends on their ability to track the sun's movement throughout the day. Different tracking systems, such as single-axis and dual-axis trackers, offer significant improvements over fixed systems, as they allow solar panels to capture more direct beam radiation, maximizing energy output. Previous studies have shown that dual-axis tracking systems yield the highest performance in terms of power production. According to research, "findings indicate that … dual-axis solar trackers ... yield 67.65% [efficiency]"[1] as compared to 57.4% for single-axis. The project will provide hands-on experience with the complexities of this cyber physical system, time based feedback loops, and system modeling.

What is hard about it: As mentioned, the automated solar tracking system relies on time based monitoring and precise control of the panel's orientation using both altitude and azimuth adjustments. It's challenging to ensure accurate tracking of the sun's position throughout the day with minimal error while avoiding unnecessary movements of the servo motors. The system needs to balance between sensor data processing, motor control, and feedback loops to maintain efficiency without overusing the motors or wasting energy.

Models (FSM/Feedback loop):





Notations:
CLK = Time in seconds since last update;
e = error between all 4 sensors;
repFlag = a flag that is set to 1 if the repositioning is complete;
motorEn = Enable motors;
motorDis = Disable motors;
	Initial state: IDLE;
	Inputs: repFlag: pure, CLK, e;
	Outputs: motorEn, motorDis: pure
	Updates:
	(CheckError) when IDLE ^ (CLK >= 1800)
	(Reposition) when CheckError ^ (e > 0.05)
	(CheckError) when Reposition ^ (repFlag)
	(IDLE) when CheckError ^ (e <= 0.05)

Hardware Components:

1x 3D Printed Enclosure (Procured Design), 2x SG90 9g servos: For dual axes control, 4x

Photoresistors/LDRs (CdS), 2x Solar Panel, 1x 3.7V LiPo Battery w/ JST-PH connector, 1x DC Solar Charger with 5V Boost Board, 1x Microcontroller: Arduino UNO

Software Components:

Arduino IDE for development & C/C++ programming language for efficient use on the arduino.

Metrics of Success:

The success of our solar tracking system will be measured by several performance indicators. First, we will try to maintain a low sunlight tracking error. We will also try to quantify our energy collection in the dynamic system compared against a stationary setup. And finally we expect reliable sensor data under different light conditions .

Experiments:

To validate our design we will conduct a series of tests. Sensor calibration tests will be performed to verify light sensor accuracy under different light intensities and conditions. We will also test the coordinated motor control for movements in both axes for smooth and accurate movement. Finally test the time triggered system by observing the system activating during daytime and deactivation at night

Final Project Demo and Report:

For the final demo, we will set up the automated solar tracking system in its 3D printed enclosure. The enclosure will contain the Arduino Uno, LDRs, two servo motors, and the solar panel. We will demonstrate the system's ability to adjust the panel's orientation in real time based on our hypothetical sun's (a flashlight's) position. The servo motors will adjust the panel on both axes while minimizing unnecessary movements and face perpendicular to the flashlight. If possible, the demonstration will be conducted live, showcasing all use cases of the system including the time-triggered mechanism and solar panel orientation. In case of technical issues, we will have a video demonstration.

Timeline of Milestones and Deliverables: [REMOVED]

References

[1] Kuttybay, Nurzhigit, and Saad Mekhilef. “Assessment of Solar Tracking Systems: A Comprehensive Review.” Science Direct, 2024, https://www.sciencedirect.com/science/article/pii/S2213138824002753.

[2] Logan, Paula E, and Brian W Raichle. PERFORMANCE COMPARISON OF FIXED, SINGLE, AND DUAL AXIS TRACKING SYSTEMS FOR SMALL PHOTOVOLTAIC SYSTEMS WITH MEASURED DIRECT BEAM FRACTION. https://ases.org/wp-content/uploads/2021/11/Performance-Comparison-of-Fixed-Single-and-Dual-Axis-Tracking-Systems-For-Small-Photovoltaic-Systems-with-Measured-Direct-Beam-Fraction-.pdf.