Solar *Tracker*

Algorithmic Solar Orientation Using GPS + Servo Actuation

Introduction

A *dual-axis solar tracker* precisely orients solar panels to follow the sun's path for maximum energy capture. This system relies on GPS data rather than light-dependent resistors (LDRs), ensuring accurate, weather-independent tracking. Our approach uses an algorithmic solution for sun positioning, eliminating calibration and drift issues commonly found in sensor-based systems.

Dual-Axis Solar Tracker *Overview*

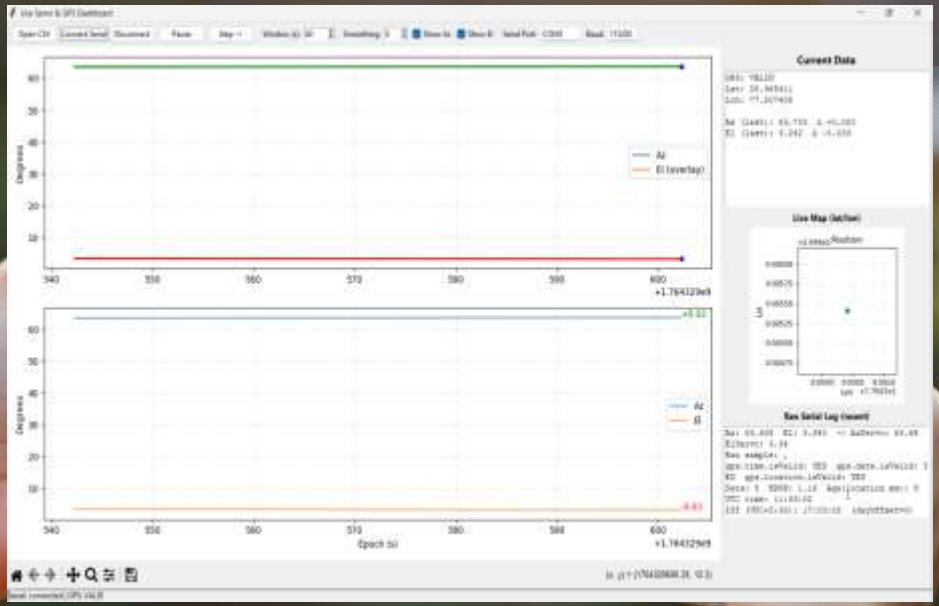
01

Dual-axis solar tracker definition and *functions*

A dual-axis solar tracker adjusts panel position along two axes: azimuth (horizontal) and elevation (vertical). This capability allows the panel to follow the sun's movement across the sky throughout the day and seasons, optimizing energy absorption. The system incorporates motors driven by precise algorithms to maintain optimal orientation continuously.

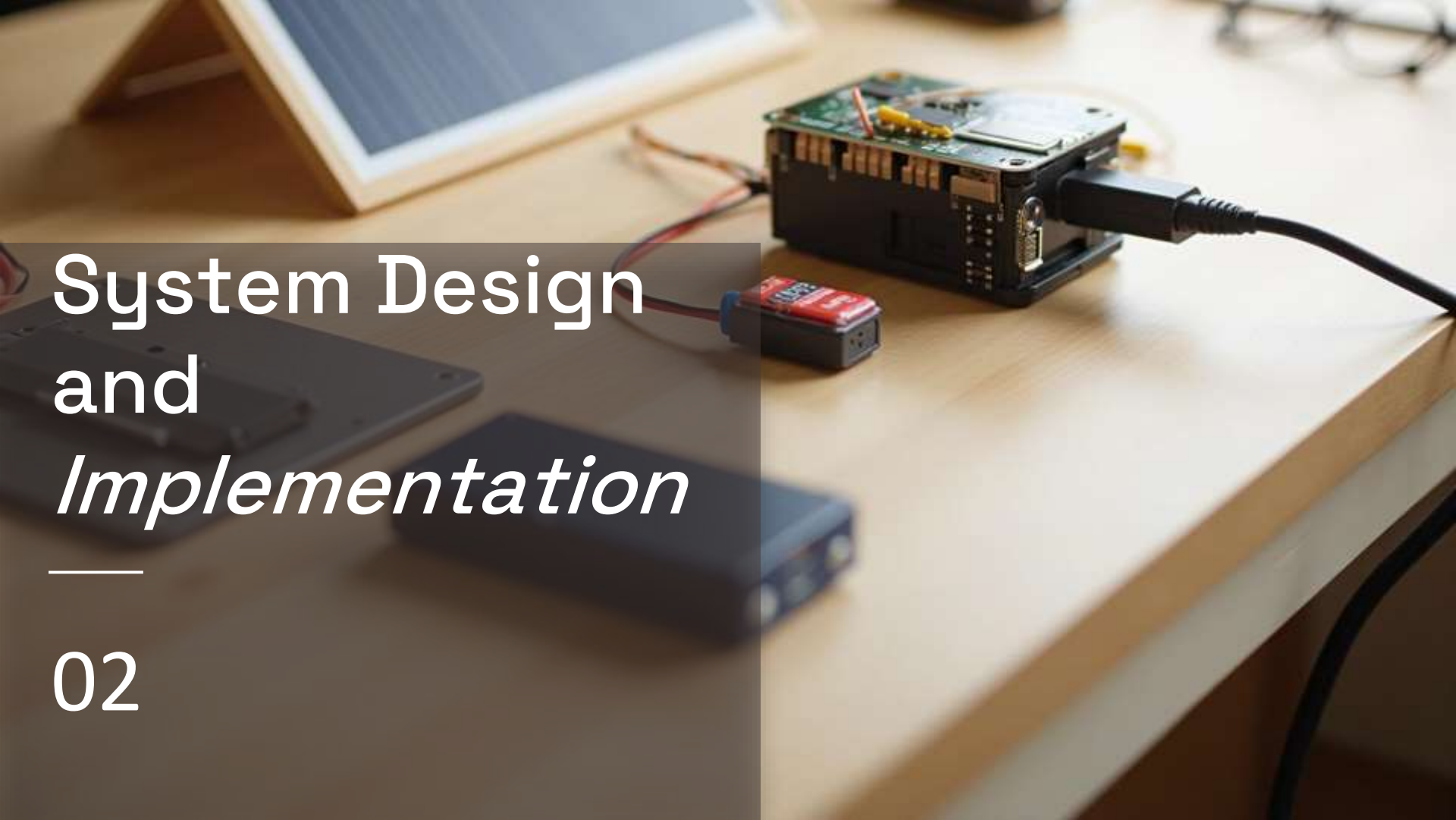
Advantages of GPS-based tracking over *LDRs*

GPS-based tracking uses location and time data to compute solar angles mathematically, providing reliable operation regardless of weather conditions. Unlike LDRs, this method avoids errors from clouds, sensor drift, and calibration needs. It ensures *algorithmic precision* and consistent efficiency, essential for renewable energy systems targeting scalability and robustness.



Weather independence through algorithmic *orientation*

The system achieves **weather-independent tracking** by using GPS data and an algorithmic approach rather than relying on external light sensors. This method eliminates issues caused by clouds, shadows, or sensor drift. By calculating the sun's position precisely based on location and time, the tracker maintains optimal panel alignment consistently, enhancing energy capture reliability in diverse environmental conditions.

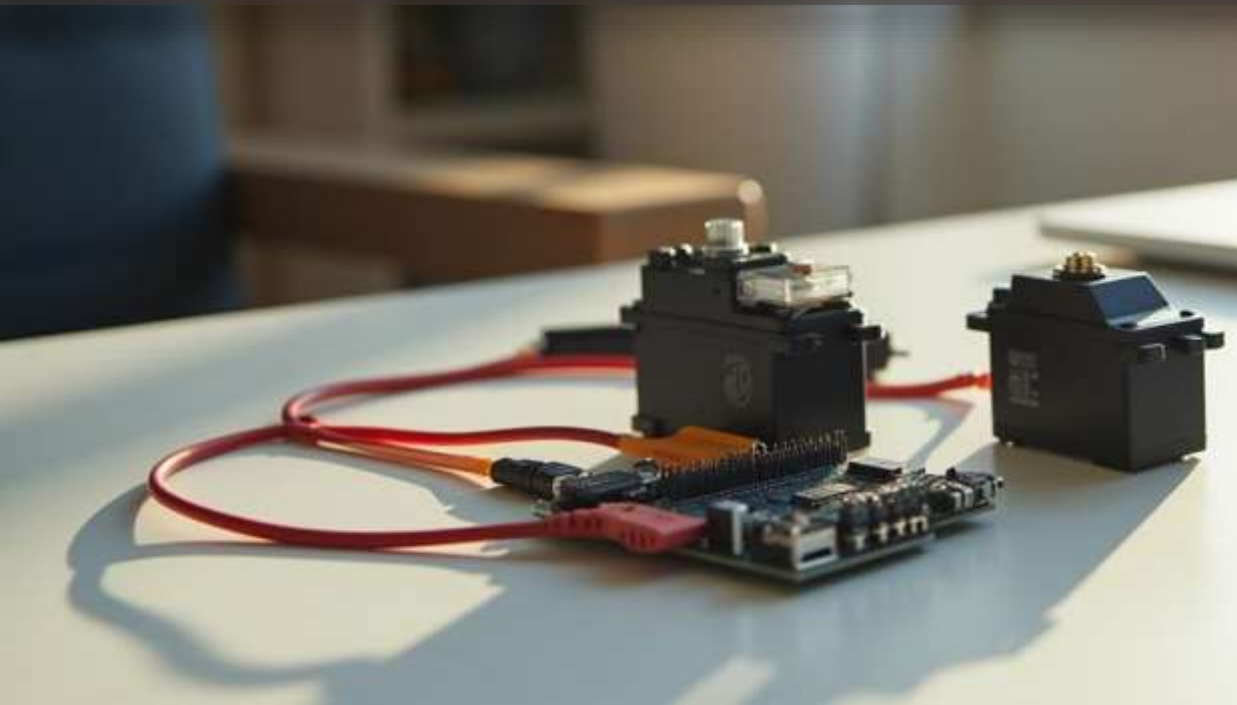


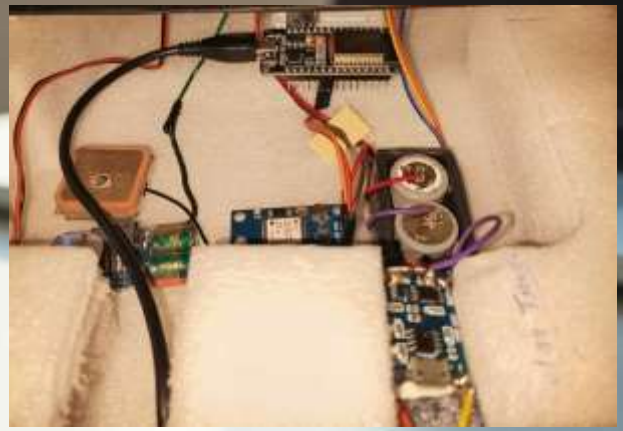
System Design and *Implementation*

02

Hardware components and *architecture*

The hardware includes an ESP32 microcontroller, a NEO-6M GPS module for accurate location data, and dual MG995 servos to control azimuth and elevation movements. Power is supplied by 18650 batteries managed via a TP4056 charger, and the setup mounts on a custom frame with a mini solar panel. A block diagram illustrates component interconnections to clarify system architecture.

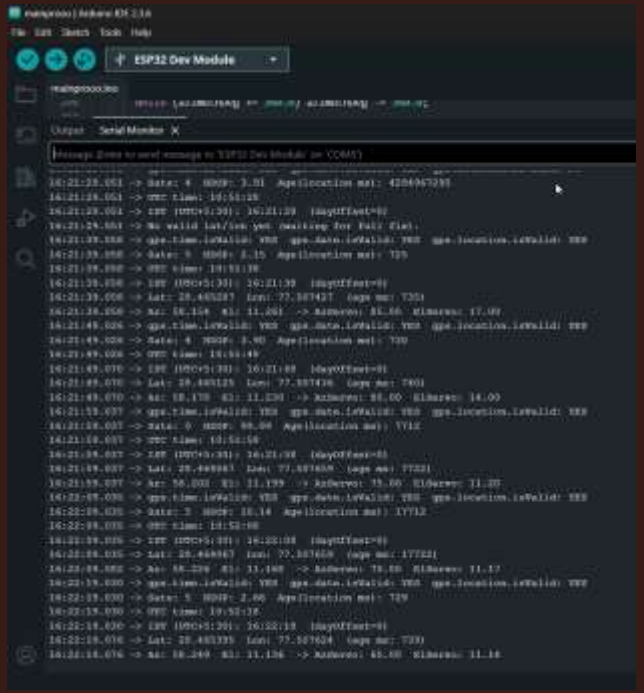




Software design: GPS data parsing and solar *positioning*

The software runs on Arduino with C/C++ code that parses NMEA GPS data. It implements a solar positioning algorithm computing azimuth and elevation angles dynamically. This data maps to servo motor commands in a closed loop, ensuring precise orientation. Additionally, a Python Tkinter GUI provides real-time telemetry and CSV logging supports detailed analytics for system performance assessment.

Algorithm workflow and mechanical *integration*



The workflow starts with reading GPS data to acquire latitude, longitude, and UTC time. The algorithm then computes the sun's azimuth and elevation angles, converting these to servo positions. Servos move the panel accordingly, maintaining accuracy through range mapping and smoothing. Data logs update a dashboard, supporting system monitoring and mechanical stability throughout operation.

Conclusions

The GPS-based dual-axis solar tracker delivers **fully algorithmic, weather-independent panel orientation** with high precision and low cost. It overcomes limitations of sensor-based methods and is scalable for various renewable energy applications. Future enhancements include expanding panel size, integrating GSM alerts, and adding automated weather monitoring for increased functionality and smarter energy management.