Institute of Technology of Cambodia

Department of Electrical and Energy Engineering (GEE)

Génie
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AI-Assisted Computational & IMU-Guided Solar Tracker

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1. Abstract

This project presents a **solar tracker** that doesn't use **light dependent resistors (LDRs)**, which can be unreliable. Instead, it uses **precise calculations** and **Inertial Measurement Unit (IMU)** to track the sun with high stability and accuracy. While not built for minimal cost, the design balances accessibility with smart features, including slip rings, AI-based feedback, and MPPT-based charging.

Two **microcontrollers** are used:

ESP32 handles internet data and sun position calculations. **STM32** handles motor control, sensor feedback, and runs the AI model. The design uses low-cost **TT motors** with gear systems and includes **slip rings** so the panel can rotate fully without cables getting twisted. **It is powered using a solar-charged battery with an MPPT system for efficient charging**.

This project is LDR-free, and useful for learning, research, and real-world solar applications.

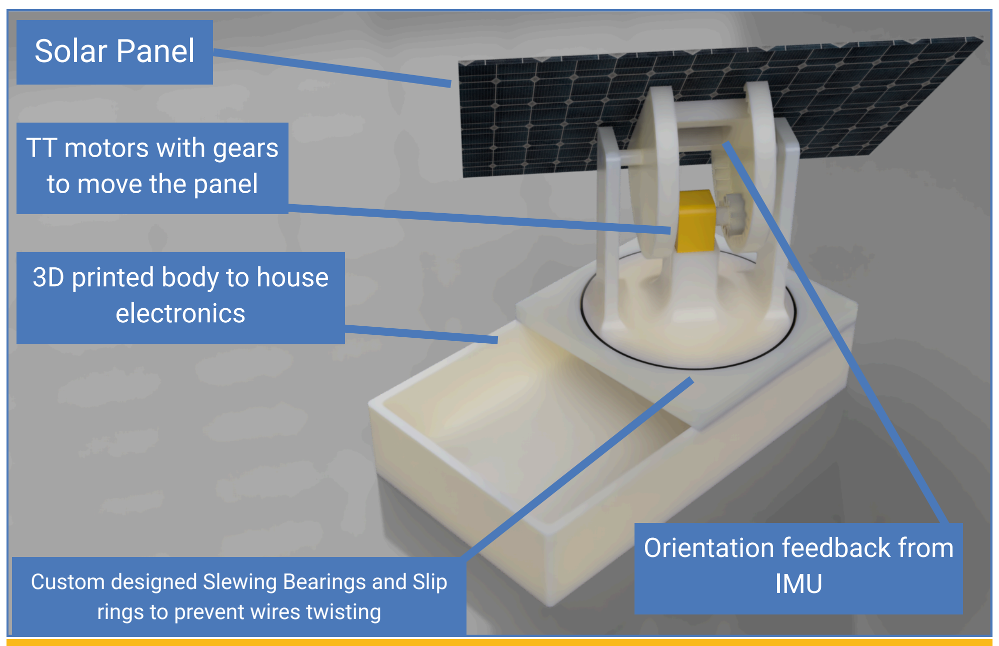

Figure 1. 3D Render of the Proposed Solar Tracker System

2. Problem & Motivation

Most **solar trackers** rely on **light-dependent resistors (LDRs)** to follow the sun. But **LDRs** are often **unreliable** in **cloudy conditions**, **reflective environments**, or **sudden light changes** leading to **poor alignment** and **reduced energy output**.

To solve this, we propose a smarter tracker that **calculates the sun's position** using **time**, **date**, and **location**, and then uses **IMU** sensor feedback with AI **correction** to keep the panel accurately aligned—even when sunlight is weak or inconsistent.

Our design is:

- Affordable, ideal for rural areas, schools, or farms
- Low-power, running on solar energy alone
- Modular and adaptable for rooftops, microgrids, or off-grid setups

This project mixes practicality with modern technologies—using microcontrollers, sensor fusion, and **TinyML** to make solar tracking more reliable, efficient, and accessible.

Figure 2. Typical LDR used in solar trackers. Performance may be affected by light noise, shadows, or weather conditions.

3. System Overview

Our system has the following **main parts**:

- **ESP32**: Connects to the internet to fetch time and location data, calculates the sun's expected position, and sends this information to the **STM32 controller**.
- **STM32**: Receives the target position from the ESP32 and uses real-time data from the IMU to determine the panel's current orientation. It then adjusts the motors to align the panel with the sun.
- **MPU9250 IMU Sensor**: Provides orientation data, including both tilt (pitch and roll) and directional heading via its built-in compass.
- **TT Motors + Slip Rings**: Drive the panel's movement in two axes. Slip rings enable continuous 360° horizontal rotation without cable tangling.
- **MPPT Charger**: Maximizes the efficiency of solar energy capture and ensures reliable battery charging to power the system.
- **3D-Printed Chassis**: Houses the gear mechanisms, motors, bearings, and structural components. Designed for lightweight strength and ease of assembly.

Together, these parts form a complete, intelligent tracking system that does not depend on external light sensing.

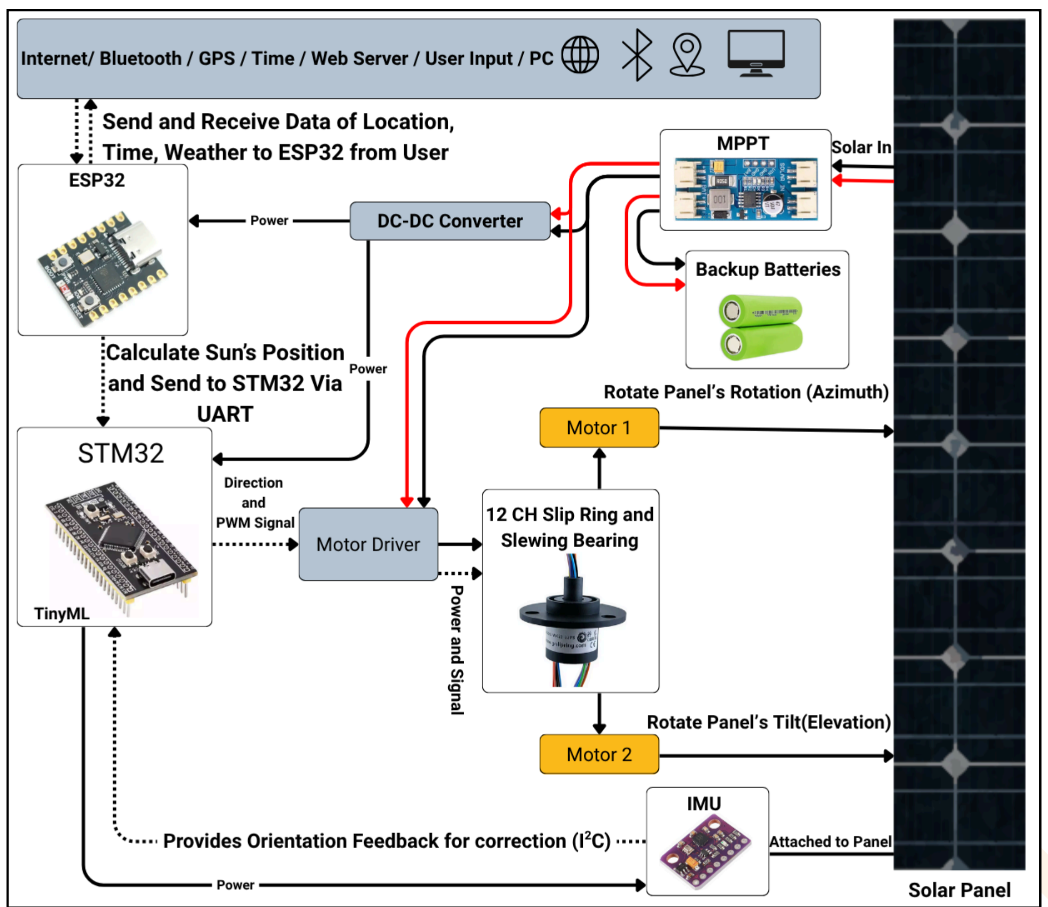

Figure 3. System Block Diagram

4. Mechanical Design

We designed a **simple and cost-effective mechanical structure**:

The **horizontal axis** uses a **slip ring**, so the system can rotate endlessly without twisting wires.

Two TT motors (very low-cost) drive the tilt and rotation.

A gear system increases torque and control.

The panel mount is **lightweight and easy to build**.

A custom **slewing bearing** helps the panel move smoothly.

This design makes the whole system modular and cheap to manufacture.

5. AI & Control Logic

Our system uses a combination of **calculated sun position** and **feedback** from the **IMU** to decide how to move the panel.

- The ESP32 **calculates** the sun's position using a known algorithm.
- The **STM32 compares this with the current panel angle**.

It then **adjusts the motors** to correct the position.

To improve accuracy, we trained a small AI model (using **TinyML**) that learns from previous movement errors (like overshooting or shaking) and corrects them in real time.

This makes even low-cost motors behave more smoothly and accurately.

The AI runs directly on the **STM32** and does not need constant updates or a full computer.

6. Software Flow

Our software includes:

- **Sun Tracking Algorithm** (based on time, location, and date)
- **IMU Orientation Processing** (using data from MPU9250)
- **Motor Control Loop** (with correction from the AI)
- **Bluetooth Upload** Option (users can upload custom coordinates or test angles)
- **UART/I2C Communicatio**n between ESP32 and STM32

We also plan to connect the whole device to a PC or mobile app for debugging or real-time control.

7. Benefits & Applications

Advantages:

- Works without sunlight detection useful on cloudy days
- Uses feedback sensors for real accuracy
- Adds AI correction to basic motors
- Fully wireless (solar-powered with battery and MPPT)
- Modular and low-cost: ideal for student or rural use

Applications:

- Educational kits, Remote solar farms, Small rooftop panels in cities, Microgrid systems, DIY renewable energy projects

Figure 4. 3D render of the solar tracker deployed in an open-field environment.