

Automatic Mirror for Plant Lighting

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1. Introduction

1.1 Problem

There are many situations where a person wants to grow a plant, but there isn't enough light where they want to grow it. An example of this is an apartment or room without a south-facing window, which would not provide enough direct sunlight for many plants. Another example is a garden or deck which was originally in the sun but became more shady as the surrounding trees grew. Many full-sun or partial-sun plants grown in these environments will have poor health or die due to the insufficient amount of sunlight they receive. Full-sun plants need at least 6 hours of direct sunlight while partial-sun plants need 3-6 hours of direct sunlight.

The inability to grow many plants in shady environments has negative impacts on mental health. A study from the National Library of Medicine has shown a link between indoor plants and decreased stress. Increasing the amount of plants that can be grown in indoor spaces would help to reduce the stress of the public. People would also likely be more satisfied with their living spaces as they would have more choices of which plants to grow. More fresh fruits and vegetables could also be grown in shady areas, since they are produced by full-sun plants. This would improve the physical health of the public by making nutritious and fresh food more widely available.

1.2 Solution

We will build a device that uses a sun-tracking flat mirror to redirect sunlight towards the plant in a non-south facing window or other shady space. The device will be powered by a battery, which will allow it to be mounted outside of a window or be placed on a yard or deck. It will use a GPS signal and compass to determine the time, location, and orientation of the device. This data will be used by a microcontroller to determine the position of the sun in the sky relative to the device. On setup, the device will be calibrated to reflect the sun at the desired angle, and the microcontroller will move the mirror to continue reflecting the sun at this angle. The mirror will be attached to a horizontal axle which will be connected by two supports to the base. The base will rotate to allow for rotation parallel to the ground and there will be a motor connected to the horizontal axle that allows for rotation perpendicular to the ground. The device will also use a light sensor to determine when it is night time or the weather is poor so that it can save energy. This device will be able to provide the extra sunlight that many plants need to thrive in shady spaces.

1.3 Visual Aid

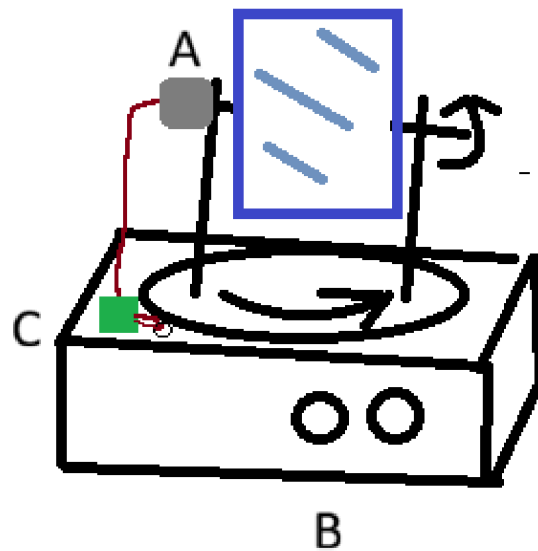


Figure 1: Visual Aid for Automatic Mirror

A: Horizontal axle connected to mirror and rotated by motor

B: Base with control buttons, rotating center connected to motor below, and battery inside

C: PCB with microcontroller and sensors, connected to motors, buttons, and battery

1.4 High-level Requirements List

In order to successfully redirect the sun to the plant in the shade, the project must exhibit the following characteristics.

1. **Position Calculations:** The device should be able to calculate the position of the sun in the sky within 5 degrees of error at any time of the day and location. It should also be able to calculate the position of the target point after set-up to within 5 degrees of error. Using the sensor data to correctly determine the positions of the sun and target points is the first step to redirecting the sun.
2. **Movement Accuracy:** The device should be able to redirect the light from the sun to the target point at any time of the day as long as the reflection angle is realizable within 5 degrees of error. It should also be consistent and keep the target point illuminated for more than 90% of the time.
3. **Power Efficiency:** The device should save power by not adjusting if the reflection angle is not realizable within 5 degrees of error or the light level is below 500 lux. The device should be able to operate for at least a day on a single battery charge.

2. Design

2.1 Block Diagram

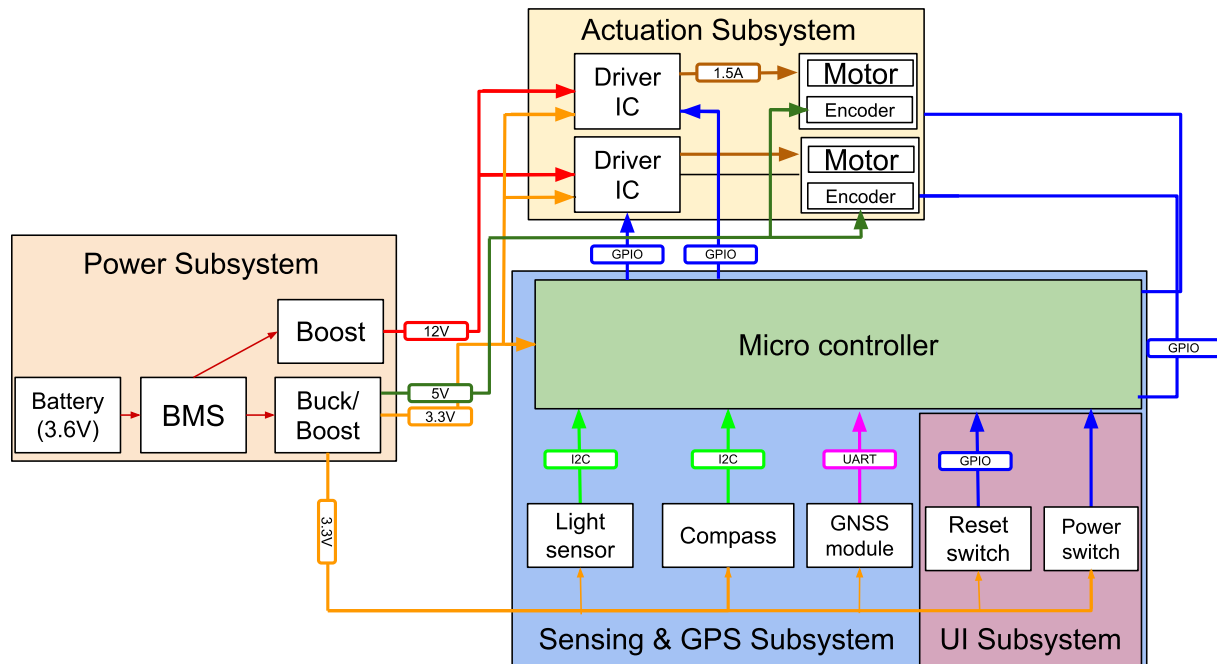


Figure 2: High level block diagram for Automatic Mirror

2.2 Subsystem Overview

- 1. Power Subsystem :** The power subsystem consists of four main components: a battery, a battery management system (BMS), a boost converter, and a buck-boost converter. A single 18650 Li-ion cell serves as the power source for the entire circuit. A BMS module will be attached between the battery and the rest of the system to isolate the battery from the circuit in order to protect circuit elements and prevent overcharge and overdischarge of the battery. The output of the BMS module will then be connected to a boost circuit to ensure 12V DC supply for the motors. For the rest of the circuit, a separated buck/boost circuit will be attached, to ensure the steady 3.3V and 5V DC supply .
- 2. Actuation Subsystem :** Actuation subsystem consists of two sets of Driver IC / Motor pair. The driver IC gets 12V DC for the motor, and the 3.3V DC to power the IC logic. Driver IC also gets GPIO signals (pulses) from the micro controller to drive the motor into a desired direction. Upon each GPIO signal from the micro controller, the driver IC supplies a pulse of 1.5A of current to the motor to drive the motor. Encoders that are integrated in the motor units will also be connected to the micro controller through GPIO pins, providing position feedback of the elements that are attached to the motor shafts. The encoders will be powered from 5V DC supply.

3. **Sensing & GPS subsystem:** Sensing subsystem consists of two sensors, a light sensor and a compass. Both of the sensors are connected to the microcontroller through the I2C bus. The GPS part consists of a GNSS module that will acquire the location data of the device. The GNSS module will be connected to the microcontroller through a UART pin. All the components that consist of this subsystem will be powered by 3.3V DC power supply.
4. **User Interface subsystem:** User interface subsystem includes two push buttons: a reset button and a power-off button. The reset button is connected to the microcontroller through GPIO and restarts/recalibrates the system when pressed. The power-off button shuts the device down by disconnecting the power supply from the rest of the circuit elements.

2.3 Subsystem Requirements

1. **Power Subsystem:** The power subsystem must be able to provide the correct amount of voltage to the components of the other subsystems, and it must be able to provide enough current during high-demand processes like moving the motors. The 18650 Li-ion cell is connected to a BMS module, which protects other subsystems from overdischarging the battery due to a short circuit or other unexpected event. The BMS is then connected to boost and buck circuits to allow it to output 12V, 5V, and 3.3V DC for the components of the other subsystems. Since the output of the Li-ion battery fluctuates between 3.0V to 4.0 V, 12V would be solely generated from the boosting part of the power circuits whereas 3.3V, and 5V will be from the buck/boosting circuit of the power system, depending on the instantaneous voltage output of the battery. If this subsystem fails, the other subsystems may not receive enough power to operate, or they could receive too much which could damage their electrical components. The requirements for this subsystem are meant to ensure correct connection of its components and adequate voltage and current supply to the other subsystems.

Requirements:

- When the BMS is connected to the battery, it is able to output the same voltage as the battery with less than 5% error.
- When the BMS is connected to the battery, it is able to output current equal to at least 90% of the battery's maximum current rating, but it does not output current greater than the current limit of the battery.
- The various boost and buck converters are able to output 12V, 5V, and 3.3V DC within 5% error respectively when connected to the powered BMS.
- The buck/boost converters are able to supply more current than the maximum current usage of the components combined.

2. **Actuation Subsystem:** This subsystem is meant to use motors to position the mirror according to the calculations of the microcontroller. If this system does not function correctly, light may not be accurately redirected to the plant even if the other subsystems work properly. The actuation subsystem must be able to move the motors correctly based on the signals sent from the microcontroller to the driver IC over GPIO. The motor encoders must also send accurate signals to the microcontroller over GPIO to ensure the position of the mirror can be correctly measured.

Requirements:

- Each driver IC should be able to acquire both 12V (for motor) and 3.3V (for logic) DC supply from the power subsystem.
- Each driver IC should be able to provide a steady pulse of 1.5A to the motors to ensure the smooth rotation of motors.
- Each driver IC must not overheat when providing high current to the motors.
- Connection between each IC and motor must be protected with fuses to ensure safety under high current environment
- Each motor should be able to rotate to an orientation sent to the motor drivers by the microcontroller within 5 degrees of error.
- The encoders should be able to measure the orientation of the motors within 5 degrees of error and send the result to the microcontroller within a second.
- When the motors are attached to the frame, they should be able to each rotate a full 270 degrees within their movement range.
- When the motors are attached to the frame, they should be able to rotate the focus of the mirror to a target orientation within 5 degrees of error.

3. **Sensing & GPS Subsystem:** This subsystem includes the microcontroller, light sensor, compass, and GNSS module. Its purpose is to measure the position of the device and the time of day to determine the position of the sun in the sky relative to the device. It then uses equations to determine where the mirror should be focused to redirect light to the target point. The microcontroller sends signals to the actuation subsystem to move the mirror to the position that it calculated, and it receives signals from the actuation subsystem to ensure that the mirror moves to this position. The light sensor also shuts down the device to save power if there is not enough light to be redirected to the plant. If this subsystem does not function correctly, the device will not redirect the sun to the correct target point. It could also cause the motors to move too much or the device to keep running at night or in bad weather, which could cause too much power consumption.

Requirements:

- The light sensor is able to determine when the light level is below 500 lux and communicate this with the microcontroller.
- The microcontroller should be able to calculate when the reflection angle is not realizable within 5 degrees of error.
- The compass sensor should determine the orientation of the device within 5 degrees of error when compared to a manual compass or known orientation.
- The GPS sensor should be able to successfully receive a GPS signal without interference and send it to the microcontroller.
- The microcontroller should be able to calculate the position of the sun in the sky relative to the device within 5 degrees of error if all other sensors are functioning correctly.

4. **User Interface Subsystem:** This subsystem includes the start button, the reset button, and the microcontroller. The reset button is used to calibrate the device, which allows it to determine position of the target point from the device's current position and the calculated position of the sun. The power button turns the device off, which could help it save power if it's not in use. If this subsystem does not work, the user will not be able to correctly set the target point for light reflection, which will cause the device to be inaccurate.

Requirements:

- The power button can turn the device on and off.
- The reset button starts the calibration process and the microcontroller calculates the position of the target point within 5 degrees of error.

2.4 Tolerance Analysis

The primary tolerance concern for the device is the angular positioning accuracy of the mirror. A reflected light changes by twice the mirror's rotation angle, so small positioning errors are amplified to where the sunlight is directed. Some sources of error include motor positioning accuracy, mechanical backlash, and mirror mounting alignment. Our device specifies an allowable tolerance of 5 degrees of error. This results in a reflected beam error of 10 degrees. The displacement of the reflected beam at the plant can be calculated as

$$d = L \tan(\theta_{beam})$$

Where L is the distance from the mirror and the plant.

As an example if the plant is located **0.5 m** from the mirror,

$$d = 0.5 \tan(10^\circ)$$

$$d = 0.5(0.176)$$

$$d = 0.088 \text{ m}$$

So the reflected sunlight could be displaced by approximately **8.8 cm** within the margin of error. If the area needed to be illuminated is smaller than 8.8 cm then some sunlight may completely miss the plant. This shows that mirror positioning is one of the most critical tolerances in the system. If testing shows that the displacement prevents sufficient illumination of the plant, then the tolerance may need to be reduced through improved motor control, calibration, or mechanical adjustment.

3. Ethics, Safety, and Societal Impact

Aligned with the IEEE Code of Ethics, the team has a responsibility to prioritize public safety and communicate honestly of the capabilities and limitations of the system. The project will be tested in various lighting conditions and the documentation will clearly state that the device supplements natural sunlight rather than guaranteeing plant health.

During the development and testing of the device, there are several safety hazards that must be considered. Some electrical hazards include short circuits and improper wiring that could damage the components or create a fire risk. Mechanical hazards include pinch points from the rotating gears and platform, which can cause minor injuries while operating. Since the mirror concentrates and redirects sunlight this also creates an optical hazard of glare or potentially a fire hazard if improperly aimed.

To reduce these risks, the team will follow established electrical safety practices such as insulation, proper wiring, and verification of the connections before powering on the system. Mechanical components will be mounted securely with help from the university's machine shop. Testing will be conducted with care to keep hands and other objects clear from moving parts. The mirror will be tested in a controlled environment aimed away from people and materials susceptible to combustion.

The project will follow and comply with the safety principles outlined in the university's laboratory safety policies, including the required safety training completed by team members. In addition, other useful guidelines are the NFPA 70 or the National Electrical Code with core goals of reducing injury, property damage, and economic loss resulting from fires and hazards. The OSHA laboratory electrical and mechanical safety guidelines which require proper equipment grounding, regular inspection of cords, and avoiding circuit overloading. Also basic electrical protection such as insulating and limiting the current to prevent potential injury. Following these

standards help minimize the risk of electrical, mechanical, and optical hazards throughout the project's development.

4. References

Institute of Electrical and Electronics Engineers. (2020). IEEE code of ethics.
<https://www.ieee.org/about/corporate/governance/p7-8>

K. Toscano, "A Gardener's Guide to Sun Exposure," southernlivingplants.com, Apr. 01, 2022.
<https://southernlivingplants.com/planting-care/a-gardeners-guide-to-sun-exposure/>

M. Lee, J. Lee, B.-J. Park, and Y. Miyazaki, "Interaction with indoor plants may reduce psychological and physiological stress by suppressing autonomic nervous system activity in young adults: a randomized crossover study," *Journal of Physiological Anthropology*, vol. 34, no. 1, Apr. 2015, doi: 10.1186/s40101-015-0060-8

National Fire Protection Association. (2025). NFPA 70: National electrical code (2026 ed.). National Fire Protection Association.

Occupational Safety and Health Administration. (1981). Electrical: General requirements (OSHA Standard No. 1910.303). United States Department of Labor.
<https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.333>