# Sun Tracking Umbrella: Introduction

**Problem:**

When sitting outside in urban third spaces, it is often too hot or bright to stay there for a while. Even at low temperatures, exposure in direct sun gets uncomfortable and/or unhealthy quickly. Many outdoor spaces do have stationary umbrellas but, once set, they only help for a period of time which can lead to discomfort from excessive heat/brightness. This can be avoided by adjusting the umbrella throughout the day but they are often quite heavy and hard to maneuver.

Some straight umbrellas weigh between 12 and 75lbs but the base can weigh up to 180 lbs. That means even with a joint that allows the umbrella some adaptability, moving it can still be very difficult. Cantilever umbrellas tend to weigh more and be even harder to adjust. Even advertisements (Walmart Umbrella) for easily moveable umbrellas highlight the need for at least one more range of motion in order to improve sun blockage.

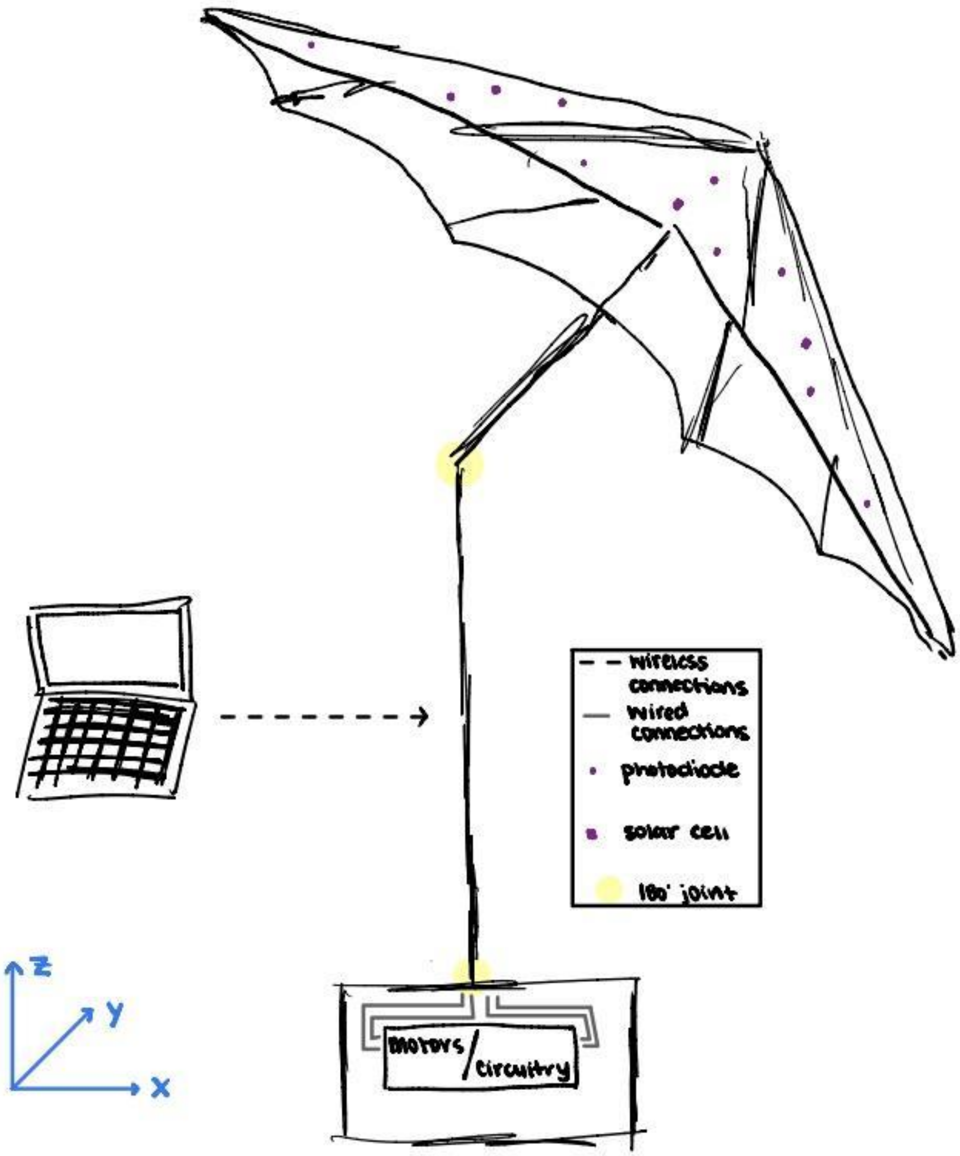
**Solution:**

Our proposed solution is to create a scaled model of a straight umbrella with two joints that allow for an increased range of shade coverage. We plan to put photodiodes and solar cells on the actual shade in order to implement a sun tracking system. That system will detect differences in the intensity incident on segments of the shade. That data will then be used to drive stepper motors that adjust the umbrella in order to redistribute the illumination across the shade. The goal is to maximize the available shade under the umbrella while minimizing the manual effort required to adjust the umbrella. That being said, if time allows, the goal is to implement manual and automatic settings. Data wirelessly communicated to a browser will allow a user to switch to manual mode and adjust the umbrella as desired and then move back to automatic as wanted.

**High level requirements:**

1. The two joints (the bottom joint can rotate 360* around the XY plane and the top joint can rotate 90* from the z axis down) are driven by stepper motors and move smoothly and safely.
2. The photodiodes can detect at least a 5 times difference in the intensity when the sun is at a 90 degree incident angle compared to a 45 degree incident angle. Then, the current output is amplified to be able to use those signals successfully.
    a. Determined with an experiment using photoresistors as detailed below.
    b. Photodiodes are more sensitive than a photoresistor and we plan on using an enclosure to limit the amount of light exposed other than the incident light
    c. We are expecting less of a difference between photodiodes on opposite sides but one option is to take a baseline measurement and compare it to a live measurement and adjust to minimize the difference.
3. Data from the system is wirelessly transmitted to an external screen in no more than 30 ms where it can be viewed and manual input can be sent back. A conservative aim is to poll the microcontroller every 250ms (i.e. 4 times every second).

**Visual Aid :**


wireless connections
wired connections
photodiode
solar cell
180° joint
motors/circuitry
z
y
x

Photodiode Sensitivity Experiment:

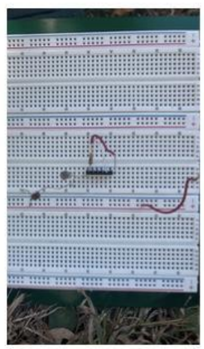
- Setup/Notes:
    - Used photoresistors instead of photodiodes which are less sensitive
        - Used two photoresistors in series to try and increase possible sensitivity
    - Did not use enclosures to limit surrounding luminance
    - Photos included were taken to demonstrate the experiment but were not the actual circumstances under which the measurements were taken
    - Measurements were taken around 2 with the solar noon occurring at 12:55
    - First measurement was taken with the board flat on the grass and two more were taken at, as best managed, a 45 degree angle facing in two different directions
        - The two 45 degrees measurements were practically the same so only one was included.

Voltage Divider: $3 = V_1\left(\frac{R_s}{R_s+10K}\right)$

$\frac{3-V_1}{R_s} = \frac{V_1}{10K} \Rightarrow \frac{3}{R_s} = \frac{V_1}{10K} + \frac{V_1}{R_s} \Rightarrow 3 = \frac{V_1R_s}{10K} + V_1 \Rightarrow 3 = V_1\left(\frac{10K+R_s}{10K}\right)$

• straight up @ sun

1. $k = \left(\frac{3}{2.906}\right)10$ $= 10.3234686855$
2. $m = k - 10$ $= 0.323468685478$
3. $m(1000)$ $= 323.468685478$




• angled away from the sun ↓@ a steeper angle, just for photo

1. $k = \left(\frac{3}{2.773}\right)10$ $= 10.8186080058$
2. $m = k - 10$ $= 0.81860800577$
3. $m(1000)$ $= 818.60800577$


$\left(\frac{323.469}{818.6}\right)^{-\frac{1}{0.7}}$

$= 3.76752220431$

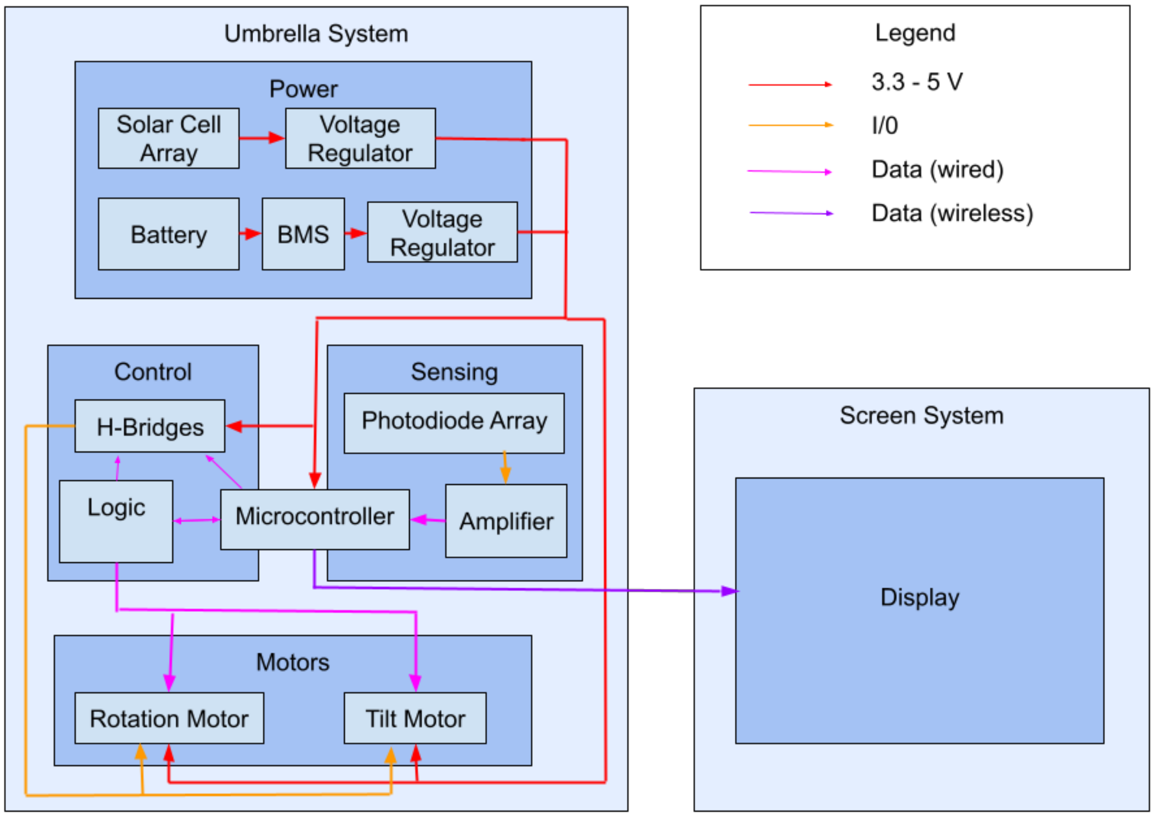
2

$R = kE^{-y}$

- Proportionally, the change in resistance indicated a 3.7 times difference in illuminance.
- I rounded up to about a minimum 5 times difference in illuminance since photodiodes in an enclosure will be more sensitive.

## Sun Tracking Umbrella: Design

**Block Diagram:**




**Subsystem Overview:**

The **Sensing** subsystem consists of the photodiodes placed on the outside of the umbrella, an amplifier to accurately obtain differences in intensity from the photodiodes, as well as other logic that will be implemented in order to communicate with the control subsystem to rotate and move the umbrella according to the photodiode light input. This subsystem will also communicate directly with the microcontroller to provide light intensity data as well as receive movement information should it be provided from the remote user interface.

The **Motors** subsystem consists of the two motors responsible for rotating the umbrella around the vertical axis as well as tilting the umbrella to the optimal angle for maximum shading. This subsystem gets its power from the solar cell array in combination with the backup battery supply from the power subsystem. The input needed to move the motors to their respective positions comes from the control subsystem, particularly the H-Bridges that are used to control the individual motors.

The **Control** subsystem consists of the microcontroller, any necessary logic, and the two h-bridges that control the movement of the motor subsystem. The components of this subsystem get their power from the power supply subsystem as needed, and communicate with one another to effectively control the motors to ensure optimal positioning. The H-Bridges then provide the motor subsystem with data that tells the motors where to move while the logic component confirms accurate movements in accordance with the data obtained by the sensing subsystem.

The **Power Supply** subsystem consists of all of the elements responsible for providing power to the other subsystems, which includes the solar cells, backup battery, and voltage regulators. The main goal of this subsystem is to utilize the solar cell array to power all of the subsequent subsystems, with the battery as a backup that is able to be charged by the solar cell array in case of low power intake from the solar cell array. This subsystem then must disperse the power obtained to the sensing, controls, and motors subsystems as these all require some form of 5V or lower voltage supply to operate.

The **Display** subsystem will consist of (a small amount of) software that uses the microcontrollers built in communication capabilities to display recorded data and includes the user interface. This subsystem will allow the user to manually override the autonomic movements of the motors based on incident light, allowing for full control of the system should a different position be desired.

**Subsystem Requirements:**

Sensing

The sensing subsystem must be able to detect differences in light intensity to send data to the control subsystem so that it knows how to move the drivetrain & motors. Requirements include a) the ability to detect differences in light intensity as small as ten times differently between 90 degree and 45 degree incident light b) the ability to scale signals gained from the photodiode array in order to set it between 0-3.3V proportionally (in order for it to be a valid input to our microcontroller) c) the ability to send the necessary information to the microcontroller, allowing for further manipulation of the system.

Motors

Motors are able to turn a finite amount at a time and hold their position when still. Requirements include a) the ability to maneuver the umbrella to tilt 45 degrees in any direction down from the z axis and b) the ability to twist 360 degrees around the center axis at the base and c) the ability to hold any given position until a manual override or new data from the photodiodes.

Control

Receives signals from the photodiode subsystem and properly turns relevant motors on and off based on those signals. Requirements include a) the ability to transmit data to the motors in less than a second (~10 nanoseconds to move 6 feet) b) the ability to accurately process incident data from the sensing subsystem to provide data to the motors to move the umbrella 5 degrees at a time (to be confirmed the capabilities of the motor recommended by the machine shop in our meeting next week)

Power Supply

Properly regulates voltage and is able to switch between voltage sources as needed. Requirements include a) the ability to provide subsequent subsystems with a 3.3 - 5 V and up to 20 A power supply as well as b) the ability to switch between utilizing the solar cell array for power supply and the backup battery supply.

Display

Displays user friendly data. User interface allows for remote control of the umbrella motors, overriding sensor input from photodiodes. Gains wireless data via UART transmission from microcontroller and provides data back to the microcontroller via the UART receiver line. Requirements include a) the ability to display accurate data as obtained by the sensing subsystem and b) the ability to transmit user input to manually override sensor input.

**Tolerance Analysis**

An aspect of our design that may be difficult to implement is the power generation from the solar cell array. There are many options available for the type of solar cell that is utilized for this device, including cells that can provide up to 5V and 200mA of current per cell (Solar Cell), making for a solid power generation even when there is minimal sunlight available. With 10 of these solar cells in parallel and a voltage amplifier, one can produce 2A of current, allowing for us to charge a battery supply continuously, then allowing for the battery to supply power to the motors which will likely require around 20A for 5 Nm of torque at a maximum of 45 degrees with the center of gravity being around 0.5m away from the rotating joint. With the solar cell array charging the battery, and the battery powering the motors, one doesn’t need to worry about the current being high enough from the solar cell array to directly power the motors.

## Sun Tracking Umbrella: Ethics and Safety

The only ethical issue that could arise from this project is IEEE I.1 and II.9, both in accordance with keeping the safety of others at the forefront of the mind. To ensure no ethical breaches we will ensure maximal safety precautions. Our main safety concerns are mechanical, and we will therefore be assisted in upholding the safety of the device by speaking with the machine shop and taking into account the expertise they have in mechanical design. We are mainly considering harsh motions of the umbrella, whether that be closing unexpectedly or moving too quickly. These can be worked on in software and ensuring the motor spins at a reasonable pace as well as integrating a warning light to show the users that the umbrella is about to turn so they can be best prepared. Another concern in ensuring that the holding torque of the tilt motor is high enough to avoid the umbrella falling. To combat this we will include mechanical stops alongside our software cues to be positive there is no possibility of the umbrella falling on the user.

Additionally, since our project is meant to be used in the Sun we wanted to consider the possibility of overheating. We will consider all of our subsystems individually for this. We have no concern with the solar cells or photodiodes for overheating. These components are meant to be in the Sun, and the photodiodes will be protected from overexposure with their enclosures. The rest of the components are susceptible to overheating, however we will ensure that they are shaded by the umbrella and have additional software to ensure that the system shuts down or gives the user a warning when the components are close to overheating.

Overall, we believe that through a few extra components we can keep the overall project entirely safe and ethical under all circumstances. We will discuss more safety criteria for the mechanical components with the machine shop next week.