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Evaluation Conclusions

Conclusion #1: Does the prototype collect enough energy to power the shade? And if not- How many solar panels are required to power the shade for 1 hour on a sunny day?

The prototype, as tested under real-world conditions, does not collect enough energy to power the shade for sustained operation. In order to power the shade for 1 hour on a sunny day, additional solar panels are required. Analysis of the solar panel's power output during a sunny day yielded an average maximum power output of 0.77W over two hours. This is evident looking at the chart presented in Fig. 1.

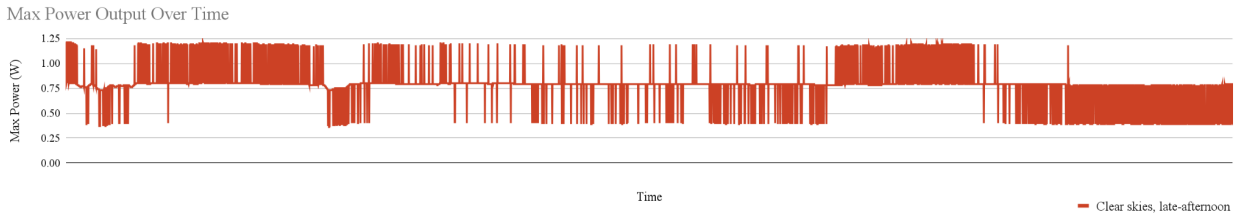

Fig. 1. Max power output over time with clear sky conditions during late afternoon

The shade's motor, based on photoresistor data, requires an average of approximately 3.78W per hour to execute necessary movements for optimal positioning.

To calculate the number of solar panels required, we can compare the power generation of a single solar panel with the power demand of the shade's motor for one hour. Considering the theoretical maximum power output of 1.25W/hour by a single solar panel under similar conditions, it is evident that this amount is insufficient to power the shade for one hour. To ensure adequate power supply for the shade's motor on a sunny day, the solar panels need to be scaled up to meet the power demand. Based on the data, the system would require a minimum of four solar panels, each with a similar output to the tested panel, to achieve the required power generation of approximately 3.78W/hour.

Therefore, to achieve sustained functionality and power the shade for one hour on a sunny day, the system must be equipped with a minimum of four solar panels, covering a total surface area of approximately 154cm^2. With this new configuration, the solar-powered prototype would be able to effectively operate the shade using solar energy.

Conclusion #2: Does the shade shape provide sufficient coverage for the majority of users?

The solar shade prototype has demonstrated promising coverage potential for adult wheelchair users based on preliminary user testing involving five university students with heights ranging from 5'4" to 6'0". A sample image of this user testing is provided in Fig. 2.

Fig. 2. Sample image of user testing with a 6’0” male

The shade's dimensions, 18" in length and 12" in width, resembling a long hexagon provide effective face coverage, offering protection from direct sunlight. The placement of the shade on top of the tube using elbow joints, as seen in Fig. 3. has been successful in not obstructing the user's body while maintaining the center of revolution above the user's head.

Fig. 1. Complete Prototype with acrylic tube

This contributes to the shade's functionality, ensuring unimpeded mobility while providing sufficient shade. Furthermore, user feedback suggests that incorporating adjustable tube segments offers enhanced usability and customization. The possibility of adjusting the tube segments allows users to tailor the shade's position to their specific needs, maximizing comfort and protection based on diverse lighting conditions and individual preferences.

Further evaluation with a larger and more diverse sample of adult wheelchair users is recommended to validate the shade's coverage effectiveness across the entire target user group. Additionally, obtaining feedback from experienced wheelchair users in real-world scenarios will provide invaluable insights for refining the design and optimizing the shade's performance for maximum usability and user satisfaction.

Design Loop Feedback

Insight #1: Impact of Wire Length on Motor Power Delivery

July 28, 2023

Evidence: During the testing of the shade's working prototype, thin wires with a total length of over one meter were used to connect the motor from the back of the wheelchair to the shade. However, the motor exhibited vibrations and remained unmoving during operation. It was hypothesized that the lengthy wire was causing excessive resistance, thereby reducing the current flow into the motor [1]. Further research indicated that wire resistance can be influenced by various factors, including temperature, thickness, and material.

Recommended Action: Optimize Wire Quality and Length

To address the issue observed in the testing and prevent potential wiring problems in future prototypes, it is crucial to consider wire quality and length carefully. When long wires are required to connect components that draw significant power, using thicker wires is recommended. Additionally, ensuring that wires are maintained at cooler temperatures is essential. To achieve this, it is advised to use hollow reflective pipe with strong UV resistance, such as white PVC pipe, instead of clear acrylic pipe for the rod. This will help prevent overheating in sunny conditions and improve the efficiency of power delivery to the motor.

Insight #2: Improved tools for orienting motor

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Evidence: The 28BYJ-48 motor lacks a programmatic center point [2], making it challenging for the shade to reset itself to a neutral position automatically. As a result, the shade's motor position cannot be accurately remembered or known without an external pin or physical component. In the current prototype, there is no user interface to set a "home" position for the shade.

Recommended Action: Provide a physical home component for the motor, and a corresponding user interface.

In future iterations of the prototype, a physical pin or component that serves as a reference "home" position for the shade should be provided. This will allow the motor to reset itself to a known starting point, providing users with a consistent position when the shade is not active.

Additionally, we must ensure that the "home" position prevents the shade from over rotating out of the user's vertical space, thereby avoiding potential collisions with pedestrians or obstacles. The home position should prevent the device from over rotating and pulling out the wires that run along the length of the shade, enhancing the overall safety and longevity of the system.

Incorporating an additional user interface such as a button or lever that enables users to manually reset the position of the shade before turning off the product should be implemented. This will offer users greater control over the shade's orientation, allowing them to set it to the desired neutral position based on their preferences and needs.

References

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[2] Last Minute Engineers, "In-depth: Control 28BYJ-48 stepper motor with ULN2003 Driver & Arduino," Last Minute Engineers, https://lastminuteengineers.com/28byj48-stepper-motor-arduino-tutorial/#:~:text=approximately%202038%20steps).-,Power%20Consumption,rather%20than%20from%20the%20Arduino. (accessed Jul. 15, 2023).

[3] Brainy-Bits, "How to set the home position of a Stepper at startup!," Brainy, https://www.brainy-bits.com/post/how-to-set-the-home-position-of-a-stepper-at-startup (accessed Jul. 20, 2023).