WINDOW AUTOMATED NATURAL DAYLIGHT ASSISTANT (WANDA)

ACCESSIBLE SMART HOMES

A Thesis Prospectus
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The Faculty of the
School of Engineering and Applied Science
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In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Computer Engineering

By
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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

Signed Kwadwo Tenkorang Date: November 2, 2020

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The growth of smart home products has brought many benefits in the home by simplifying many tasks through automation. A study by Stojkoska and Trivodaliev (2017) surveyed thousands of scholarly articles showed a significant increase in academic research into smart home technologies (p. 1456). Much of this automation has been accomplished by incorporating standalone devices to automate everyday household products from thermostats to doorbells. While many of these smart devices simply make tasks more convenient for most users, they can also serve to make previously inaccessible tasks accessible to some groups of individuals. This can be of incredible benefit to disabled and elderly individuals who have barriers to engaging in everyday activities around the home. Although these groups can experience many benefits from these devices, they can also be set back by them when these devices are not designed with accessibility in mind. The overall research motivation of this thesis is to determine underlying issues with developing smart home tech for elderly and disabled and determine possible solutions.

The technical project seeks to create a device to allow for automation of a household window blinds. The STS topic will be loosely coupled to the technical project and seeks to explore assistive technologies for disabled and elderly individuals and answer the research question: To what extent do smart home technologies improve the quality of life of disabled and elderly individuals and how can these technologies be made more accessible? Both of these projects will be completed over two separate timelines. The technical project will be done over the course of one semester as detailed int the Gantt chart shown in Figure 1 on Page 2 shows the major deliverables. The STS research project will be done over the course of an academic year.

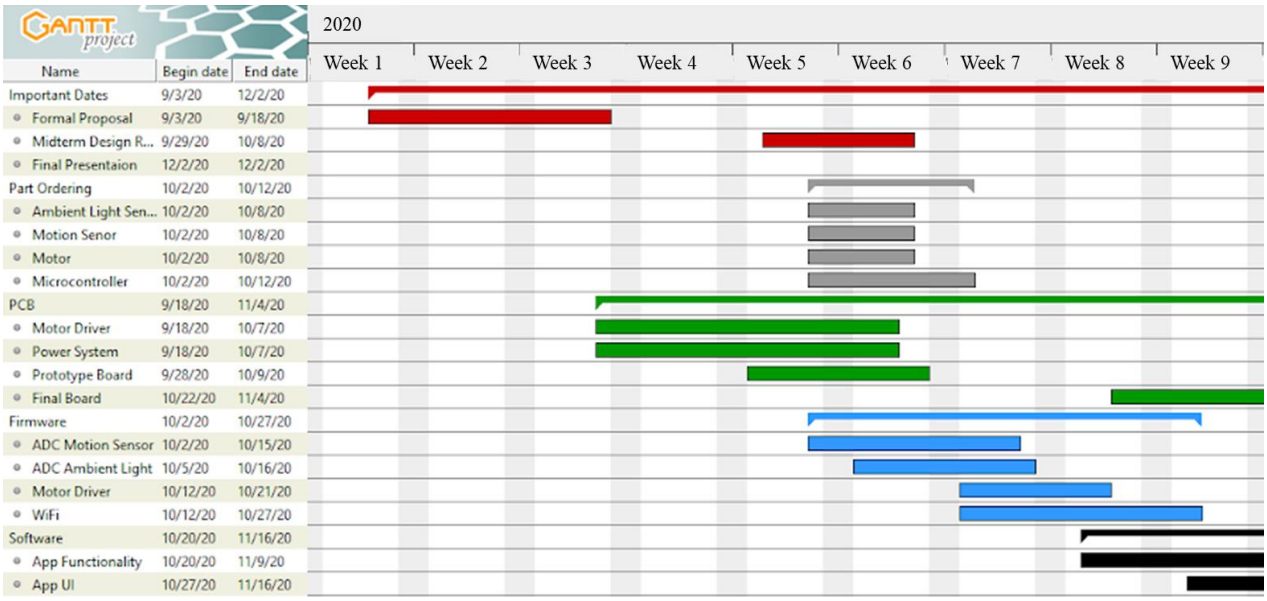

Figure 1: Gantt Chart for Technical Project. A Gantt chart that presents a timetable that indicates the major deliverables for the technical project. (Tenkorang, 2020)

EMERGENCE OF THE SMART HOME

Emerging “smart home” products ease the life of many homeowners and have affected many different aspects of the living experience. Though it might not seem as important as some of the other products, window blinds can also be improved. It is hassling to some people to constantly open the blinds during the day and close them during the night, especially disabled or elderly individuals. However, people need sunlight to improve their mood throughout the day, which demonstrates the need for automatic window blinds. In 2016, An, Colarelli, O'Brien, and Boyajian studied the effects of sunlight on the mental health and attitudes of employees. Their work found that natural sunlight positively affected commitment and satisfaction, while diminishing depressed and anxious moods. This study showed that exposure to natural elements reduced levels of anxiety, depression, reduced mental fatigue and reduced the impact of stress (p. 1). Thus, reducing any barriers to natural sunlight in a living space can have benefits everyone.

In academia, previous work has been done to introduce a method to either upgrading or replacing blinds. Although some groups such Taufik and Hasanah (2018) have attempted to use a

create smart blinds by changing the blind tilt based on light intensity, there have been few attempts to modularize the system to make it applicable to any window blind (p. 2). Karmakar et al (2017) at the Federation University Australia suggested the approach of adding and automating an exterior awning, exterior blinds, and interior curtain to conserve energy optimally during each season (p.487). Conversely, Alghamdi and Almawgani (2019) at Najran University IN Saudi Arabia proposes to remove blinds and change the glass of the window to Polymer Dispersed Liquid Crystal (PDLC) glass which can vary between transparent and opaque due to the amount of sunlight (p. 2). The aforementioned systems present various methods toward reducing energy consumption, but improvements could be made for the overall design, installation process, and additional functionality.

Our proposed system is a unique design that primarily focuses on modularity while still providing the additional benefit of optimal lighting through automation to conserve energy. The implementation of a modular device that attaches to a window. Specifically, when the sunlight levels change, the stepper motor will be activated to open or close the blinds. Unlike most prior designs, the proposed prototype will be a simple replacement of the wand and arrangement of the motion sensor for simple installation.

PROJECT DESCRIPTION

The smart window blind is a universal attachment that mounts to most household window blinds wand and will regulate the amount of light entering a room by turning the wand accordingly. The system has four primary subsystems: sensing, actuation, communication and power. These systems work together in order to properly calibrate, sense, actuate and control the system as a whole. All of these systems will be coordinated using a microcontroller.

Sensing

Sensing is broken up into two main components: ambient light and motion sensing. An ambient light sensor will be used in order to detect how much light has entered into a room. There are a few configurations of light sensors that will allow the best detection of light. Simple tests can be done between location and number of ambient light sensors in order to determine which configuration works best for the system. The other sensor needed is the motion sensor in order to detect if someone walks in front of the window. This will be achieved using a motion sensor similar to a PIR sensor which, Gami (2017) states is commonly used in many motion detection systems (p. 1).

Actuation

Actuation for the system will primarily be done using a stepper motor because of its high torque at lower speeds and the team's familiarity with programming it in an embedded course.

Communication

Communication is separated into two main options: physical device and mobile application. In order to ensure the system can be properly calibrated and configured, the device will have physical buttons that will allow the user to properly determine which settings they want in place. These buttons will act as inputs to the embedded system and allow changes to be made directly to the functionality of the blinds. The second mode of communication will be done over Bluetooth using a mobile app. Bluetooth was chosen as the preferred mode of wireless communication because of its low power consumption and wide availability and adoption. A Bluetooth module will be integrated into the system to allow the CC3200 microcontroller to communicate bidirectionally between the physical system and the mobile app.

Power

In order to deliver power to the various subsystems, a persistent power supply will need to be designed to ensure that each component will work properly. A rechargeable battery will be used to deliver the necessary power for each component.

The major subsystems will be all connected to and controlled by a microcontroller as demonstrated in figure 2.

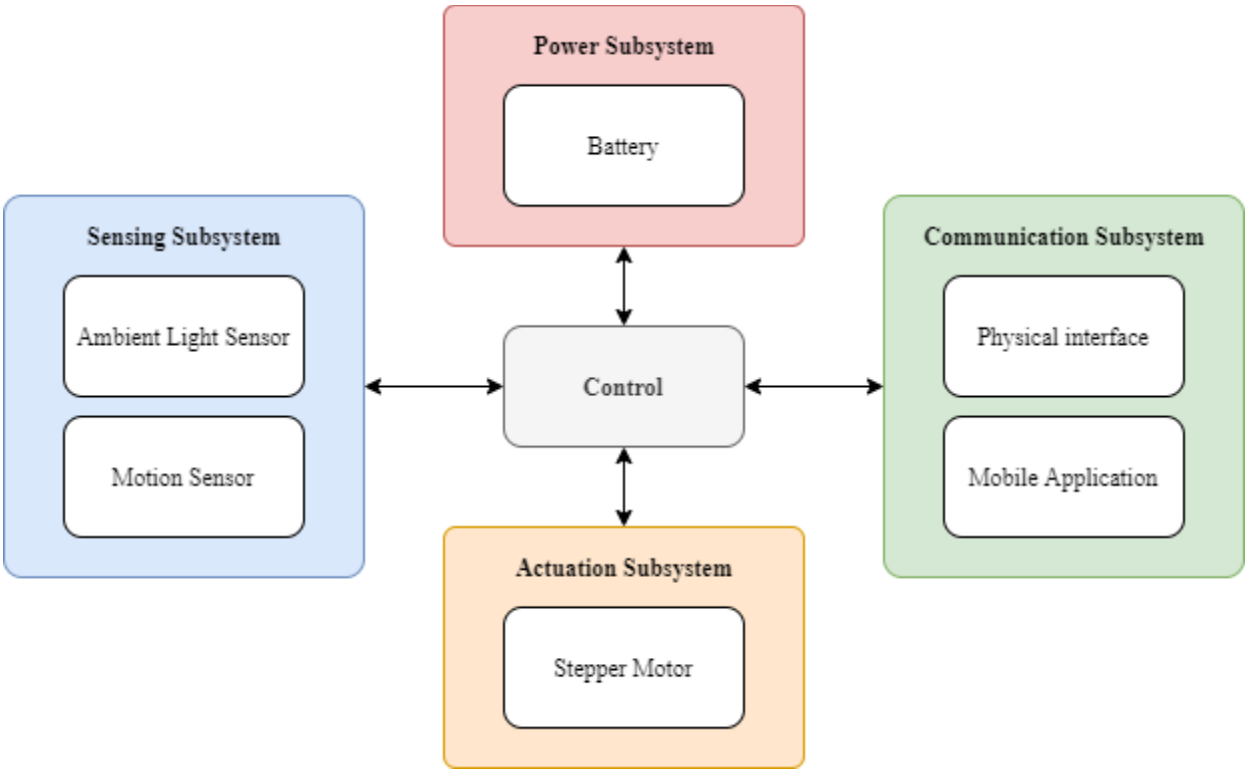

Figure 2: WANDA Subsystems. A block diagram showing the major subsystem of the physical product: Sensing, Actuation, Communication and Power. (Tenkorang, 2020)

PROJECT LOGISTICS

The design process for this project will make use of various simulation software and test-driven prototyping approaches. The project will last for one semester and the advisor will be Harry C. Powell, a faculty member of the Charles L. Brown Department of Electrical and Computer Engineering. Financial support for the project will be provides solely through the department and there will be no external clients. Available resources for the project include the

National Instruments (NI) Laboratory which includes tools for soldering, designing and prototyping solutions. Additionally, there is access to 3D printers across grounds and a local company called WWW Electronics Inc that can provide custom PCB soldering services. The technical project will culminate in a physical product as well as a conference style paper.

IMPACT OF SMART HOMES ON DISABLED AND ELDERLY INDIVIDUALS

Applications of smart window blinds and other smart home technologies have the potential to be of great benefit to many different stakeholders. The STS topic will be loosely coupled to the technical project and seeks to explore assistive technologies for disabled and elderly individuals and answer the research question: To what extent do smart home technologies improve the quality of life of disabled and elderly individuals. According to El-Basioni, Sherine, and Husseein (2014), the population over age 65 was 14% in 2010 and 16% live with disabilities. As a result, many governments see smart homes as a way to offset the financial costs of caring for elderly and disabled individuals (p. 11). This presents the opportunity to explore the intersection of technology and disability. A common finding of studies about this intersection is exposing the mindset that all technology is good and helpful for these individuals. According to Blume, Galis, and Pineda (2014) "Technology is often cast as an instrument for redressing disability, but sometimes technology may stand in the way"(p. 100). Thus, a holistic analysis is needed to design smart homes to assist these groups similar to the approach taken by Drewsbury et al. (2003) to uncover the hidden difficulties of designing smart home technologies for elderly and disabled groups (p. 192).

APPLYING SOCIAL CONSTRUCTION OF TECHNOLOGY (SCOT)

The hidden difficulties are what makes it so challenging to design effective smart homes for elderly and disabled individuals and why more research in this area is needed. Drewsbury et al. (2003) make a compelling argument that through the interrelatedness of technology and disability, ineffective technology can actually be disabling (p. 191). As designers and engineers go immediately to technology as the solution to obstacles faced by elderly and disabled individuals, they often neglect to address the social and environmental issues which are at the core of the obstacles faced. This is a clear demonstration of what Rifkin (1985) would describe as a mechanical worldview in which technology is seen as the ultimate solution to all problems. The mechanical worldview elevates technological process as the primary means of eliminating flaws in everyday life (p. 19). This worldview can fuel engineers to over emphasize technological solutions to barriers faced by elderly and disabled individuals while overlooking other viable nontechnical solutions. A natural result of this world view is the idea that technology is deterministic and dictates the how societies will form around that technology. Thus, the Social Construction of Technology (SCOT) approach by Pinch and Bijker (1987) will be useful in deconstructing this view in order to determine underlying barriers to technology for elderly and disabled individuals as well as solutions similar to how Figure 3 on Page 8 uses SCOT to determine the relevant social groups and potential problems of a new technology.

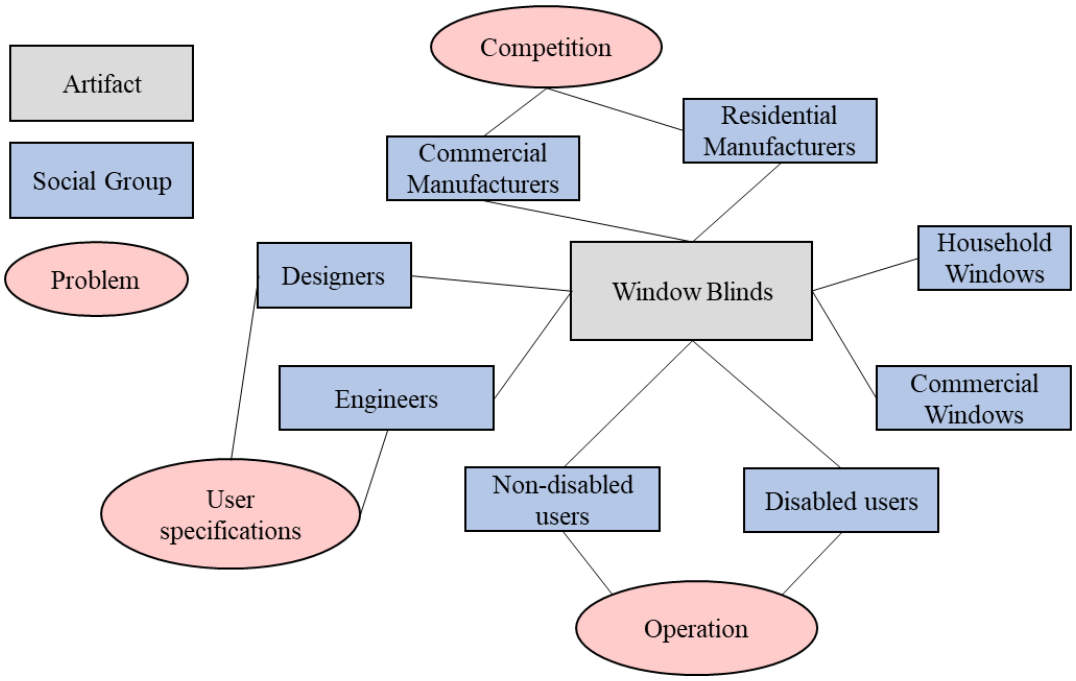

Figure 3: Window Blinds Groups and Problems. A diagram applying SCOT to the artifact of window blinds to determine the relevant social groups and some problems faced by them. (Adapted by Kwadwo Tenkorang (2020) from Pinch and Bijker 1987).

Applying SCOT will allow for an in-depth analysis the social groups impacted by smart home technologies, particularly around elderly and disabled individuals and how their changing interpretation of technological artifacts have helped shape those artifacts. According to SCOT, different social groups develop different meanings to technologies leading to interpretive flexibility of a technology. Smart home technologies can mean different things to different groups of users. For everyday users without any disabilities, these technologies are a luxury used for convenience and not a necessity. By using interpretive flexibility to break down how different groups view smart home technology, a deeper analysis can be done into the needs of these groups. By breaking down the problem this way, a possible set of solutions an be more effectively found as demonstrated in Figure 4 on Page 9, where possible solutions to the problem of turning a blind wand is shown.

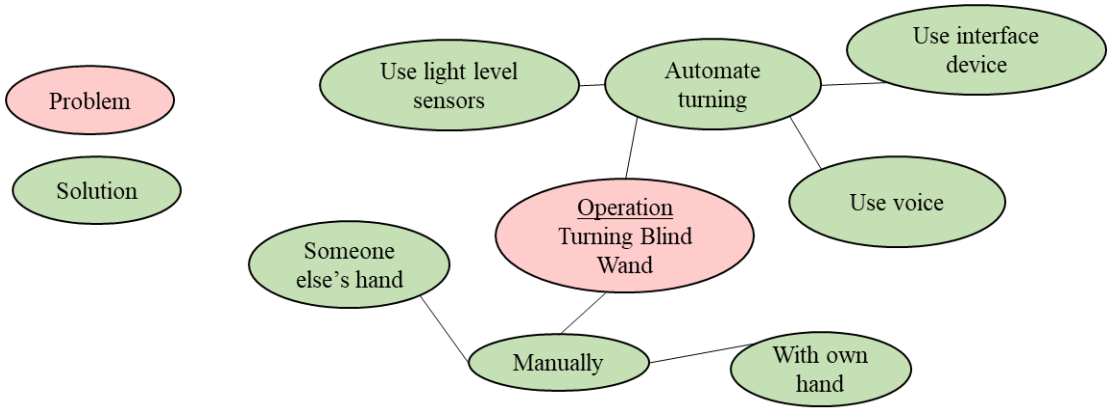

Figure 4: Window Blind Problem and Solutions. A diagram applying SCOT to the problem of operating a window blind and posing possible solutions. (Adapted by Kwadwo Tenkorang (2020) from Pinch and Bijker 1987).

The outcome of the SCOT analysis will provide insights into the underlying issues that make designing spaces for elderly and disabled individuals so difficult as well as uncover possible solutions that holistically address those issues across various social groups. The overall paper will be constructed as an issue analysis that leverages SCOT to determine the current state of smart home technology for elderly and disabled individuals.

REFERENCES

Alghamdi, H., & Almawgani, A. H. M. (2019). Smart and efficient energy saving system using PDLC glass. *2019 Smart City Symposium Prague (SCSP)*, 1–5. https://doi.org/10.1109/SCSP.2019.8805731

An, M., Colarelli, S. M., O'Brien, K., & Boyajian, M. E. (2016). Why we need more nature at work: Effects of natural elements and sunlight on employee mental health and work Attitudes. *PLOS ONE*, *11*(5), 1-17. https://doi.org/10.1371/journal.pone.0155614

Bijker, W., Hughes, T. P., Pinch, T. J. (1987). The social construction of technology systems. Cambridge, MA: MIT Press.

Blume, S., Galis, V., & Pineda, A. V. (2014). Introduction: STS and disability. *Science, Technology, & Human Values*, *39*(1), 98–104. https://doi.org/10.1177/0162243913513643

Dewsbury, G., Clarke, K., Rouncefield, M., Sommerville, I., Taylor, B., & Edge, M. (2003). Designing acceptable "smart" home technology to support people in the home. *Technology & Disability*, *15*(3), 191–199.

El-Basioni, B. M. M., El-Kader, S. M. A., & Eissa, H. S. (2014). Independent living for persons with disabilities and elderly people using smart home technology. *International Journal of Application or Innovation in Engineering & Management (IJAIEM) 3*(4), 11-28.

Gami, H. (2018). Movement direction and distance classification using a single PIR sensor. *IEEE Sensors Letters*, *2*(1), 1–4. https://doi.org/10.1109/LSENS.2017.2782179

Garland, S. (2020, June 5). Did mom take her medicine? Keeping eyes on elders in quarantine—*The New York Times*. The New York Times. https://www.nytimes.com/2020/06/05/business/elderly-health-quarantine.html

Karmakar, G., Roy, S., Chattopadhyay, G., & Xiao, Z. (2017). Dynamically controlling exterior and interior window coverings through IoT for environmentally friendly smart homes. *2017 IEEE International Conference on Mechatronics (ICM)*, 487–491. https://doi.org/10.1109/ICMECH.2017.7921156

Ravneberg, B., Söderström, S. (2017). *Disability, Society and Assistive Technology*. Routledge. https://doi.org/10.4324/9781315577425

Rifkin, J., & Howard, T. (1985). The machine age. In *Entropy: A new world view* (pp. 18-19). London: Paladin.

Risteska Stojkoska, B. L., & Trivodaliev, K. V. (2017). A review of Internet of Things for smart home: Challenges and solutions. *Journal of Cleaner Production*, *140*, 1454–1464. https://doi.org/10.1016/j.jclepro.2016.10.006

Roulstone, A. (2016). I'm not sure we've been introduced: Disability meets technology., *Disability and Technology: An Interdisciplinary and International Approach* (pp. 87–121). Palgrave Macmillan UK. https://doi.org/10.1057/978-1-137-45042-5_3

Taufik, T., & Hasanah, R. N. (2018). Light sensing smart blinds. *2018 Electrical Power, Electronics, Communications, Controls and Informatics Seminar (EECCIS)*, 1–4. https://doi.org/10.1109/EECCIS.2018.8692805

Tenkorang, Kwadwo. (2020. *Gantt Chart for Technical Project*. [1]. Prospectus (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Tenkorang, Kwadwo. (2020. *WANDA Subsystems*. [2]. Prospectus (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Tenkorang, Kwadwo. (2020. *Window Blind Groups and Problems*. [3]. Prospectus (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Tenkorang, Kwadwo. (2020. *Window Blind Problem and Solutions*. [4]. Prospectus (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.