2020 Vision: Wearable Haptic Ultrasonic Object Detector

(Technical Paper)

The Role of Human-Centered Design in Humanitarian Engineering

(STS Paper)

A Thesis Prospectus Submitted to the

Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements of the Degree
Bachelor of Science, School of Engineering

Renee Lin Mitchell
Spring, 2020

Technical Project Team Members
Joshua Raphael Arabit
Jazlene Rae Guevarra
William Tiger Zhang

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

Introduction

According to the World Bank Group, 736 million people around the world live in extreme poverty (The World Bank Group, 2019). Many humanitarian groups and non-profit organizations have tried their hand at tackling this plague, and the world has seen mixed outcomes as a result. On one hand, there are certainly remarkable benefits of intervention and resource allocation that help enable upward mobility for the currently impoverished. However, this collective effort to usher in the end of poverty has begged the question of what constitutes a successful solution for impoverished communities. As such, the research question for the science, technology, and society (STS) portion of this proposal is as follows: To what extent does human-centered design (HCD) increase the effectiveness and impact of humanitarian engineering?

The technical portion of this proposal functions as a case study of the STS topic by integrating HCD into the project. The final product is 2020 Vision, a device that detects potential collisions in the users' blind spots and notifies them accordingly. The motivation is to accommodate the visually impaired, so that they may partake in everyday activities such as walking with alleviated fear of having a collision. Of course, the use of 2020 Vision is not limited to accommodating clinical disabilities. For anyone who wishes to be notified of potential incoming collisions, such as a baseball about to hit one's head, 2020 Vision is very advantageous. Overall, this proposal explores the effectiveness and impact of HCD in the context of developing an object detection device as well as in humanitarian engineering.

Technical topic (capstone)

Disabilities of any form are a significant hindrance to performing simple tasks on a day-to-day basis, which often leads to feelings of inferiority. Visual impairment is particularly grievous due to its alienating nature and how it affects physical mobility. With this prevalent issue at hand, the team, consisting of Jazlene Guevarra, Joshua Arabit, William Zhang, and Renée Mitchell, is inspired to start a project that aims to ameliorate the lives of those who are visually impaired.

As precedent for the project, one may consider the plethora of research papers in the field of autonomous vehicles, and how this topic necessitates the study of obstacle detection. For instance, engineering has seen the development of robots with the ability to identify objects as well as humans, for the purpose of navigating office settings and performing basic tasks. One such example is an autonomous system that aids nurses in hospitals by helping with bed transports (Kovala, 2015). Similarly, engineers create electromechanical surveillance systems that likewise need to deploy object recognition techniques, even if those systems are not mobile. In military applications, the continuous tracking of objects through image processing serves an important role in establishing security measures (Gade & Wanare, 2014). An example of such image processing algorithms involves hyperspectral imaging, which finds anomalies in order to detect objects of significance that "stand out from the cluttered background" (Ke, 2018).

While there have undoubtedly been a lot of projects around the world that produce wearable systems to aid the visually impaired (Ramadhan, 2018; Dionisi, Sardini, & Serpelloni, 2012), this particular project is significantly simpler and more straightforward to use. Furthermore, what sets this project apart from previous projects is its use of haptic feedback that responds not to human touch, but rather to object detection. More specifically, if the device detects an approaching object with its ultrasonic signals, haptics will communicate the potential upcoming collision. Moving objects within a minimum distance threshold of 30 centimeters, calculated using an algorithm programmed in the Texas Instruments MSP430G2553 microcontroller, will trigger the vibration motor to draw attention to the hazard.

In short, the project 2020 Vision involves the design and production of a wearable device that communicates using haptic feedback concerning approaching objects in the user's environment. The driving microcontroller will perform the necessary calculations and power the embedded system. Users will wear this device during their daily routines to be notified of dangers in their environment, increasing situational awareness. A group of four people advised by Professor Harry Powell will finish manufacturing the device, presenting the project poster, and authoring the corresponding technical report by the end of the Fall 2019 semester. Mitchell is in charge of the printed circuit board design, Arabit is in charge of system integration and interfacing the software with the hardware, Guevarra is in charge of the test plan and overall device design, and Zhang is in charge of the software and algorithm design.

STS topic

In a world with "strong demand from crises prone regions for the voice of affected communities to be heard," effective design thinking frameworks such as HCD are essential to the long-term success of humanitarian engineering projects (European Union, 2015). The definition of HCD is a "systematic approach to problem solving that is human-centered, that is, the problem and its solution is [*sic*] defined with the user in mind" (Naval Postgraduate School, 2017). The essence of HCD is that each design stage must prioritize the needs and desires of the end users of the engineered system; as such, the designers engage the clients in each design stage to help ensure that the resulting system will meet their needs to the fullest extent possible. HCD is therefore highly valuable in humanitarian projects and is germane to their sustainability.

Given the context of technological momentum as an informative STS theory for this topic, it is important to consider how the user shapes the HCD process, and vice versa. After all, engineers who successfully create a technically proficient system for a society that does not or cannot use it could arguably evaluate the overall system as unsuccessful in meeting the needs of its end users. Counterinterpretations to the theory of technological momentum include the social construction of technology (SCOT) as well as technological determinism, both of which portray the relationship between technology and society as one-way processes. Both function as critiques since they do not weigh social and technical factors equally; however, in HCD, the social and technical factors are so intricately weaved into the design process that neither of the counterinterpretations make sense apart from each other. If the technology has more weight than the end users (which this proposal argues is the status quo), then the design will not fully benefit the users. Similarly, SCOT posits that the end users drive the development of technology without considering how the design in turn motivates the society to further enhance the system.

For instance, humanitarian projects have addressed a wide range of problems faced in various impoverished communities. When designing public services, designers often “fail to inquire into human experiences and human interaction,” especially when deterministic management approaches emphasize technological advancement over meeting clients’ needs (Junginger, 2018). Even worse, the solutions that designers implement often fail after a short term period. As the society that uses those solutions encounters new hardships, its members don’t know how to address them and ultimately cannot develop independently (Freire, 1972). Therefore, it is imperative that engineers conducting humanitarian projects design self-reliant, sustainable solutions to ensure a lasting impact on the end users, who are active participants in the process (Godfrey, 2014). HCD significantly contributes to this aim by incorporating empathy into every stage of the design cycle, as well as giving end users project ownership and practical life skills (Pick & Sirkin, 2010). In this manner, technological momentum is harnessed in a way that ensures positive feedback between the technology and the society.

In an article for the *Sustainability* journal, three members of the engineering faculty at the University of Colorado at Boulder discuss the importance of community development in humanitarian projects. Such societal enrichment follows partnership with the community and entails “education, training, empowerment and the integration of economic mechanisms to ensure long term success” (Amadei, Sandekian, & Thomas, 2009). The European Union agrees with this principle, adding that there have been plenty of innovative humanitarian engineering projects enforced without giving thought to their sustainability (European Union, 2015). Additionally, the notion of empowerment is imperative to humanitarian projects, and it is one that HCD addresses well. Otherwise, if engineers focus on resolving technical problems without actively engaging the community in both the process of the project and preparations for project continuation, the result includes “improperly ‘solved’ problems, unanticipated impacts, and alienation of the community” (Bergeron et al, 2019). As such, the potential of HCD to render a humanitarian project sustainable is twofold: it emphasizes the design of a system that is catered specifically to the end users, and it empowers them by transferring ownership of the project to them, having trained them to expand upon its functionality for generations to come.

Research Question and Methods

The research question is as follows: To what extent does human-centered design increase the effectiveness and impact of humanitarian engineering? The following methods shall aid in the pursuit of answering this question: documentary research, historical case studies, and interviews. Documentary research is invaluable because of the philosophy-level content that many engineers and technical historians have addressed through reports and books, and there are many research papers on HCD and humanitarian projects available. To complement those papers, companies such as IDEO.org have published stories that exemplify the use of human-centered design in the context of humanitarian engineering, which will serve as historical case studies (IDEO.org, n.d.). Finally, interviews with faculty at the University of Virginia (UVA), as well as with leaders in service organizations such as Engineers Going Global and Habitat for Humanity, will greatly contribute personal narratives to the research documentation. David Chen, Instructor in Design, as well as students who work in his lab, are candidates for interview. PhD students in the Link Lab are also candidates for interview, such as John Lach's smart health group since its members value the active participation of end users in ongoing projects. These interviews will be tremendously helpful since the proposal evaluates the effectiveness of human-centered projects in making a positive difference in the lives of their beneficiaries. The research for this question will be complete by the end of the Spring 2020 semester.

Conclusion

The anticipated deliverable for the technical portion of this thesis is a device, 2020 Vision, that will detect incoming object collisions and notify the user ahead of time using haptic feedback. The purpose of 2020 Vision is to help improve the lives of those who are susceptible to collisions, such as those who have visual impairment and want to be notified of hazards. The

HCD component of this portion relates well to the STS topic, which consists of a thorough exploration of how the engineering design process, as seen through HCD, helps mitigate the effects of poverty.

The STS research culminates in a paper that investigates the given question with respect to the theory of technological momentum. Overall, the goal of this proposal is to serve as a call to action for engineering students to use the technical skills that they have been incredibly privileged to learn at UVA in ways that enrich the lives of those with no access to similar educational benefits. HCD is an excellent starting point for this discussion because it naturally encourages the transition from pity to compassion, and integrates that mindset into every step of the engineering design cycle.

References

Amadei, B., Sandekian, R., & Thomas, E. (2009). A Model for Sustainable Humanitarian Engineering Projects. *Sustainability*, 1087-1105. doi:10.3390/su1041087

Bergeron, C., Hargrove, A., Tramontana, B., Steyer, J., Adoue, E., Davison, D., . . . Lima, M. (2019). Design for the Soul of the Community: Using Community-based Design Principles. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship, 14*(1), 47-59.

Brown, T. (2015, July 7). Design Is Our Answer: An Interview with Leading Design Thinker Tim Brown. (C. Luebkeman, Interviewer). Retrieved from https://doi.org/10.1002/ad.1922

Dionisi, A., Sardini, E., & Serpelloni, M. (2012). Wearable object detection system for the blind. *Conference Record - IEEE Instrumentation and Measurement Technology Conference*. doi:10.1109/I2MTC.2012.6229180

European Union. (2015). *Towards more effective global humanitarian action: How the EU can contribute.* London: European Parliament.

Freire, P. (1972). *Pedagogy of the Oppressed.* Middlesex: Penguin Books Ltd.

Gade, R. D., & Wanare, A. (2014, August). Object Recognition, Tracking and Destruction for Military Application. *International Journal of Advanced Engineering & Innovative Technology (IJAEIT), 1*(3).

Godfrey, P. C. (2014). *More Than Money: Five Forms of Capital to Create Wealth and Eliminate Poverty.* Stanford: Stanford University Press.

IDEO.org. (n.d.). *Clean Team: In-Home Toilets for Ghana's Urban Poor.* Retrieved from DesignKit.org: http://www.designkit.org/case-studies/1

IDEO.org. (n.d.). *SmartLife: Designing a Scalable Water and Hygiene Business*. Retrieved from DesignKit.org: http://www.designkit.org/case-studies/4

Junginger, S. (2018). Inquiring, Inventing, and Integrating: Applying Human-Centered Design to the Challenges of Future Governments. *JeDEM - EJournal of EDemocracy and Open Government, 10*(2), 23-32. doi:https://doi.org/10.29379/jedem.v10i2.520

Ke, C. (2018). Military object detection using multiple information extracted from hyperspectral imagery. *International Conference on Progress in Informatics and Computing (PIC)*. doi:10.1109/PIC.2017.8359527

Kovala, W. (2015). *Autonomous vehicle with obstacle identification and detection.* Västerås: Mälardalen University.

Naval Postgraduate School (U.S.). Center for Homeland Defense and Security, Argonne National Laboratory. (2017, April). *HSx Core Competency: Design Thinking [presentation]*. Retrieved from Homeland Security Digital Library: https://www.hsdl.org/?view&did=803733

Pick, S., & Sirkin, J. (2010). *Breaking the Poverty Cycle: The Human Basis for Sustainable Development.* Oxford University Press, Inc.

Ramadhan, A. J. (2018, March 13). Wearable Smart System for Visually Impaired People. *Sensors, 18*(3). doi:10.3390/s18030843

The World Bank Group. (2019). *Poverty Home: Overview*. Retrieved from The World Bank: https://www.worldbank.org/en/topic/poverty/overview