Thesis Portfolio

The Design and Optimization of a Lighted Kinetic Art Surface Display

(Technical Report)

An ANT Analysis of Open-Source Development

(STS Research Paper)

An Undergraduate Thesis

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

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

Philip Renkert
Spring, 2020

Department of Mechanical and Aerospace Engineering

Table of Contents

Sociotechnical Synthesis

The portfolio includes two projects: a technical capstone report and an STS research paper. The capstone relates to the STS research paper because the project, a pedagogical tool developed by students, is exactly the type of project for which Arduino, the subject of the research paper, was designed. Though no Arduino product was used in the capstone design, a similar open-source microcontroller from Parallax offered the ease of use, flexibility, and features necessary to complete the project. The purpose of the capstone is to inspire others to learn how it was designed; it is equal parts physical object and engineering teacher. Open source enables this hardware-based learning; it encourages anyone with sufficient curiosity to study the design, learn from it, and apply it to future projects. Both Arduino and the capstone project, then, participate in a larger network that aims to educate and enable with open hardware designs.

The technical project is a kinetic art display that users can program to obtain a physical representation of a surface or image. The design consists of a grid of transparent rods with colored light-emitting diodes (LEDs) attached at one end to illuminate the rod. A servo motor coupled to each rod assembly, or voxel, facilitates linear motion. Interesting surfaces or images are displayed by coordinating the colors and positions of the voxels. The design is optimized to reduce cost, complexity, and manufacturing time. The design intends to demonstrate the creative potential of mechatronics, to inspire viewers to learn the fundamentals of mechanical engineering and mechatronics, and to apply that knowledge to their own projects. It shows that STEM education need not be confined to classrooms, as open, project-based learning allows great engineers to develop concurrently with great products.

The STS research paper explores Open Source Development (OSD). OSD is a new model of technological development that emerged with the invention of the internet and has grown to

power much of today's modern technology. Despite its rising popularity and economic significance, the sociotechnical mechanisms of OSD are not well understood. This analysis employs Actor Network Theory to examine the network surrounding Arduino, a popular microcontroller board and canonical example of Open Source Hardware. In addressing how heterogeneous actors contribute to the success of open-source projects, this paper traces key events in Arduino's development back to the responsible actants and interactions between actants. The attributes and motivations of each actant are then analyzed to understand how a network of diverse actants led to the success of the Arduino project. These findings provide to the field of Science, Technology, and Society a high-level sociotechnical model of networks surrounding successful Open Source Hardware projects.

In working on the capstone project and STS research paper simultaneously, I gained a greater appreciation for the efforts of open source communities, learned the principles of OSH design and put them into practice, and came to understand the difficulties inherent in open, collaborative design. In designing the capstone project, the team leaned on tools like GrabCAD for 3D CAD models, Propeller "objects" for microcontroller software, and online engineering calculators and gear profile generators. Each of these tools were free, resources shared openly among the community. Access to these resources drastically reduced time spent during the design and programming phases. Researching the Arduino community while leveraging similar communities for the project reinforced my understanding of and appreciation for them.

Research for the STS paper also exposed several principles of open design that were applied in our capstone project. Open, digital manufacturing tools like 3D printers or CNC machines were used whenever possible, and inexpensive, off-the-shelf components were used when not. Electronics hardware and software which power the design are open source, and care

was taken to thoroughly document design rationale and assembly procedures. These principles accelerated the design process while making it easy for others to replicate, modify, and share the design as per the open-source philosophy.

Finally, working on the project and paper simultaneously highlighted the difficulties inherent in collaborative design. Several of the drawbacks noted by Arduino's founders materialized in the capstone project despite the team's small size. Principally, it was difficult to reach a decision and move forward with the design without one individual occupying a decision-maker role. In design, there is always room for improvements, and a purely collaborative process would struggle to find traction as imperfections and new possibilities stall the conversation.