Design and Construction of a Ferrofluid Kinetic Art Clock

(Technical Paper)

Viability of 3D Printed Prosthetic Devices

(STS Paper)

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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

Introduction

In the United States, amputees pay between $5,000 and $50,000 each time they buy a prosthetic (Sharington, 2017). Children in need of prosthetics have it worse, needing frequent replacements as they grow. In a study at the University of Illinois, it was found that children, on average, require a new lower-limb prosthesis annually up to age 5, biannually up to age 12, then every 3 years until age 21 (Lambert, 1959). That's 10-12 entirely different prosthetics, not counting replacements or upgrades through adulthood. For the two million amputees in the US, these costs add up fast and are entirely unaffordable for many families. For a time, solutions for this problem have been in the form of nonprofit organizations that help raise money for families in need of these devices, however this is merely addressing the symptom rather than the root of the problem. With the recent rise of cheap rapid manufacturing capabilities accessible to the public, a new solution emerges that can potentially radically change the future of prosthetics and their affordability.

The key technology driving this change is the 3D printer. Fast, widely available, and affordable, 3D printers have the potential to change the prosthetics industry for the better. 3D printers have become nearly a standard offering for libraries in metropolitan areas, and are a likely recent edition to more rural libraries as well (Griffey, 2017). They are becoming more and more ubiquitous at schools and universities, and get cheaper every year. The material cost to print a prosthetic arm is a miniscule fraction of the cost of current available prosthetics. Also significant is the fact that they could be entirely customizable. Making the 3D models open source could allow anyone with a basic understanding of computer aided design (CAD) to edit their prosthetic however they like and resize the component when needed.

The use of rapid manufacturing techniques like 3D printing can be applied to a wide variety of fields, both practical and aesthetic. While prosthetics are one intersection of practicality and aesthetics, another is the clock. The technical prospectus will further explore this idea, describing the creation of a kinetic art clock using rapid manufacturing processes to create a product that fulfils both form and function.

Technical Prospectus

Kinetic art is any form of art that moves, often lending itself to having a helpful function through this motion. The core idea of this capstone project was to create a piece of kinetic art that also functioned as a digital clock through the deployment of magnets to cause ball bearings to display the time. The clock should have the same functions as any other digital clock, such as the ability to have the time reset in case of Daylight Savings Time or a power loss. The constraint of keeping the clock reasonably quiet was artificially applied so that the clock could be displayed on the second floor of the Mechanical and Aerospace Engineering building. The clock should be able to be powered by a standard 120V AC wall outlet. The aesthetic concept is that magnets would attract the bearings through a thin front face, obscured from the sight of the viewer. This will create the illusion that the bearings are being held "by magic." Additionally, as much of the mechanism not involved in the actuation of the magnets should be visible to add visual interest to the piece.

In order to control whether or not a section of a digit will be displayed, two options were presented: electromagnets or actuated permanent magnets. Electromagnets could be kept in a fixed position and either be turned off or on depending on the numeral to be displayed. Alternatively, permanent magnets could be actuated closer or further ("on" and "off" positions, respectively) to the front face of the clock. Ultimately, the option of using actuated permanent magnets was chosen due to concerns with the amount of power electromagnets would consume in holding the bearings.

The clock will be controlled using a Parallax propeller microcontroller chip, utilizing its features of parallel processing and an internal clock. The propeller chip will be used in conjunction with I2C protocol to allow the 28 motors controlling the magnets to be run using only one propeller chip.

The original strategy devised by the group was to make iteratively larger and more complex prototypes. First, a prototype of a single section of a digit would be made, followed by a prototype of a full digit, then all 4 digits, then finally the finished product. The key to success in this project will be the utilization of Computer Aided Design (CAD), advanced manufacturing techniques such as 3D-printing and laser cutting for the purpose of rapid prototyping, and the use of iterative design techniques to overcome challenges as they appear.

This project will add value to both the Mechanical and Aerospace Engineering department as well as the educational development of team members. The department will have a functional and beautiful art installation that will hopefully service students and faculty for years to come. Group members will gain skills and knowledge in the additive manufacturing and other advanced manufacturing techniques, the design process, and working as part of an engineering team and the organizational skills and tools there involved.

STS Topic

To say that additive manufacturing and 3D printing are a perfect fit for the prosthetics and orthotics fields would be an understatement. By nature, prosthetics are complex structures requiring specific strengths aided by customizability, so 3D printing is a clear candidate as an emerging field to take over the industry. As opposed to $50,000 prosthetics commonly on the market, 3D printed prosthetics can be manufactured and sold for as little as $400 (“Amputees Find Cheaper Alternative”, 2018). These prosthetics become even more relevant in today’s technological landscape with the inclusion of sensors providing a wide array of data useful for both the prosthetic user and prosthetics developers. Improvements on this front are quickly being developed and only time will tell where the limits of sensor integration will be (“Improving 3D-Printed Prosthetics”, 2019). Currently, scientists are creating a 3D printed prosthetic that can read the brain activity of its user to replicate mobility as closely as possible to a functional human hand. "The patient just thinks about the motion of the hand and then robot automatically moves. The robot is like a part of his body. You can control the robot as you want. We will combine the human body and machine like one living body." explains Professor Toshio Tsuji of the Graduate School of Engineering, Hiroshima University (“Japanese Scientists Develop”, 2019).

Aside from cost, customizability is a major benefit of 3D printed prosthetics. The ability to quickly and inexpensively change out or edit a component on a prosthetic is a key advantage to this method of manufacturing, both for aesthetic purposes and for function. One study finds that personalization of the prosthetic interface increased the tissue-prosthesis contact area by 408% relative to comparable non-personalized devices (Tont et al. 2019). This is particularly significant considering that 95% of amputees report experiencing socket discomfort, and such an improvement in the prosthetic interface could alleviate some of this discomfort (Bhatia & Sharma, 2014).

This technology is a prime example of a paradigm shift (Kuhn, 1964). Ten years ago, 3D printing technology was in its infancy and had barely started to emerge into the commercial world. The alternative to a costly prosthetic was to go without one. All of a sudden, as additive manufacturing technology boomed in the late 2000s, a shift in perspective on the possibilities for orthotics and prosthetics emerged. Now, as the field continues to grow, a realistic path for disabled people to gain newfound mobility has appeared where it hadn't been before. Framed as a wicked problem, the process of securing cheaper alternatives for increasing mobility for the disabled appears to be a valid possible solution.

This technology is as socially relevant as it is scientifically. In a technologically deterministic sense, it has already begun to permeate culture in the public realm, like a girl throwing the first pitch at a baseball game using a 3D printed prosthetic (Kuhn, 1964; "Stratasys", 2017). The hands are an incredibly powerful social symbol, often representing power or agency, and the ability to regain hand functionality is a priority for many people using prosthetics (Alpenfels, 1955). In the US, 75% of patients with tetraplegia— paralysis in all four limbs— state that they would prefer to regain hand function to any other lost abilities, including bowel, sexual functions, and the ability to walk (Portnova, Mukherjee, Peters, Yamane, & Steele, 2018).

Research Question and Methods

The research question to be proposed is to discern whether or not 3D printed prosthetics can be a truly viable alternative, if not a virtual replacement, of traditional prosthetics, and the extent to which this shift has already begun. First, existing models or examples will be provided to outline exactly how prevalent this technology really is in the field of prosthetics. For example, companies like UNYQ have already began selling 3D printed leg prosthetics in the UK and Germany, and plan to expand operations to the US and Japan (“Company to Market”, 2019). Then, the drawbacks of the technology will be analyzed in the context of their direct comparison to traditional prosthetics. Using the STS framework of a paradigm shift, the current movement of thought from traditional to cutting edge in the field of prosthetics will also be analyzed. While Alvial et al state that there is a lack of studies reporting on quantitative functional evaluations of 3D printed prostheses, a conclusion will be surmised based on relevant practical and qualitative findings, including responses from prosthetic laboratories at the University of Virginia (2018).

Conclusion

The intersection between aesthetic and practical applications of 3D printing technologies and additive manufacturing techniques in general will be explored in both the technical project and the STS thesis. The magnetic bearing kinetic art clock will serve as a visually appealing and intellectually stimulating piece of public art to be displayed in the mechanical engineering building. This piece will ideally invoke ideas of form and function on passerby and students in the engineering school. On a more practical level, the STS thesis will cover 3D printable prosthetics and their viability in comparison to traditional prosthetics. While the kinetic art clock is intentionally anti form, taking a simple technology and making it more complex for the sake of aesthetic value, 3D printed prosthetics may cause a shift to simpler, cheaper, and more efficient designs for prosthetic users now and in the future.

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