DESIGN OF ABACUS CLOCK – "ABACLOCK"

EFFECT OF THE EMERGENCE OF MICROCONTROLLERS ON THE MECHANICAL ENGINEERING INDUSTRY

A Thesis Prospectus
In STS 4500
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In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Mechanical Engineering

By
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Technical Team Members: Mollie Bauer, Mrinaal Lorengo, and Jack Thomson

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.

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The demand for “work-ready” engineers becomes more and more prevalent each year which highlights the importance of combining the education of mechanical systems with electronics (Li, 2021). Since the 1970’s, there has been rapid development in the field of microcontrollers and computers (Mahmood, Ahmed, Mahmood, 2022, p.2). As technology has progressed, microcontrollers have expanded their role into various industries from automotive to military. A. Mahmood, Ahmed, and H. Mahmood argue that “microcontrollers have become the basis for the design of a large number of devices, so learning of using them becomes imperative, not only for students of engineering colleges but even for school children” (Mahmood, Ahmed, Mahmood, 2022, p.3). The influence of these imbedded processing systems have impacted the mechanical engineering industry enough that more and more mechatronics programs are being offered at universities (Li, 2021). Mechatronics combines the study of mechanical engineering with electrical and computer engineering and has sprouted into a category of its own. The technical project and loosely coupled STS research project address this topic. The objective of the technical project is to create a mechanical wall clock using a combination of mechatronic systems. Further, the STS research topic aims to address how the emergence of microcontrollers has impacted the mechanical engineering industry. The technical work will be completed throughout the Fall 2022 semester while the STS research will continue into the Spring 2023 semester. A timeline of the technical project can be seen in the Gantt chart depicted in Figure 1 on page two.

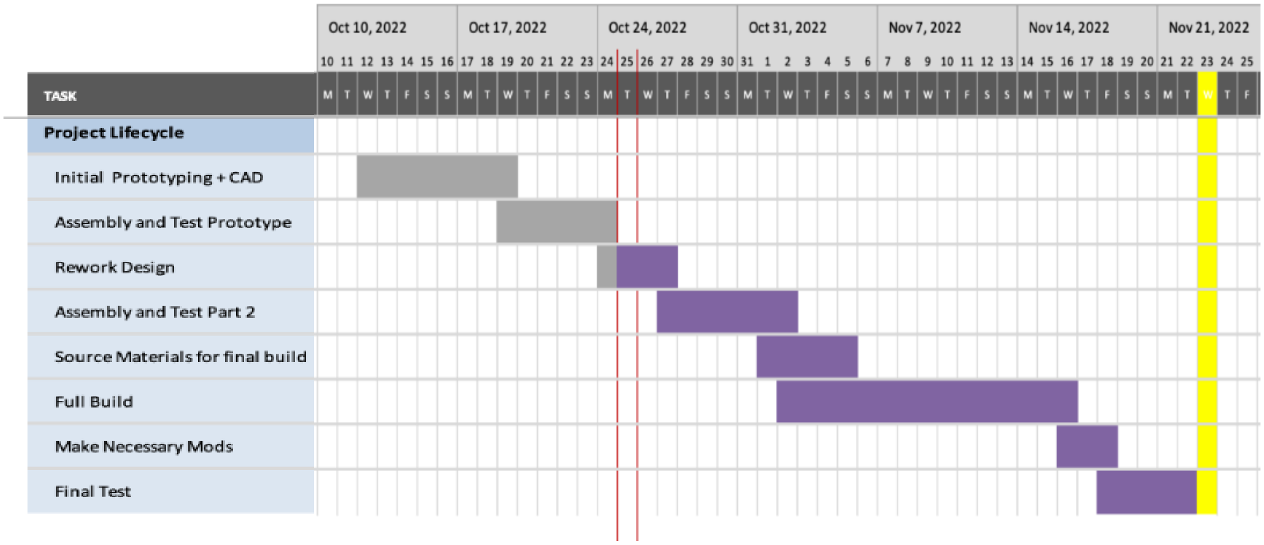

Figure 1: Gantt chart of UVa "Abaclock" Capstone Project. This figure shows the projected timeline of the proposed technical project (Peoples, 2022).

DESIGN OF ABACUS CLOCK – "ABACLOCK"

Despite the numerous hours involved studying the field of mechanical engineering, there are very few opportunities for undergraduates to demonstrate their knowledge and skills. Lab and course work provide adequate experience when it comes to the theoretical practice of mechanical engineering through simulations and closed experiments. However, such methods of learning often disregard real life variables such as feasibility, reliability, and practicality. A major cause of the lack of open-ended experimentation opportunities is of course due to online learning during peak Covid times. A study on engineering education during the COVID-19 pandemic stresses concern with the severe lack of hands-on learning and argues that personal engineering kits can allow students to better grasp new technical skills by letting students learn via hands-on trial and error (Asgari et al., 2021, p. 12). Our team's technical advisor utilized such a teaching method by providing extensive kits to each student in the third-year mechatronics course. This technical project will rely on coding and wiring skills learned in that course while also providing an opportunity for us to grow mechanical design skills through our own design iterations.

The object of this project is to create a mechanical wall clock in the form of an abacus. This clock will integrate mechanical and mechatronics systems that both demonstrate the practical skills of undergraduate mechanical engineers at the University of Virginia while paying homage to the origins of numerical methods. An abacus is a computing tool used for the four arithmetic operations (addition, subtraction, multiplication, and division). The abacus does not require pen or paper, works for any base number system, and such technology has over 2000 years of documented use (Samoly, 2012, p. 58). Just as an abacus performs under any base counting system, this clock will perform through the combination of mechanical, computer, and electrical engineering systems in order to physically display the time of day in the form of a number on an abacus. The design will consist of beads lined with magnets that travel along linear guide rails. The beads will be 3D printed and will have pockets for the magnets as shown in Figure 2. The beads will be the only part of the clock visible in order to add to the mysterious aspect of the clock. An opaque sheet of acrylic will separate the beads from the mechanisms that move them.

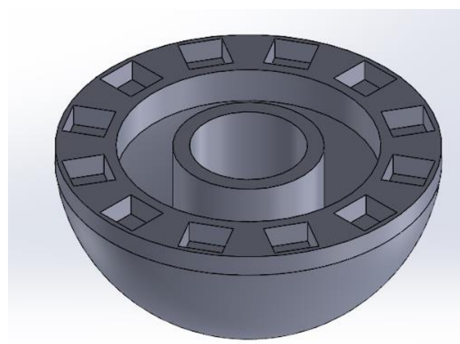

Figure 2: Computer Aided Design (CAD) model of an abacus bead with magnet housing. (Peoples, 2022)

For each column of beads, a stepper motor and lead screw system will move a linear actuator up and down. The actuator will engage and retract a permanent neodymium magnet that will use its magnetic field to interact with magnets in the beads. The magnetic force combined with the force of friction will allow the lead screw system to move the beads while being hidden behind the acrylic sheet. A prototype of a single column mechanism can be found in Figure 3.

The abacus clock will be designed, tested and built during the 2022 fall semester under the guidance of Gavin Garner, a professor of mechanical and aerospace engineering in the Department of Mechanical and Aerospace Engineering at the University of Virginia. The design process used to complete the project will consist of the following steps: (1) define the problem, (2) identify constraints, (3) generate designs, (4) test prototypes, and (5) build and validate final design. The team members included in this project are Jack Thomson, Timothy Peoples, Mrinaal Lorengo and Mollie Bauer. Each team member is a fourth-year student studying mechanical engineering at the University of Virginia School of Engineering and Applied Science. The final goal of this project is to have a clock display in a prominent location on grounds in order to demonstrate the practical skills of undergraduate engineers. This project will be fully documented in a technical report.

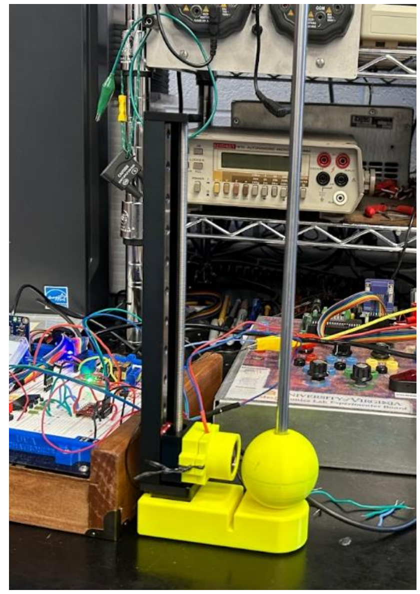

Figure 3: Initial prototype of electromagnet and stepper motor system (Peoples, 2022)

EFFECT OF MICROCONTROLLERS ON THE MECHANICAL ENGINEERING INDUSTRY

The rapid development of microcontrollers, especially low-cost options, is progressively changing the mechanical engineering industry. In education, more and more universities are creating or adding mechatronics coursework and degrees in order to better accommodate the influence of embedded processing systems. The explosion of low-cost options has thrust microcontrollers into everyday households. Controllers such as Arduino and Raspberry Pi, seen in Figure 4, have adopted incredibly simple user interfaces in order to appeal to the average person. Though controllers such as these are marketed as simple their abilities are not. Rick Stehmeyer (2016) argues that “this new market is flourishing as everyday people program these microcontrollers to hack cars, build 3-D printers, and augment drone functionality” (p. 42). Particularly in the HVAC industry, one primarily dominated by mechanical engineers, microcontrollers are paving the way for new developments. Typical commercial microcontrollers cost thousands of dollars yet the consumer versions are a fraction of the price with many of the same capabilities (Stehmeyer, 2016). Further, these commercial options require expensive software and equipment in order to operate. Stehmeyer (2016) argues that in order to keep up with the influence of technology such as the Raspberry Pi, commercial systems must become nimbler and more in tune with users. While the effect of microcontrollers can be analyzed in specfic mechanical industries, this research aims to note the effect on the mechanical industry as a whole.

Figure 4: A Raspberry Pi (Stehmeyer, 2016, 2)

The effect on the mechanical engineering industry can also be seen in engineering education. The prevalence of low-cost microcontrollers is redefining how engineering courses are taught. Fidai, Momin, and Umatiya (2021) argue that microcontrollers such as arduino have “reduced the costs of laboratory equipment and made hands-on engineering more accesable to more students” (p. 2). Hands on learning allows more students to learn the skills needed to solve complicated real-world problems (Fidai, Momin, Umatiya, 2021). Further, microcontrollers are impacting students enthusiasm for engineering courses. At the University of Wyoming, a 2018 study found that “students’ perception about their own creativity in STEM fields underwent a statistically significant change after students engaged with a coding/microcontroller intervention (Bicer et al., 2018, p.4).

In order to adequately research this topic, the paper will follow the Social Construction of Technology (SCOT) method. Using this framework, this paper aims to research how mechanical engineering has changed and ways in which it must adapt due to the influence of microcontroller processors. In this framework shown in Figure 5, various groups provide different perspectives that result in the development and charactersitics of microcontrollers. Because of this, the product developed reflects the concerns and goals of various societal groups. Through understanding how the engineer shapes microcontroller development to reflect these groups, the social construction of microcontrollers will be improved.

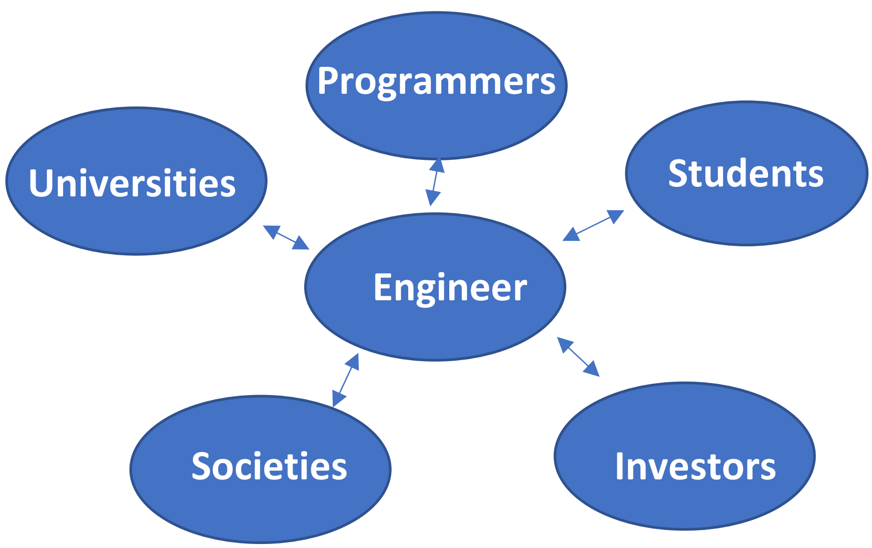

Figure 5: Social construction of technology (SCOT) diagram displaying the relationship between engineer and each social group (Peoples, 2022).

THE MODERN ENGINEER

The influence of technology can be seen throughout the world, especially in the area of engineering. In mechanical engineering, one must be able to adapt to these changes in order to better aid society. Universities across the globe are arguing how it is imperative that educators "introduce the broad field of mechatronics to non-traditional mechanical engineering students" (Li, 2021, 1). The University of Virginia has adapted to this change itself by requiring students to take mechatronics only recently in the mid-late 2000's. According to Pradip Sheth, a former professor at the University of Virginia, "thanks to the proliferation of inexpensive microcontrollers in recent years, machines that were formerly passive can now be made intelligent." (Feignoff, 2008, 1) This wave of microcontrollers has made it imperative to adopt new teaching methods in order to evolve mechanical engineering students and prepare them for the real-world industry. This influence of microcontrollers has permeated into educated allowing students to achieve practical hands-on skills of their own projects. While microcontrollers are here to stay, the mechanical engineering industry must adapt as well. This begs the question of "are the major players in the industry ready for this change" (Stehmeyer, 2016, p.47).

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