HYBRID HUMANOID ROBOT

AUTOMATION AND AESTHETICS: THE TRADEOFFS OF ROBOTIC PERFECTION AND HUMAN CRAFTSMANSHIP IN GUITARS

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Mechanical Engineering

By
Carson Peters

December 18, 2023

Technical Team Members:

Amelia Dinsmore	Ekow Daniels	Patrick Lam
Colin Halligan	Jack de Bruyn Kops	
Dorian Thomson	Morgan Carr	

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.

ADVISORS

Kent Wayland, Department of Engineering and Society

Pawandeep Matharu, Tomonari Furukawa, Mechanical and Aerospace Engineering

Introduction

Despite the improving ability of machines to replicate human behavior, the work produced by machines does not exactly mirror human craftsmanship. My technical project seeks to develop a humanoid robot that can play the role of a human crewmember on a ship. My STS research takes a deeper look at what makes the relationships and products created by robots and humans different. An evaluation of what makes the work of human hands unique reveals a value that is lost in automated manufacturing, one that craftsmen throughout history have held to the highest standard. In building a robot and recognizing its limitations, I can help my reader to appreciate the strengths of both humans and machines without neglecting one in favor of the other, searching for a balance in which both can contribute to a better world.

Technical Research Problem: Hybrid Humanoid Robot

How can a robot navigate complex human environments?

The environment in which a mobile machine operates dictates the optimal mode of transportation. Each mode of transportation has advantages and disadvantages, and some are better suited for certain environments than others. Difficulty arises when designing a machine for a complex environment in which one mode of mobility may be optimal at times and disadvantageous at others. For this reason, it may be of interest to accommodate multiple transportation functions into a device that can be interchanged according to the required movement. On naval ships, the environment consists of flat ground surfaces, steep staircases, and watertight doors. This poses difficulties for the design of a robot capable of navigating these obstacles. A bipedal robot could be specialized to climb stairs and step over watertight doors, but they are generally very slow when walking on flat surfaces. Wheels provide speed in obstacle-free, level terrain, but cannot climb stairs without the integration of a second mechanism. A robot

capable of navigating the ship in the same manner as a human could have comparable dexterity and movement speed by combining both rolling and walking mechanisms in its design. This is the goal of the technical project: to build a hybrid humanoid robot that can be equipped with transformable limbs for easy maneuverability on naval craft.

This project was originally commissioned by the US Navy to Princeton with the goal of prototyping a humanoid robot that could be used to assist sailors on aircraft carriers. The complex environment of the ship presents challenges for the design of a robot that can carry payloads, as it needs to move with speed and agility in a complex environment. The Navy proposed a solution to this problem was for a robot to have reconfigurable limbs that could transition into the necessary mode of transport required. This project was originally given to Princeton, where two generations of seniors created projects that failed. It was moved to Virginia Tech, where students created a robot body made of machined aluminum, but had issues with the weight of the body. Finally, the project came to UVA, where a team last year continued work on the Virginia Tech body and was able to move the limbs using a controller. However, they failed to balance the robot without the aid of external support and were unable to make it walk up stairs. This year, we are redesigning the body to decrease weight, in the hopes that controlling the robot will be more feasible.

This project involves designing, prototyping, and controlling an advanced lightweight 3D printed Hybrid Humanoid Robot. The robot will have capacity for the integration of custom-fabricated transformable limbs, allowing a single mechanism to act as both a hand and wheel, or as a foot and wheel. With the future development of these reconfigurable limbs, the robot will be capable of navigating the complex environment of ships with dexterity and speed, with the potential to assist the crew with operations that could pose danger to humans. The project will

begin by researching existing materials that can be 3D printed to develop a lightweight structural body for the robot. CAD design and optimization on SolidWorks will be conducted to study and analyze the structural strength of each component, determine the material to be used for each part, and conduct rigorous testing to control movement and balance of the robot. Design and control inspiration will be found by researching similar successful humanoid robots to find suitable degrees of freedom, types of joints, and algorithms to control stability. Using the robot control software ROV, we will tailor one of these programs to apply to the degrees of freedom of our robot to control each of the motors for coordinated movement. Our focus is on building a functioning Hybrid Humanoid Robot, which can be used to test multimodal limbs for the demonstration of the hand-wheel and foot-wheel concepts.

STS Research Problem: Automation and Aesthetics: The Tradeoffs of Robotic Perfection and Human Craftsmanship in Guitars

How do the values of consumers impact the product manufacturing process?

Advancements in computer-guided control and manufacturing techniques have created a world in which most consumer goods are produced by robots. Because of the repetitive nature of manufacturing, many shops have successfully automated production (Lee et al., 2024). The role of humans in the manufacturing world has shifted from one of rote manual labor to one of management and maintenance, supervising the machines that do the repetitive work (Horváth & Vicsek, 2023). Case studies interviewing manufacturing managers in Asia show that available technology has several widespread benefits, such as increasing the profitability of the manufacturers, the reduction of product costs, and an increase in the quality, inventory, and variety of consumer goods (Sharif & Huang, 2019). Relevant groups include the manufacturers, who want to stay competitive in the market, businesses, who want to produce the best products

for the lowest cost, consumers, who want the highest quality products at the lowest cost at their convenience, factory workers, who want to remain employed in a safe environment, technological innovators, who create automation systems for factories to make a profit and drive change in the world, and craftsmen, who value artisanship and enable people to appreciate what they make. There is a conflict of interest at stake; the adoption of automation encourages instantaneous perfection, while craftsmanship encourages patience, variety, and the incorporation of the human spirit in the art of human hands (French et al., 2009). Other values, such as product safety, cost, consumer experience, worker safety, and ease of manufacturing, are revealed through the way a product is made, and the consumer audience often trends toward some of these values over others. For example, Martin Guitars adopted CNC machining in part because of the experience of the craftsmen ("Martin's Continuing Investment in Automation," 2012). Although handmaking guitars from start to finish made each product unique, the use of automation technology reduced the risk of injury to the craftsmen, as well as improving production time. A choice was made about which values were more important to Martin, its employees, and customers. However, many classical guitarists feel strongly about using handcrafted guitars, which consider the unique character of the wood when building the instrument (Edgeworth, 2024). Some would even go so far as to say that "the successful diffusion of wave upon wave of new [automation] technology threatens to destroy essential human qualities" (Schillinger, 2005, p. 148). Additionally, changes in manufacturing processes can change consumption patterns, driven by an increase in consumption due to lower costs (Dusik, 2019).

To address this conflict in values in manufacturing, I will present an analysis of why products are made and of who determines which products are successful, using guitars as a case study to illustrate the conflict and narrow the scope of this project. Research into the motives

behind design choices and consumption habits will give insight into the values of various historical groups. I am studying the mutual shaping between manufacturing techniques and consumption patterns. Specifically, I am looking at the use of computer-guided automation in the production of guitars because I want to learn about the values intrinsic to production techniques, to help my reader understand the strengths of both craftsmen and machines, and to lead to the use of manufacturing techniques that best satisfy customers. Understanding how the desires of conflicting social groups dictate the way products are produced is important because this information can be used by machine shops to gratify people more effectively, and may lead to the creation of new methods of production when current techniques are unsatisfactory.

Background

Because automation technology is so widely available today, such that almost any process has potential for automation, I will focus on a case in which the difference in quality of the products produced by craftsmen and machines is contested: the creation of musical instruments. Guitars, one of the most produced instruments in the world, have a history of detailed processes used to create them, one that took skilled craftsmen to give the instrument its unique timbre. The development of businesses selling large quantities of guitars and the availability of automation technology have enabled companies to mass produce guitars with reduced human intervention. Strong preferences among musicians for traditionally handmade instruments reveal a backlash against the development of autonomous manufacturing techniques. Although they can have satisfactory timbres, these mass-produced guitars are seen as inferior by those who have spent a lifetime perfecting the woodworking techniques necessary to create guitars with strong resonance and a sound attractive to professional musicians. Although computers precisely model the resonance of a guitar body to design the timbre before it is milled

autonomously, the guitars created by master craftsmen are more widely accepted by artists. Both craftsmen and computers have the potential to come close to some sort of perfection in manufacturing, one through experience and intuition, and the other through modeling and math.

Data Collection and Analysis

To examine this, I will read published interviews and scholarly articles documenting the perspectives of artists, artisans, and manufacturers about their experiences and values relevant to the production of guitars. Recorded interviews and documentaries with manufacturers will reveal the motivations behind automation. Research on the history of guitar manufacturing and how the public responded to it will be useful background information. Studies on the changes in workers' lives before and after the introduction of automated machines to factories can provide information about how automation directly impacts people. Studies on consumer satisfaction comparing mass-produced and hand-crafted goods could show if there is any bias in what they purchase, and variation in studies at different times and geographical locations can point to reasons why certain products were successful.

Conclusion

The interplay between technical innovation and the societal implications of automation underscores the complexity of advancing technology while respecting human values. The development of a lightweight hybrid humanoid robot capable of navigating naval environments demonstrates the immense potential of engineering solutions to tackle specific, high-stakes challenges. Suited for the integration of transformable limbs, the robot merges dexterity and adaptability, meeting the unique demands of shipboard mobility.

The exploration into the contrast between human craftsmanship and robotic automation analyzes the topic of automation from a different perspective. Guitars, as a case study, reveal that

while automation offers efficiency, consistency, and affordability, it often lacks the intangible qualities imbued by human artistry. These qualities—derived from intuition, patience, and the individual's connection to their craft—highlight an intrinsic value that resonates deeply with certain consumer audiences. This tension between machined perfection and human imperfection mirrors the challenge of integrating robots into roles traditionally filled by humans, whether in manufacturing or as crew members on a ship.

Together, the technical and STS dimensions of this research emphasize the need for balance. Robots can enhance human capabilities, handling repetitive and physically demanding tasks, at the cost of human creativity and empathy. Recognizing the strengths and limitations of both enables the pursuit of a future where machines complement rather than replace human endeavors. By striving to design technology that respects and aligns with human values, we can foster innovations that are not only functional but also meaningful, ultimately contributing to a more harmonious coexistence between humans and machines. I hope to find insight into the motivations of the actors in the design field and of consumers to better understand how manufacturing techniques are mutually shaped by the values of these groups.

Works Cited

Dusik, J. (2019, January 22). *What Effect Will Automation Have on the Environment?* International Institute for Sustainable Development. https://www.iisd.org/articles/automation-environment

Edgeworth, M. (2024, January 7). *What are handcrafted classical guitars and who are they for?* Handmade Classical Guitars UK. https://www.michaeledgeworthguitars.com/en/uk-classical-guitar-maker/am-i-ready-for-a-handmade-guitar

French, M., Handy, R., & Jackson, M. J. (2009). Manufacturing sustainability and life cycle management in the production of acoustic guitars. *International Journal of Computational Materials Science and Surface Engineering*, *2*(1–2), 41–53. https://doi.org/10.1504/IJCMSSE.2009.024922

Horváth, Á., & Vicsek, L. (2023). Visions of Hungarian Artificial Intelligence Specialists About the Future of Work and Their Roles. *Science, Technology and Society*, *28*(4), 603–620. https://doi.org/10.1177/09717218231186105

Lee, E., Kim, H., & Hong, S. (2024). A Network Analysis of the Relationship Between Automation and Job Characteristics. *Science, Technology and Society*, *29*(3), 478–496. https://doi.org/10.1177/09717218241265004

Martin's Continuing Investment in Automation. (2012). *Music Trades*, *160*(5), 22–26.

Schillinger, A. G. (2005). Automation. In C. Mitcham (Ed.), *Encyclopedia of Science, Technology, and Ethics* (Vol. 1, pp. 146-148). Macmillan Reference USA. https://link-gale-com.proxy1.library.virginia.edu/apps/doc/CX3434900074/GVRL?u=viva_uva&sid=bookmark-GVRL&xid=919c5127

Sharif, N., & Huang, Y. (2019). Achieving Industrial Upgrading Through Automation in Dongguan, China. *Science, Technology and Society*, *24*(2), 237–253. https://doi.org/10.1177/0971721819841982