**Design of Hybrid Humanoid Robot for the U.S. Navy**

**Incorporation of Humanoid Robots into Automotive Manufacturing and How It Affects the Human Workforce**

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
**Morgan Carr**

November 9, 2024

Technical Team Members: Ekow Daniels, Amelia Dinsmore, Colin Halligan, Jack de Bruyn Kops, Patrick Lam, Carson Peters, Dorian 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.

ADVISORS

**Prof. Pedro Augusto P. Francisco**, Department of Engineering and Society

**Pawandeep Matharu**, Department of Mechanical and Aerospace Engineering

**<u>Introduction</u>**

In manufacturing, time is money and efficiency is key. Many manufacturing jobs are focused solely on increasing efficiency through process optimization. This is shown through methodologies known as lean manufacturing and six sigma; both provide organizational tools to increase productivity with the express goal of making more products and thus more money. One of the main ways to increase efficiency in a manufacturing line is by automating processes with consistent and streamlined tasks (*Humanoid Robots Are Getting to Work - IEEE Spectrum*, n.d.). Operators in manufacturing assembly lines tend to be repeating the same process for their entire work shift. Not only does this make the work day very menial, but it can cause a large strain on workers' bodies when moving around heavy parts. Manufacturing lines are designed to reduce this strain on workers' bodies, but sometimes it is unavoidable. As a result, companies have begun to allocate the more tedious, time-consuming tasks from humans to automated solutions, namely robots. Not only does this make the manufacturing process go by quicker and more safely for humans, but it frees them up to do tasks that require the creativity of a human mind and the human eye for error, such as product inspections.

The development of robotics for manufacturing has shifted focus in the last few decades. In most manufacturing plants you will see large industrial robots that can lift heavy loads but do not interact with and respond to human factors. As manufacturing has gotten more complex, more flexibility has been needed in automated solutions. This has caused a shift toward more intelligent robotic systems that are more adaptive to the work environment with humans (Garcia et al., 2007). More recently companies have been developing collaborative robots; these robots respond to human touch which makes it safer for operators to work directly with them. There has been a further shift to develop humanoid robots, which have a human-like appearance. This factor detracts people from wanting to work with robots as they create a strange sense of the Uncanny Valley Phenomenon, which describes the way people feel when they encounter something almost human but not quite (Berns & Ashok, 2024). There is an additional fear of robots replacing humans and taking away jobs for operators (Dekker et al., 2017). This fear of humanoid robots and artificial intelligence is reflected in and played up by horror films dating back to the 1920s. The robots present in this media are typically not reflective of the scientific capabilities of the present, yet they can stir more distrust from the public. As a result of this, designers have to be very intentional in the way they design the robots to make them work well with humans and facilitate their incorporation into the manufacturing line.

This project will include both a technical and STS portion which I will outline further. For the technical portion of my capstone project, I will be working with a team of seven undergraduate mechanical engineering students to design and build a hybrid humanoid robot. For the STS portion, I will be studying the relationship between humanoid robots and humans in manufacturing to determine if the quality of life of human workers is enhanced or diminished by the addition of automated solutions as well as how the work environment in a plant is affected as a whole by humanoid robots. I will be focusing on manufacturing within the United States, and primarily in the automotive field.

## Technical Description- Hybrid Humanoid Robot

Our project involves the design and development of a hybrid humanoid robot. This project is contracted by the U.S. Navy for application in naval ships. The robot will be utilized in lower levels of ships where conditions are unfavorable for humans to work in. The bottom of ships tends to have more intense temperature conditions as well as a lack of light and difficult terrain to traverse. All of these factors make it difficult for humans to perform their tasks to the best of their abilities.

The project specifications involve the ability of the robot to walk or roll over unstable terrains. Other specific objectives include the ability of the robot to climb a 63-degree ladder and climb through airtight doors. Given the time frame of the project, we are focusing on making a robot that is able to wheel on flat terrain, stand up from its rolling position, and step like a human.

The word 'hybrid' symbolizes that the robot will have dual mobility: it will be able to step like a person as well as roll on its hands and feet. The purpose of this is because there are benefits to either bipedal or wheeled robots depending on the task at hand. Bipedal robots can move over more irregular terrains as well as climb stairs and ladders. Additionally, the more human-like appearance of a legged robot has advantages for how the robot is integrated into the human workforce. However, a bipedal robot introduces more complexity as there are more degrees of freedom with the robot's movement. This is the difficult tradeoff between dexterity in movement and simplicity in design (Mikolajczyk et al., 2022). Additionally, having only one solid "foot" on the ground at a time while moving creates a stability issue, and programming the robot to balance itself is a very cumbersome task. This is where the wheeled robot has an advantage. Having more stable points of contact with the ground allows the robot to move continuously and quickly over smooth surfaces. Wheeled robots are also able to carry heavier load capacities due to the increased stability (Altagar, 2023). Due to the variety of takes outlined in the project, it is more beneficial to have a hybrid robot that can perform functions most suited to both bipedal and wheeled robots, with the ability to switch between walking patterns.

The ability to switch between these climbing and rolling functions presents the need for reconfigurable mechanisms for limbs that allow both wheeled functions as well as more stable feet. In the case of the hands, they must be able to roll as well as grip the ladder. To comply with this requirement, we are designing a pneumatic system that will push wheels out of the bottom of the foot and from the forearm of the robot. With these capabilities, the robot will be able to bend over into a push-up position and roll on 4 wheels. The dual mobility allows the robot to be more adaptable to the terrain it is traversing and the task it is needed for.

To increase overall stability, especially in the transition between mobility functions, one of our main focuses is keeping the weight of the robot to a minimum. Our design is composed of 2 materials: 3D printed ABS plastic, a material known for its high strength-to-weight ratio, for the structural components, and aluminum for the high torque components such as motor brackets. All structural components were passed through a topology optimization software on SolidWorks to remove non-load-bearing material and have the strongest and lightest shape. Another factor we need to consider when reducing the overall weight is the amount of motors used. The motors supplied by the previous team are Dynamixel motors that weigh 0.5 lbs each, meaning that we must be very intentional in where we place motors and how many. This means selecting how many degrees of freedom to afford to each joint for the robot to be able to complete all required tasks. Additionally, we will be using gearboxes to increase the torque output from each motor to move the limbs without increasing the motor count.

Though the power system has not been finalized yet, we will likely be powering the HHR through an Arduino Uno in conjunction with a Dynamixel Shield I/O in order to power each motor. A more detailed power system plan will be developed in the next few months.

**<u>Humanoid Robots in Manufacturing</u>**

In manufacturing, some tasks are more susceptible to automation than others. Tasks with more repetitive actions that are consistent and simple have a higher risk of automation, whereas tasks that require decision-making and creativity have a lower risk (*A Network Analysis of the Relationship Between Automation and Job Characteristics*, n.d.). This proposes the idea that automation with robotics might open up humans to new, more creative tasks that require a human mind. This could provide a more engaging and enjoyable work experience for humans as well as the opportunity to grow more and develop new skills that can lead to further opportunities.

However, even if robotics are allowing humans to work on more fulfilling tasks, they are still replacing humans in a given role, which adds to people's fears of robots stealing their jobs (Dekker et al., 2017). Some people are generally afraid of robots and newer technologies featuring artificial intelligence as a whole, being labeled "technophobes". These fears can lead to anxiety-related mental health issues that can further people's fears surrounding job stability (*"You're Fired," Says the Robot: The Rise of Automation in the Workplace, Technophobes, and Fears of Unemployment - Paul K. McClure, 2018*, n.d.). These fears are particularly common in people who are not technologically literate, as they simply do not understand these newer technologies. Technology has been rapidly advancing, especially in robotics where the number of robot density per 10,000 employees doubled from 2015 to 2020 (Robotics, n.d.). This increase is scary for people who do not understand it. Manufacturing may be particularly impacted by this due to the educational requirements for operator roles in plants. While the number is increasing, only about 40% of manufacturing workers have a college degree (Picchi, 2019). This means that many workers probably are not knowledgeable of advanced robotics with humanoid robots, making them more susceptible to these technological fears.

The humanoid aspect of newer robots adds an additional element. Not only do some of the robots create the sort of uncanny valley effect mentioned previously, but it also affects the interactions humans have during their work day. Having interactions between humans, with true friends in the workplace or even casual passings, has a large impact on not only how much people enjoy their jobs and their mental health, but also on their physical well-being. Social connection can lead to many physical health benefits, including a strengthened immune system, increased chance of longevity, and quicker disease recovery (Seppala, 2014). With robots being more incorporated into manufacturing, this means that human workers are interacting with each other less daily, and spending more time completing tasks with robots. This will change the work environment, making it harder to foster human connections, which can negatively affect the workers.

All of the factors expanded on above, including which tasks can be automated, technological fears of humanoid robots, the uncanny valley phenomenon, and the importance of human connection in the workplace will be examined to determine how human workers are affected by the implementation of humanoid robots into their daily routine. This thesis will utilize Actor-Network theory to analyze the manufacturing work environment with humanoid robots to determine if humanoid automation has a positive or negative impact on the roles of human workers. Research methods will include analyzing existing literature on robotics, manufacturing work environments, and quality of life of workers. I will also be contacting and interviewing old colleagues that work in the automotive manufacturing industry to see what robotic changes have been made in the past 10 years and what changes are expected in the coming years. The combination of existing literature and data on the topic and personal experiences from people in the industry will give a varied perspective on the issue. Humanoid robots provide the possibility to revolutionize manufacturing, but only if they can work well in conjunction with humans.

## Conclusion

Automation, particularly with humanoid robots, is rapidly changing automotive manufacturing by making processes safer and more efficient, which allows more products to be produced, reducing the cost of production. This benefits the industry and customers as a whole but affects the workers who interact with these robots. Humanoid robots can positively impact workers by pushing them into more creative tasks, but can negatively impact them due to common fears of robots.

The success and positive impacts that robots can have on the industry hinge on their ability to be seamlessly integrated into the human work environment. This thesis will highlight the large problem areas in human-robot interactions in order to better inform robotic designers on how they can cater their robots to work well with humans. A human-robot working environment is the future of manufacturing, so designers and manufacturing operators must balance the benefits of optimizing processes with the need for human connection.

## References

Garcia, E., Jimenez, M. A., De Santos, P. G., & Armada, M. (2007). The evolution of robotics research. *IEEE Robotics & Automation Magazine*, *14*(1), 90–103. IEEE Robotics & Automation Magazine. https://doi.org/10.1109/MRA.2007.339608

*Humanoid Robots Are Getting to Work—IEEE Spectrum*. (n.d.). Retrieved October 7, 2024, from https://spectrum.ieee.org/humanoid-robots

Berns, K., & Ashok, A. (2024). “You Scare Me”: The Effects of Humanoid Robot Appearance, Emotion, and Interaction Skills on Uncanny Valley Phenomenon. *Actuators*, *13*(10), Article 10. https://doi.org/10.3390/act13100419

Dekker, F., Salomons, A., & Waal, J. van der. (2017). Fear of robots at work: The role of economic self-interest. *Socio-Economic Review*, *15*(3), 539–562. https://doi.org/10.1093/ser/mwx005

Mikolajczyk, T., Mikołajewska, E., Al-Shuka, H. F. N., Malinowski, T., Kłodowski, A., Pimenov, D. Y., Paczkowski, T., Hu, F., Giasin, K., Mikołajewski, D., & Macko, M. (2022). Recent Advances in Bipedal Walking Robots: Review of Gait, Drive, Sensors and Control Systems. *Sensors*, *22*(12), Article 12. https://doi.org/10.3390/s22124440

Altagar, G. (2023, March 12). *Robots—2 legs or wheels. Which is better?* Robotics. https://guyaltagar.editorx.io/robotics/post/robots-2-legs-or-wheels-which-is-better

*A Network Analysis of the Relationship Between Automation and Job Characteristics—Eunsoo Lee, Hyojin Kim, Sehee Hong, 2024*. (n.d.). Retrieved November 9, 2024, from https://journals-sagepub-com.proxy1.library.virginia.edu/doi/full/10.1177/09717218241265004

*"You're Fired," Says the Robot: The Rise of Automation in the Workplace, Technophobes, and Fears of Unemployment—Paul K. McClure, 2018*. (n.d.). Retrieved November 9, 2024, from https://journals-sagepub-com.proxy1.library.virginia.edu/doi/full/10.1177/0894439317698637?casa_token=Ct2laj87gecAAAAA%3AFl20Z6nMGwEOKmtrHDA8QtnAu8srdKx9eVPamD4IRDkgtBg6vThCMNAZlGDNtn3sOiIjOKN-vvX8

Robotics, I. I. F. of. (n.d.). *Robot Density nearly Doubled globally*. IFR International Federation of Robotics. Retrieved November 9, 2024, from https://ifr.org/ifr-press-releases/news/robot-density-nearly-doubled-globally

Picchi, A. (2019, December 10). *Want a factory job? You may need a college degree - CBS News*. https://www.cbsnews.com/news/factory-job-college-degree-want-a-factory-job-you-may-need-a-college-degree/

Seppala, D. E. (2014, May 9). *Connectedness & Health: The Science of Social Connection*. The Center for Compassion and Altruism Research and Education. https://ccare.stanford.edu/uncategorized/connectedness-health-the-science-of-social-connection-infographic/