MECHATRONIC ORRERY DISPLAY

(Technical Project)

THE EFFECTS OF AUTOMATED TECHNOLOGIES ON INDUSTRIAL WORKERS

(STS Paper)

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By

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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.

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Introduction

As technology continues to grow towards a digital landscape, majors such as computer science and electrical engineering are becoming more popular in industry. To continue to thrive as a major, mechanical engineers developed a new type of engineering subset called mechatronics. Mechatronics engineering combines mechanical, electrical, and computer science engineering to develop new systems that breathe life into inanimate objects. These systems involve three components: a sensor, a controller, and an actuator (Brooks and Roy, 2021). The sensor takes data from a real-world setting and sends it to a controller, and the controller then responds to the data using an actuator.

An example of a mechatronic system can be seen in automatic sinks seen in bathrooms. The infrared sensor in the sink detects when there is a hand nearby. This sensor will then send a signal to a microcontroller of some type which is coded such that if a signal from the sensor is received, it sends an output signal towards the actuator (Larranaga, 2022). The actuator used in most cases is a solenoid. The solenoid is arranged such that when it is off, the electromagnet in the solenoid will block water flow (Holzner, 1992). Engaging the solenoid with an electrical signal will cause the solenoid to engage, allowing water to flow for a certain period. This simple mechatronic system helps eliminate the need to turn on and off water, potentially saving a small office up to 3,000 gallons of water a year compared to an old mechanical lever (Martin, 2017).

Mechatronics can be used to create small, intricate motions that seem easy while also keeping accuracy. Although subtle, the use of mechatronics can be seen across a vast majority of disciplines. For instance, mechatronics can be used to create a kinetic art display for the public, similar to the display that our technical team is constructing. The display will be an orrery, but unlike the traditional orrery using gear ratios to rotate planets around the sun, ours will contain

systems of motors and controllers that allow the system to rotate freely with an electrical input as well as have a user interface to let a user control the motion of the system.

Note. This is a complex example of an orrery of the solar system. Notice the complexity of the gears to capture the motion of the selected planets around the sun with a constant input from the user. From *Staines & Son Orrery Makers Personal Gallery.*

This project demonstrates how mechatronics can be used to enlighten the public through kinetic art as well as redefine an old method of technology into something that is more efficient. The brilliancy of mechatronic systems is that they can be designed to do almost any task with extreme accuracy for an unspecified amount of time. This leads to their popularity in the mass-production manufacturing industry where speed, efficiency, and quality are valued to make the most profit. For instance, it is estimated that the global product growth will increase roughly 0.6% relative to the normative value. Although this value might seem small, the long-term effects of this value create a strong order of magnitude of production in the industry (Chui et al. 2017). A classic example of mechatronics in manufacturing can be seen with a computer numerical control (CNC) machine. A CNC machine works by running a specified code through a microprocessor. This code contains the complex movements that will move an actuator, which

either contains a milling bit or a device for cutting material. This allows for people to manufacture complex shapes with extreme accuracy (Yang, 2022). A team of manufacturers could produce a part that would take days instead takes only a few hours under the supervision of one attendant.

It is with machines like the CNC machine that increase the ease of a procedure but are reducing the number of hands needed to complete a task. The people that are manufacturing these parts are factory workers working for a company that is mass producing parts. These blue-collar workers are tirelessly completing jobs in industries where the only option is to work in these factories. It is with the addition of the CNC machine that changes the scope of the job for these workers. This is a common theme in industry where the career of the worker has been completely redefined by the introduction of a new technology. It's with these changes that workers tend to switch career paths or change professions altogether (Lent, 2018). These products increase the productivity of a factory, but at what cost to the current floor workers?

Technical Project

Orreries are mechanical models of the Solar System that represent the positions and motions of the planets and moons. A mechanical arm can be turned so the correct speed and position of the planets can be shown. Traditional orreries are created with complicated gear ratios and lever arms stemming from a concentric shaft (Cooke, n.d.). The complication to this design is that you cannot look into the future very far, unless you plan on spinning the gears hundreds of times, which will be time consuming. Traditional orreries are also inefficient and will lose accuracy as you continue to spin the planet because of imperfections with gears. (Cooke, n.d.).

The purpose of creating a mechatronic orrery is to demonstrate in a unique and fun way, the positions of the earth and moon, relative to the sun. This project will create a more aesthetically pleasing and accurate model of the Earth, Moon and Sun, while educating people on the seasons, moon phases, eclipses and so on.

The final design will consist of a sun and an earth and moon that will rotate around the sun. The sun itself will not be a traditional sun in that it will be more aesthetically pleasing rather than an accurate representation. However, the sun will contain a lighting fixture that will shine light on the earth as well as the moon. As the earth rotates, the light will show how the seasons are made relative to the earth's atmosphere. As the light shines on the moon, it will show a rough estimation of how the phases of the moon are created. There will also be an electronic display that will show the phase of the moon as well as the date and the position of the earth. The orrery will have two modes. One mode is where the orrery will rotate on its own at a constant space, showing how the earth and moon are revolving around each other and the sun. The second mode will involve the user input in which a user can put in a date, and the orrery will automatically rotate to show the earth and moon's position at that time. It will also be able to indicate the next eclipse, as well as other events regarding the lunar cycle.

Our project will extensively employ two types of rapid prototyping that are essential to modern mechanical engineering: 3D printing and laser cutting. 3D printing is an additive process where an object is created by laying down successive layers of material until the object is created (Robertson, 2021). Extremely complex geometries can be sliced into thin layers and quickly built from the bottom up. Laser cutting is a fabrication process that, "uses a thin, focused, laser beam to cut and etch materials into custom designs, patterns, and shapes as specified by a designer"

(Obudho, 2019). Using these methods allows us to quickly build parts with complex geometries and precise features while constantly iterating on our design.

Mechanical orreries, while very breathtaking, reflect traditional mechanical engineering principles, producing precise motion using gears and other mechanical components. With the emergence of cheaper electronic components, most notably microcontrollers, over the past couple of decades, antique mechanisms have been increasingly replaced by mechatronic systems. A mechatronic system is characterized by one or more sensors feeding information to a microcontroller, which is controlling the actuation of a motor. Mechatronic systems improve upon antique mechanisms by simplifying the creation of complex mechanical motions. Our mechatronic orrery will allow us to improve upon antique mechatronic orrery designs by allowing user input. The user will input a date, and the orrery will display the position of the earth and moon in their orbits on that date. This can only be accomplished using servo motors. Servo motors use a closed-loop control system to "allow for precise control in terms of angular position, acceleration, and velocity" (Lavaa, 2021).

STS Topic

In some areas, such as cities and densely populated locations, there are many work opportunities that people have the liberty to choose from whereas others are forced to find work doing any job necessary to gain income. These jobs are typically blue-collar positions that consist typically of manual labor, working with machinery and equipment, or construction and are seen in Midwest states known for industry such as Indiana or Arkansas (Umwuga, 2021; Mota, 2019). It is also important to think how these industrial manufacturing employees interact with the autonomous machines they are working with as well as how these machines are designed to interact with the worker, especially considering how technology is changing to

become more autonomous. These autonomous machines are being added to manufacturing systems with the hope of creating easier work and efficient outcomes, when it tends to make these systems more complicated, creating harder tasks for the workers at hand (Resnikoff, 2022). With blue-collar work already causing depression and other mental illnesses due to the nature of the work, the addition of a change in career definition increases the stress placed on these workers (Hou, et al. 2019). This relationship between worker and machine can be seen in the sociotechnical discussion of actor network theory presented by the work of Bruno Latour. Latour, being a key contributor to actor network theory, develops the invisible relationship of actors and their respective networks in the context of technology. These actor-networks are unseen but present, and they represent how these two groups interact with each other (Latour, 1992).

Based on Latour's work on actor network theory, Steve Woolgar created a discussion titled, "Configuring the User: the case of usability trials." Woolgar explores the metaphor that the design of a machine is like text on a page. Machines are designed for a particular group of users attempting to interact with the machine, such as a writer carefully writes and places sentences to create an environment or deliver an argument in writing (Woolgar, 1991). The organization of these machines is controlled, specified so that the user can properly interact with the device without causing interruption or confusion with the user. This idea is developed through Woolgar's work with a project management team in which he conducted research on how new computer interfaces were designed and tested on a team of users. Although this is theorized by Woolgar himself, I am interested in the idea of purposeful configuration of users using technology. This area of discussion can be related to those working in these high manufacturing facilities working in blue-collar positions. The developers of these autonomous,

mechatronic machines are creating devices that are easy to interact with while offering extreme efficiency and reliability. This is in the hopes of increasing the quality of the manufacturing goods, which in turn would increase the production of the factory as well as the quality of the goods produced. All key ingredients of a manufacturing plant wanting to turn profits. These new manufacturing machines are designed by the user to have little to no interaction with the user to maintain agility (Drossell, et al. 2010).

Some of these systems have even led to the displacement of jobs. Most of the time, these new autonomous machines redefine the type of work that these employees originally have been trained to complete. Instead of being in a blue-collar position that was hands on, the worker's position has become monotonous consisting of small movement or equipment checks (Hirischi, 2018). It is important to recognize that this is how the user is being configured in this scenario, realizing that the main influence of design is profit and not the user.

Research Question & Methods

This information has led me to propose the following research question: how does the effect of automation in blue-collar jobs effect the lively-hood, mental health, and well-being of the employees involved? This question will be studied under the configuration of the user STS framework presented by Woolgar. To begin this process, the user will have to be defined in detail. By studying the user and the machines they use, information regarding how the effects of these machines is having on these users. This will be completed by using different case studies around the manufacturing industry, as well as surveys and studies regarding the mental health of factory workers comparative to similar studies completed more recently. It will also be researched into what type of new technology has been implemented into manufacturing, and how these implementations have affected current workers.

These results will be found by searching UVA's academic libraries for information regarding mechatronics, automation, and worker satisfaction in the manufacturing industry. The information gathered will be able to help aid in the definition of the user, and with the addition of the knowledge of mechatronic systems, an understanding of how an automated machine was developed can be formed. It is with this understanding, coupled with the information collected from the research completed, that will allow a viable conclusion to be drawn to answer this proposal.

Conclusion

It is with these results that will shed light on an area of industry that is often overlooked. More attention can be paid to the common factory worker in the hopes of attempting to improve their lively hood and making blue-collar professions easier on the person. It will also bring attention to the methodology behind design. In which it is important to not only think about how the user will be interacting with a new technology, but how this technology will be affecting the user.

I expect to conclude that newer autonomous technologies in manufacturing industries have led to the decrease in the well-being of the workers that interact with this technology. I feel that most cases will present workers with the feeling of insignificant work, leading to a decrease in mental health in the workplace. I also expect to find there are some instances where people have lost jobs or switched professions due to this technology.

References

Woolgar, S. (Ed.). (1991). *A sociology of monsters: Essays on power, technology and domination.* Configuring the User: the case of usability trials, (1. publ). Routledge.

Latour, B. (n.d.). *Where Are the Missing Masses? The Sociology of a Few Mundane Artifacts*. 35.

Brooks, S., & Roy, R. (2021). An overview of self-engineering systems. *Journal of Engineering Design*, *32*(8), 397–447.

Cooke, J. (n. d.). Orrery. *Orrery*. https://www.hsm.ox.ac.uk/orrery

Drossel, W., Neugebauer, R., Pagel, K., Bucht, A., & Junker, T. (n. d.). *Mechatronic Options for Increasing and Accuracy in Production*.

Hirschi, A. (2018). The Fourth Industrial Revolution: Issues and Implications for Career Research and Practice. *Career Development Quarterly*, *66*(3), 192–204.

Holzman, P. (1992). *Solenoid Valve Maintenance and Application Guide. Final Report.* (EPRI-NP-7414). Office of Scientific and Technical Information.

Hou, L., Leung, P., Cheung, M., & Xu, Y. (2019). Religion Affiliation and Depression Risk: Factory Workers Working in Hi-Tech Companies in Shanghai, China. *Journal of Religion & Health*, *58*(2), 490–505.

Larranaga, O. (2022, February 28). *Bathroom Sink Automation*. https://oceanbuilders.com/blog/bathroom-sink-automation/

Lavaa, A. (2021, August 2). *A Full Explanation on Types of Servo Motors*. https://www.linquip.com/blog/servo-motor-types/

Lent, R. W. (2018). Future of Work in the Digital World: Preparing for Instability and Opportunity. *Career Development Quarterly*, *66*(3), 205–219.

Linecita, M. (2019, June 8). *The Blue Collar Resurgence*. https://ojt.com/blue-collar-resurgence/#:~:text=Indiana%201%20Arkansas%20Here%2C%20blue-collar%20jobs%20account%20for,7%20Wyoming%20...%208%20Mississippi%20...%20More%20items

Marvin, J. (2017, January 5). *Advantages and Disadvantages of Sensor Taps*. https://www.intelligenthanddryers.com/blog/benefits-sensor-taps-problems#:~:text=Automatic%20taps%20contribute%20to%20a%20more%20sustainable%20world,automatic%20taps%2C%20the%20equivalent%20of%20155%20full%20baths

Michael, C., James, M., & Mehdi, M. (2017, April 12). The Countries Most (and Least) Likely to be Affected by Automation. *Harvard Business Review*. https://hbr.org/2017/04/the-countries-most-and-least-likely-to-be-affected-by-automation

Resnikoff, J. (2022). THE AUTOMATION PARADOX. *Saturday Evening Post, 294*(3), 8–12. Academic Search Complete.

Umwuga, T. (2021, March 11). *What Are Blue Collar Jobs?* https://umwuga.com/blog/what-are-blue-collar-jobs/

Yang, X. (2022). Remote Diagnosis and Detection Technology for Electrical Control of Intelligent Manufacturing CNC Machine Tools. *Scientific Programming*, 1–14. Academic Search Complete.

Roberson, D. (2021, May 3). *What is 3D printing?* Https://Ultimaker.Com. https://ultimaker.com/learn/what-is-3d-printing

Obudho, B. (2019, August 31). *What Is a Laser Cutter? – Simply Explained*. All3DP. https://all3dp.com/2/what-is-a-laser-cutter-simply-explained/

Staines & Son Orrery Makers. (n.d.). *Orreries for Sale—Gallery*. https://www.orrerydesign.com/