**GESTURE-DRIVEN ROBOTIC VEHICLE**

**A SOCIOECONOMIC ANALYSIS OF HUMAN-ROBOT INTEGRATION**

A Thesis Prospectus
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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**

We are entering an age where humans and robots work as one. Over the past few decades, monumental strides have been made towards advancing human-robot collaboration. Rapid advancements in computer hardware and firmware platforms, such as ROS 2, have enabled the creation of advanced robotic systems (Macenski et al, 2022). In the past, primitive robotic systems were highly specialized, and were primarily deployed in industrial environments for automationing repetitive tasks (Grau et al, 2021). However, modern systems are much more intelligent, versatile, and collaborative. In many cases, humans can seamlessly cooperate with these advanced robotic systems in both home and industrial environments. As a result, the applied robotics landscape is experiencing expanding efforts in both robot teleoperation and autonomous robotics.

In autonomous robotics, the system typically executes an operational algorithm asynchrounously, thus allowing it to function without human intervention. Conversely, robot teleoperation is the act of controlling a robot remotely using human intelligence, often requiring a salient human-robot interface. This can range from simply moving a toy robot via a remote control to controlling fleets of complex robots over long distances. Furthermore, robot teleoperation is critical in many field task scenarios where human beings would otherwise be in danger. In recent times, we have seen robot teleoperation applications in search and rescue, reconnaissance, or even active combat situations such as mine detection (Gonzalez., 2022). Advancing teleoperation capacities truly has the potential to save lives. In my technical capstone project, I explore novel methods of teleoperation by creating a robotic vehicle that can be controlled using hand gestures via a glove controller.

The expansion of robot teleoperation paired with the growing adoption of autonomous systems has undoubtedly led to increased robotics integration into human society. However, the uptick in human-robot integration has had some unintended consequences in spite of its benefits. Rapid advancements in applied robotics has resulted in increased human-robot replacement, especially in the service industry where roles have traditionally been considered “human”. Whether or not this is a net benefit for society is currently a nuanced question. Thus, in my STS research, I will analyze the consequences of human-robot integration in the service industry from a social, economic, and ethical standpoint. Specifically, I will argue whether human-robot replacement is an overall benefit or detriment, and attempt to construct a sociotechnical balance between total human-robot replacement and total technological negligence. The problems addressed in the technical and STS research sections are inextribally linked. While the technical section of this prospectus deals with the development of new technology, the STS section analyzes the consequences of that technology. Furthermore, the complete profile of a technology includes both its development and its effects, and one cannot exist without considering the other. As engineers, we must consider the analytical design of our projects, but also the social consequences of the technologies we develop.

## Gesture-Driven Robotics: A Novel Teleoperation Investigation

As a computer engineering major, my fourth-year capstone class is ECE 4991: Embedded System Design. In this major design course, teams of 3-5 independently develop an ECE project consisting of a microcontroller-based embedded software system in conjunction with a printed circuit board (PCB) hardware system. My capstone project is a gesture-driven robotic vehicle, which consists of two components: the controller glove, and the robotic car itself. The controller glove is designed to be worn by the user and is responsible for reading hand gestures and transmitting data to the car via Bluetooth. Conversely, the car is responsible for translating the commands sent by the glove into vehicular motion, which is executed via a motor controller PCB. The system is complete with several peripheral features, including a precision mode for tighter robot control, an obstacle detection system paired with haptic feedback, and a robot backtracking algorithm for disconnect handling.

The core component of the glove system is a Raspberry Pi Pico W microcontroller that runs the user-side software and interfaces with all peripheral components. First, an MPU6050 sensor attached to one of the glove's fingers transmits raw gyroscope and accelerometer data to the glove microcontroller over an I2C connection. Using several helper functions, the glove microcontroller translates the raw gyroscope data into one of several command numbers used to represent the different hand gestures. For example, if a user tilts their fingers down, this translates to a command number of 1, and the desired functionality is to have the car drive forwards. The table below summarizes the hand gestures alongside the movement commands they correspond to.

| Hand Gesture | Car Motion | Command Number |
|---|---|---|
| Fingers Straight | Stop | 0 |
| Hand Down | Move Forwards | 1 |
| Hand Up | Move Backwards | 2 |

| | | |
|---|---|---|
| Hand Tilted Left | Turn Left | 3 |
| Hand Tilted Right | Turn Right | 4 |

The command numbers are then sent via a Bluetooth socket to another Pico W microcontroller mounted to the robotic car. This microcontroller is connected to the car's motor controller PCB over another I2C connection. Based on the command number, the car microcontroller then activates specific motors using PWM signals, allowing the car to perform different movements corresponding to different hand gestures. Attached to the front of car is an ultrasonic sensor that measures the distance between the car and the nearest obstacle. This measurement is then interpreted by the car microcontroller and sent back to the glove over a different Bluetooth channel. On the user-side, a haptic motor is attached to another glove finger and will vibrate at different frequencies depending on the distance measurement. This design allows to the user to receive haptic feedback if the robot gets too close to an obstacle.

The glove controller also contains a hall effect sensor and a magnet mounted on the thumb and pointer fingers, respectively. If the user presses their thumb against the rest of the hand, this will toggle the system between “normal” and “precision” modes. Furthermore, the glove board sends an integer representing the operation mode to the car microcontroller over a third Bluetooth channel. If the system is in precision mode, the car microcontroller will reduce the duty cycle of the motors, allowing the user to operate the car at a lower speed. Finally, the car microcontroller software maintains a queue of movement commands, which allows the car to backtrack to its initial position in case the Bluetooth connection is lost. This feature is meant to reflect real-life teleoperation scenarios, where it may be dangerous for a user to physically retrieve a robot if a connection is lost. Both the glove and robot systems are complete with custom-designed PCBs that handle power distribution, GPIO connections, and hardware interfacing. Specifically, the car PCB also contains a slot to attach an analog camera, which can be paired with a receiver that connects to a standard monitor to fetch real-time video data from the robot.

The central purpose of this capstone project is two-fold. For one, it explores robot teleoperation by introducing a new control mechanism via hand gestures. Because the teleoperation procedure relies heavily on comprehensive user control, discovering novel methods of human-robot interaction is critical to expanding the applicability of the field (Rahimi, 1992). Furthermore, the development context of this project will be a toy car/glove controller marketed toward STEM-inclined teenage enthusiasts. Recently, there has been an uptick in educational robotics for STEM education (Morgan et al, 2019). Thus, this project will tap into this by enabling teenagers to explore robot teleoperation by providing a fun and approachable entry point for developing interest. Fostering the next generation of young engineers is critical for advancing society and technology.

**Integration of Service Robots: A Nuanced Perspective**

As we enter a new age of AI and robotics, we must consider the social repercussions of the technologies we innovate. Due to advancements in foundational robotics technologies, there has been a paradigm shift to design intelligent systems that are even more collaborative and interactive with humans (Grau et al, 2021). In fact, modern robotics research is increasingly driven by human social needs, with particular focus on human-robot interaction and service robotics (Garcia et al, 2007). Following the automation era and early industrial robots, the service industry in particular has seen a revolutionizing influx of intelligent robotic systems. In many cases, organizations are placing service robots in frontline service encounters, replacing the traditional role of human employees (McLeay, 2023). However, whether or not this is socioeconomically beneficial is currently a major debate. On one hand, technologists argue that replacing humans with robots in service roles yields a net positive, since robots are more efficient at completing the tasks they are assigned (Rosete et al, 2020). Conversely, others argue that service robot replacement harms society, since it both phases humans out of jobs and deprives customers of necessary human trust and social cues (Etemad-Sajadi et al, 2022). Overall though, this is an incredibly important STS investigation. As foundational technologies continue to mature, robots will be increasingly integrated into human society. Not only will this question be relevant far into the future, we must be prepared to answer the nuanced question once further human-robot integration is achieved. Furthermore, the consequences of human-robot replacement in the service industry affects all parties involved. For one, it influences the quality of service presented to the customer. Additionally, it influences the reputation of the service industry as well as any potential human workers that were phased out.

In my STS research, I will address this question by analyzing it on three fronts. First, I will investigate whether human-robot replacement is socially and operationally favorable. This includes researching the capacity of service robots to operate in social situations, customer perceptions of frontline service robot implementation, and operational outcomes of human-robot replacement. Next, I will consider economic perspective of the research question by addressing the economic viability of a human-robot substitution and its affects on the labor market. Lastly, I will look at the question from an ethical perspective, and investigate whether it is ethical to humanize robots placed in traditionally human roles. This research question also has a second dimension in that service robots can be considered as both substitutes, in the case of human-robot replacement, and complements, in the case of human-robot collaboration (Decker and Fischer, 2017). Thus, in addition to the central question, I will also argue to what degree human-robot substitution is optimal and attempt to find a balance between human-robot replacement and human-robot collaboration. I will collect evidence for the research through two avenues. First, I will conduct a thorough literature review on all facets of the question and evaluate the presented evidence to form my central thesis. Because both ends of the debate present valid arguments, I will have to analyze sources critically and determine whether some sources present evidence against others. Additionally, I will gather statistical evidence to support any economic and operational arguments.

**Conclusion**

Overall, my main technical deliverable for my capstone project is a functioning robotic vehicle that can be controlled via hand gestures from a glove controller. Additionally, the final deliverable must incorporate all the peripheral features laid out in our capstone proposal. This includes the haptic feedback obstacle detector, precision mode toggle, and analog camera. For my STS research deliverable, I will produce an analysis of the social, economic, and ethical consequences of human-robot replacement in the service industry. After conducting a preliminary investigation on the literature, I predict that I will find partial human-robot replacement paired with partial human-robot collaboration to be the most optimal conclusion to the research question for all facets. While robots do not yet have the capacity for high emotional intelligence, I believe I will find robot replacement optimal for highly repetitive service settings, and robot collaboration optimal for hospitality-focused service settings. As we enter a new age of human-robot interaction and collaboration, this topic will be increasingly relevant to society. Since the dawn of automation, robots have been phased into more and more industries, from manufacturing, to service, to even medicine. As computing and robotics continue to evolve, we will continue to observe new cases of human-robot replacement. We, as engineers, must not only advance society through technology, but also analyze the consequences of our work.

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