A Sociotechnical Analysis of Service Robotics and Human Replacement

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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 automating 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 the robotics field, autonomous robotics refers to systems that execute an operational algorithm asynchronously, allowing majority 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. The expansion of robot teleoperation paired with the growing adoption of autonomous systems has undoubtedly led to increased robotics integration into human society. In many cases, this has yielded great benefits, such as aiding human personnel in dangerous field tasks such as active combat mine detection (Gonzalez., 2022). 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.

Currently, there exists a nuanced debate as to whether or not the integration of robotics into the service industry is beneficial to society from a replacement perspective. On one hand,

technologists argue that replacing humans with robots in service roles may yield a net positive in certain scenarios, 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). From a purely objective standpoint, both sides' arguments possess some degree of validity. Thus, in my sociotecnical research, I will analyze the consequences of human-robot integration in the service industry from a social, economic, and ethical standpoint and attempt to construct a sociotechnical balance between total human-robot replacement and total technological negligence. Through synthesis of literature, statistical analysis, and STS frameworks, I posit that partial integration and human-robot collaboration is favorable over total replacement due to the limited emotional intelligence of robots, the imperfect substitutability of humans and robots, and the psychological importance of human-human interaction in service environments.

Background and Significance

The year is 1961. Deep in the industrial production grounds of Ewing Township, New Jersey lies the General Motors assembly line bustling with production line employees working at peak efficiency. A group of ecstatic engineers burst through the entrance of the assembly line. They have with them a strange-looking contraption consisting of a metal claw attached to a neck mounted on a steel base: the first industrial robotic arm. Within weeks, dozens of these devices are installed onto the assembly line and begin cranking product after product after product. Most importantly, these devices work without complaint, without exhaustion, and with minimal cost. This is the story of the Unimate industrial robot, the origins of automation, and the origins of a

debate that would last for decades to come (Wallen, 2008). By now, it is well known that the field of robotics has revolutionized industrial environments through automation. Factories once bustling with human labor are now the domain of robotic arms, automated assembly lines, and monitoring systems. This influx of robotics has undoubtedly yielded positive results, both optimizing production processes and elevating standards of safety and quality assurance. Tasks once deemed monotonous or hazardous for human workers are now effortlessly executed by robots, without complaint, boredom, or labor costs. But what about the workers that the robots replaced? As automation swept across industrialized countries and the benefits of increased productivity began rolling in, many factory workers stood in fear of being replaced by the mindless, primitive machines that could effortlessly outpace them (Noble, 2011). However, as economies waned away from industrialization and towards service, statistical reports from the time show a myriad of job opportunities opening up in the growing sector (Urquhart, 1984). However, this was only the beginning.

As we enter a new age of AI and robotics, we must consider the social repercussions of the technologies we innovate, especially when they are incorporated into new sectors. 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). While industrial predecessors excelled at automating monotonic tasks, their technical capability and operation were strictly one-dimensional, and did not allow for much human interaction. This was mostly due to technical limitations, since each implemented robotic system essentially had its own fundamental architecture that was specialized for the task the robots were programmed to do. However, as advancements in modern robotics firmware began to roll in, the robotics field as a whole began to shift away from automation and towards human-robot interaction. With the

invention of generalized firmware platforms such as ROS, the design of salient human-robot interfaces was now possible, allowing for the introduction of robotics to social settings. 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. The historical success of industrial automation in conjunction with the increased interactive capacity of robotic systems has fostered a new trend. In many cases, organizations are now placing service robots in frontline service encounters, replacing the traditional role of human employees (McLeay, 2023).

Overall, analyzing the consequences of human-robot replacement in the service industry is an incredibly important sociotecnical 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, but we must also 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 affect all parties involved, influencing the quality of service presented to the customer, the reputation of the service industry, and any potential human workers that were phased out. As we continue to advance human-robot interaction and collaboration, this topic will only become 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. This result is unavoidable. We, as engineers, must not only advance society through technology, but also analyze the consequences of our work.

Methodology

The nuanced nature of the research question requires an analysis from multiple facets. In this STS thesis, I will address the central 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 the economic perspective of the research question by addressing the economic viability of a human-robot substitution and its effects 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. Furthermore, this will encompass a psychological discussion on the importance of human-human interaction in service settings. The central 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. Overall, the three central facets upon which the thesis statement is founded were chosen on the basis of overarching relevance to both the criticism and encouragement of human-robot replacement.

Evidence for this research paper will be collected through two primary avenues. First, a thorough literature review is conducted on all facets of the question: social, economic, and ethical. Additionally, the evidence will be synthesized and evaluated to form my central thesis. Because both ends of the debate present valid arguments, sources will have to be analyzed critically, especially in cases where some sources present evidence against others. Since a sizeable majority of the central question is qualitative in nature, a literature review methodology is a valid approach.

If done critically, this will provide insight into expert research within the overarching topic. Secondly, statistical evidence will be collected to support any economic and operational arguments. For these thesis constituents, primary sources and data collection is an appropriate evidentiary approach since this aspect of the thesis statement has a quantifiable nature.

Lastly, the concepts and evidence gathered from the research process will be analyzed in the context of the technological momentum framework. The core idea behind this STS perspective is that societies accept a novel technological development in alignment with social contexts and goals, and that technology is often adopted in stages (Hughes, 1983). These stages typically follow the order of initial invention, local application, transfer and broadening to other places, and the development of supporting infrastructure. The technological momentum process culminates in the final acceptance of the technology system, making it difficult to phase out. The prototypical example of technological momentum is the adoption of the US electrical grid, that began as a small scale experiment in the 1870s (Hughes, 1983). Following local application, the electrical grid began to scale out in conjunction with the supporting infrastructure, such as power lines, generators, and the advent of electrical companies. Nowadays, the US electrical grid is a ubiquitous technological system that is firmly established and adopted by society. For my research, I will use the technological momentum framework to guide my reasoning and form my stances on the three core aspects of the thesis statement. Moreover, I will frame the conclusions of the central question and commentate on how they align with the core arguments of the theory.

Literature Review

A myriad of supporting literature has been published discussing the topic of service robotics, its history, and its viability. These include papers published at the dawn of the service robotics breakthrough, to recent papers and case studies providing up to date commentary on the topic. Furthermore, the prior literature I have compiled branches into all three facets of the central research question. Because the literature review is one of my central research methods for evidence collection, I will use this section to introduce the compiled literature and discuss their key arguments. In the Discussion and Results section of this paper, I proceed to discuss the literature in further detail while synthesizing their key arguments for my research question.

Several of the literature surrounding the topic delve into the history and context regarding the rise of service robotics. For example, in the 2007 paper "The Evolution of Robotics Research", the authors survey the development of robotics research in three core areas: robot manipulators, mobile robots, and biologically inspired robots. The paper argues that the recent evolution in robotics research is primarily driven by human social needs, leading to increased focus on human-robot interaction and service robotics. As evidence, the author cites several examples of recent robotic systems developed explicitly for human aid, such as medical assistance machines and rehabilitation robots. Additionally, the paper argues that the physical design and morphology of robots is being tailored to support human service, and cites upward trends in anthropomorphic design and bipedal movement as evidence. Interestingly, this paper was published right at the dawn of the service robotics surge, and it correctly predicts the future emphasis of automation in the service industry. Other papers that cover context provide an even more comprehensive overview regarding the history of robotics in various sectors such as "Robots in Industry: The Past, Present, and Future of a Growing Collaboration With Humans", published in 2021. This paper discusses

the history of industrial applied robotics and argues that the first robots operated as incredibly specialized, stand-alone machines meant to automate repetitive tasks. Additionally, it argues that recent technological developments allow for a paradigm shift where robotic systems are becoming increasingly collaborative with humans. Interestingly, one core issue that this paper emphasizes is the safety surrounding human-robot collaboration. It argues that since systems were not originally intended to be collaborative, we should be cautious about forcing human-robot collaboration in circumstances where it does not make sense.

The rest of the literature compiled during the literature review directly tackle key aspects of the research question and will be used as evidence in the following section. Some of the papers argue against total human-robot replacement from a social aspect, such as one that claims that emotional communication executed by service workers are critical during service interactions (Becker et al, 2022), or another that posits that the hospitality industry is tightly dependent on empathetic intelligence, and that service robots have not yet reached that level of complexity. Furthermore, the literature that tackles the economic side of the research question are more in favor of integrating robotics into service sectors, but still are hesitant in advocating for total replacement. This includes one paper that advocates for human and robot actors to be viewed as economic complements in service scenarios (Decker et al, 2017), and another that presents hard statistics for labor shortages in certain service subsectors such as hospitality, following the COVID-19 pandemic (Kwok, 2022). The remaining literature presents interdisciplinary analysis of the human-robot replacement phenomenon that also branches into ethical consequences of customer perceptions, including a case study of a fully robotic hotel in Japan (Reis et al, 2020), and a paper detailing customer attitudes towards service robotics in the hospitality industry (Akdim eta al, 2023).

Discussion and Results

Upon synthesis of the literature discussed above in conjunction with other supporting literature, I conclude that total human-robot replacement is a suboptimal practice from social, economic, and ethical standpoints. On the social front, service robots are not yet technologically equipped to completely replace human workers due to their lack of emotional intelligence and empathetic complexity. On the economic front, service robots should not completely wane out human workers since human and robot actors cannot be perfect labor substitutes in highly social settings. On the ethical front, phasing out human actors entirely leads to general unease from a consumer perspective, since it deprives consumers of necessary human-human interactions. This results in an ethically suboptimal outcome since customer perceptions and experiences should be prioritized in service scenarios. Moreover, although total human-robot replacement is not ideal, the expanding capabilities of modern-day robotics should not be neglected. Thus, the optimal balance for robotics integration is to emphasize human-robot collaboration, where human and robot workers can complement and support each other to maximize efficiency and experience. This section will discuss each of the above arguments in detail.

While service robot integration may not be fundamentally detrimental from a social standpoint, total human-robot replacement is not an ideal practice due to the constrained social capacity of robotic systems. Firstly, the emotional communication required for service encounters is not a strictly one-dimensional concept. Rather, different emotional communication strategies are required for different types of service encounters (Becker et al, 2022). As outlined in the referenced paper, service robots must be able to emotionally communicate both proactively and reactively. Additionally, a hypothetical frontline service robot must be able to both react to negative customer

emotions and mimic or infuse positive customer emotions. That being said, the first step in deciding which emotional communication strategy to employ in any service scenario is to successfully read the situation and interpret the corresponding customer emotions. Although humans are trained to do this process naturally and effortlessly, the paper posits that current robots are not yet equipped to perform this "emotional interpretation" from a technological standpoint, and that more research must be done in the area before human-robot replacement can be prioritized. This finding is corroborated by another paper that posits how the hospitality industry in particular is directly built upon empathetic intelligence, and that current service robots are not yet able to perform standardized tasks that require high degrees of social and emotional complexity (Rosete et al, 2020). Specifically, the paper posits that in order for the service to become highly personalized, providers need to have complex cognitive and emotional skills, and that it is unlikely for current robots to possess the social intelligence and communications skills needed to deal with these complex scenarios.

Based on the arguments presented above, skeptics may be quick to point out that these conclusions overshadow and ignore all of the potential positives of integrating modern robotics technologies into service. However, it is important to stress that although both sources are against total human-robot replacement, they express rather positive arguments for a partial integration approach. For example, the Rosete paper claims as a secondary argument that partial integration of service robots for standardized tasks is economically optimal, since modern social robots can be relied upon for their analytical capability. Furthermore, the Becker paper is optimistic that "emotionally communicative service robots could deliver highly engaging and interactive service experiences" (Becker et al, 2022) once the necessary research is conducted. Thus, although we should be hesitant about totally phasing out frontline human workers, we should still tap into the

strength of modern robotics and incorporate service robots into areas where emotional communication and empathetic complexity is not emphasized.

From an economic standpoint, robot integration into the service industry is also generally viewed as a viable adaptation. However, the degree of integration should not only vary depending on the industry, but also align towards collaboration over replacement. When discussing the economics of incorporating robotics into a labor sector, many opponents are quick to fear robots depriving human workers of necessary jobs. However, over the past few years, there have actually been labor shortage challenges within several service sectors, particularly tourism and hospitality (Kwok, 2022). Following the Covid-19 pandemic, the supply of service workers has declined steeply compared to previous years due to the sector's traditionally low pay and high turnover rate. Specifically, the paper cites that while the industry offered almost 300 million job openings globally during 2020, there were still significant labor deficits in the market despite the unemployment rate rocketing to almost 10%. Thus, we should not be concerned over service robots eliminating service jobs, but rather turn to technology to aid an ongoing labor issue.

However, this does not mean we should hastily begin replacing vital service workers with machines. Several economic analyses have been conducted on the potential of human-robot substitution in the labor market, and most have found that in more socially involved settings such as human service, human and robot actors are better viewed as complements since the production functions of both actor types do not align in more social settings. (Decker et al, 2017). Moreover, this paper posits that the substitution potentials for a given industry generally scale with the degree of repetitiveness of the work. This means that corporations should look to integrate service robots collaboratively rather than substitutionally in social service settings to fill any labor gaps that may appear. Specifically, corporations should try to integrate robotics into aspects of the service

workflow that are highly repetitive, such that humans and robots can function as perfect substitutes. Proponents of total replacement due to economic factors will often argue that in many common service scenarios, salient machines can, and do, already replace human workers, such as ordering kiosks for fast food businesses. However, it is important to note that in this example, the human worker and the kiosk are actually complements, not substitutes. From the business's perspective, the kiosk functions not to replace the human worker, but to increase the service capacity of the business by adding a new avenue to place orders, thus reducing the queueing delay.

Lastly, it is important to recognize that completely replacing frontline service workers with robots is not the most ethical decision, since it not only dehumanizes the human worker being replaced, but also undermines the core customer experience. In many service industries, it has long been established that the customer experience should be a top priority in order to generate service loyalty, hence the phrase “the customer is always right”. In light of recent robotics advancements and integration, several studies have been conducted on the customer perceptions of service robots phased into frontline service settings. Specifically, a 2021 study by Khaoula Akdim et al, was conducted on explicit and implicit customer attitudes towards service robots categorized by degree of anthropomorphism. The analysis built atop the uncanny valley and construal level theories, and it found that the more human-like a service robot was, the more likely it was for customers to express negative attitudes and reject the robot in the frontline setting. Furthermore, the paper theorizes that root of this trend is a customer’s implicit need for some degree of human-human interaction within frontline service scenarios that simply cannot be replicated via anthropomorphic robots without eliciting discomfort. This finding therefore constructs a paradoxical situation wherein frontline service robots should be made less human-like to increase customer comfort, but in doing so, would decrease the potential of simulating human-human interaction. Thus, one

consistent conclusion is that completely replacing frontline service workers with robots, *even if it were operationally optimal*, would be unethical since it harms the customer experience.

One objection to this argument is that subjective conclusions about customer perceptions should not be drawn from isolated studies where participants are away of the study's context. However, this conclusion is further corroborated by a case study of a fully autonomous service environment. In a 2020 paper, Reis et al analyzes the customer perceptions of the fully robotic Henn Na hotel in Japan. Upon first entry, customers are greeted with the sight of an autonomous, humanoid robot rolling in behind the reception counter. After checking in, guests are then served by a pair of bipedal robots that ultimately escort them to their room, all while never interacting with a single human. The paper discusses how while some customers were impressed with the novelty of the hotel, many experienced some degree of discomfort and uncanniness due to the lack of human-human interaction. The paper concludes by arguing that while service robots can outperform humans for standardized customer service tasks, the technology is not advanced enough for cases where emotional intelligence is required. It should be recognized that the hotel itself is actually rather successful due to the novelty of the idea and appeal to tourism. However, in a world where fully autonomous service environments are commonplace, and the novelty of the environment no longer applies, having extreme situations of human-robot replacement would drastically harm customer experience.

Looking at the arguments at a higher level, it is clear that their conclusions fit within the context of the technological momentum framework. Although many sources are not in favor of human-robot replacement, they are generally not against increasing human-robot integration into the service industry in general. In fact, many papers proactively advocate for further research into expanding the emotional and social capacity of service robots such that higher degrees of human-

robot collaboration can be achieved. This trend can be explained by applying the concepts of technological momentum. As evident by the advancements in service robot technology, we have surpassed the stage of initial invention and local deployment. However, the supporting infrastructure has not yet been developed enough to support high degrees of human-robot replacement. Even in situations where high degrees of human-robot integration has been achieved, such as the fast-food kiosk example, human workers are still needed and are still depended upon. For example, if a fast-food kiosk breaks, human technicians are needed to fix them, and human order-takers are depended upon as failsafe. At a societal level, the development of advanced service robots to begin with is entirely dependent on the human engineers that design them. Thus, it can be argued that within the technological momentum timeline, total human-robot replacement will likely never advance past the supporting infrastructure phase. In contrast, advancing the goal of human-robot collaboration through the technological momentum lifecycle is a far more viable effort. Rather than building the infrastructure needed for entire fleets of robotic workers to support themselves, we can develop systems where robots serve to increase the efficiency of human workers, and human workers function to support the operation of robots. With the recent advancements in robotics firmware paired with the accelerated research into advancing their capacity, human-robot collaboration has the potential to transform the service industry for the better.

Conclusion

Overall, the debate over the integration of robotics into the service industry is incredibly complex, and the answer to this question differs depending on the perspective. On one hand, we should be hesitant towards human-robot replacement since robots do not have a high capacity for

emotional intelligence, humans and robots are not perfect substitutes in highly social situations, and depriving customers of necessary human-human interactions is not ethically ideal. On the other hand, we cannot simply neglect the technological advancements of service robotics, especially amidst the labor shortage in several service sectors. For each industry, and for each environment we must work to find that perfect balance of cooperation where robots can aid human labor and human can bolster robot efficiency. With the recent advancements in robotics firmware paired with the accelerated research into advancing their capacity, human-robot collaboration has the potential to transform the service industry for the better. As computing and robotics continue to evolve, we will continue to observe new cases of human-robot integration. From the dawn of automation to the expanse of service to the dawn of medicine, robotics will thrive and robots are here to stay. We, as engineers, must not only advance society through technology, but also analyze the consequences of our work. Only then can we enter an age where humans and robots *live* as one.

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