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THE IMPACT OF ROBOTICS IN FOOD SERVICE

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ABSTRACT:

Robots and humans in the food service industry were the subjects of this quantitative research that aimed to compare their efficiency and security. In particular, it sought to provide proof of how human and robot workers fared in terms of general performance and safety. These were categorized into the following scales: perceived intelligence, perceived safety, dependability, responsiveness, assurance, social capacity, and predicted service quality. Expert views on the relative safety of human and robot workers in the food service business were also an aim of this study. The need to assess the efficacy and security of robots in comparison to human workers was driven by the fast expansion of robots in the food service sector. This research sought to investigate this contrast based on expert opinions and was based on the complex adaptive systems (CAS) theory. Statistical tests including Wilcoxon Sign ranking, ANOVA, Spearman Rank, and Kendall Tau were used in a quantitative descriptive investigation. The results indicated that human workers and food service robots were equally safe and effective. Dissecting the performance metrics revealed notable variations in Anticipated Service Quality and Responsiveness, with food service robots achieving higher medians for the latter. According to these findings, when it came to performance and safety, humans rated human workers in the food service industry higher than robots.

Keywords: Food Service, Complex Adaptive Systems, Robots and humans, impact of robotics, boundless.

I. INTRODUCTION

The field of robotics, a significant branch of artificial intelligence, has made an indelible mark on the food service industry in recent years. This industry, a critical component of the economy, has been significantly impacted by the advent and proliferation of robotic and AI technologies (Pickett, 2018). Factors such as automation, job transformation, including the loss and creation of jobs, and global issues like pandemics and labor shortages have contributed to this technological shift (Naudé, 2019). More specifically, the food service industry has seen a surge in the use of robotics to automate tasks, enhance safety measures, and boost overall efficiency (Grobbelaar et al., 2021). The impact of robotics in this industry has been profound, from manufacturing to service delivery. This paper delved into the role of robotics in the food service industry, exploring its benefits, potential risks, and the future implications of this technology in this sector. The food service industry is a vital part of the economy, and its decline affected businesses that relied on it for profits and the flow of social structure and consumption (Dunn et al., 2020). Governments have taken steps to support those affected by the pandemic, such as increased funding for unemployment benefits and job training programs. robotics on the workforce and economy if many levels of the industry were switched to automated systems and robotics, such as the fast-food industry (Furman & Seamans, 2019). Many believed jobs would be reduced; however, evidence showed that robots could solve a workforce shortage and create jobs that increased safety (Grobbelaar et al., 2021). In conjunction with implementing robotics, these practices could replace many other jobs, such as dangerous ones, which could save numerous human lives. The future applications of robotics were boundless.

II. ROBOTS' EFFECT ON THE RESTAURANT INDUSTRY

Industry was essential to consider. However, many issues hindered its full utilization, such as cost, skill requirements, and technological advances, among the few mentioned (Aaltonen & Salmi, 2019). Other, even more technical issues included uncertainty, error handling, and mechanical limitations in robotics. As robotics technology advanced, so did the solutions to these issues. Therefore, the food service industry had to continually assess the benefits of robotics and the potential risks involved. Ultimately, robotics in the food service industry should have increased efficiency, reduced human labor costs, created jobs, and eliminated dangerous

Additionally, some companies had implemented hiring freezes to limit the economic downturn's impact on their workforce. The development and implementation of robotics have been critical to helping the food service industry get back on its feet and adapt to the changing times. However, many were concerned about the impact of drawbacks of integrating robotics into the food service industry, it provided valuable insights that could inform further discussion and investigation into this significant and timely issue.

III. LITERATURE REVIEW

The need for robotics and AI has garnered excellent traction. This quantitative study aimed to investigate the impact of robotics in food service. As robotics grows, it is essential to see its effects; however, the more complex the system becomes, the more uncertainty is created. Challenges in a live environment where changing variables could cause robotics to face uncertainty, error handling, and mechanical limitations. This chapter looks deeper into the literature to further emphasize the claims and research on robotics and its effects on the service sector, chapter two presents:

1. A literature overview of theories related to robotics in food service.

work and labor-intensive jobs (Seyitoğlu etal., 2021). This study evaluated the perceived views of experts in information technology to see how performance and safety differed between food service robots and food service employees. While this research did not definitively establish the benefits (besides the perceived performance if evident) and

10. A literature overview of theories related to robotics in food service.

11. A review of these theories over the past five years as they connect to the topic.

12. An examination of the topic of robotics in food service specifically within the past five years.

13. The contributions of this study to the existing body of knowledge.

14. Conclusions derived from the study.

The ever-changing landscape and advancements of humankind have shifted us into a world of information. One of the many modern technologies is robotics, a branch of artificial intelligence that focuses on the physical application of artificial intelligence and its interaction with objects and the world around us. As a branch of artificial intelligence, robotics can employ multiple layers of artificial intelligence and its many other extensions, such as machine learning, intelligent controls, pattern recognition,

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IV. SEARCH STRATEGY

Google Scholar was the leading search engine used to collect and search for articles, journals, and studies. The University of the Cumberland's acted as a secondary library for the search. Using Google Scholar integrated databases along with the University of the Cumberland's library added to access links.

A combination of keywords was used to diversify results and sample the most accurate information. Below is a list of those keywords.

V. Literature Collected

automation, and so forth. Robotics and AI have been widely accepted in the industry as efficient and effective solutions to various problems. Robotics has been used in multiple sectors and industries, including the service sector. The service sector has seen growth in recent years, and the number of restaurants and other eateries has increased. This increase in the demand for food and other services affected the development of eateries. The use of robotics in the service sector has been growing, and it was essential to study its effects. In this literature review, we looked at the impact of robotics in the food service industry.

However, one of the first nominal definitions of complex adaptive systems was mentioned and defined by Holland (1992). In Dooley's nominal definition of complex adaptive systems, Dooley made mention of many authors, including but not limited to (Jantsch, 1980; Lewin, 1999; Holland, 1992; Gell-Mann, 1994). Dooley discussed complex adaptive systems as a meta-theory, an assortment of methods and ideas that were more or less integrated and mutually consistent.

Complex systems were composed of many parts that interacted with each other. These interactions gave rise to behavior patterns characteristic of the system. A complex adaptive system could adapt to its

Research point	Unique articles in this chapter 2018 or prior	Unique articles in this chapter 2019-to present
Introduction	21	20
Search Strategy	47	98
Procedures and Methodology	21	05
Research Findings	15	1
TOTAL UNIQUE REFERENCES	104	124

Note. Some references may be utilized in multiple Articles; however, they are only counted within the research point where they appear.

The foundational theory of this study was complex adaptive systems. A few early papers introduced complex adaptive systems (Jantsch, 1980; Lewin, 1999; Holland, 1992; Gell-Mann, 1994; Dooley, 1997; Jost, 2004).

The study of complex adaptive systems has influenced many areas of science and technology. It was a foundational area in which systems of complexity were built. One such field was robotics. A complex adaptive system was in an optimal state when operating at the environment to survive and thrive (Holland, 1992; Gell-Mann, 1994). Adaptability was essential for complex systems because their environment was constantly changing. The complex adaptive system was a subset of systems theory (Jantsch, 1980; Lewin, 1999; Holland, 1992; Gell-Mann, 1994; Dooley 1997; Jost, 2004), which was an extensive set of assumptions, constructs, theories, models, and methodologies. Some examples of complex adaptive systems are the immune system, financial markets, social organizations, ecological systems, and climate. Many authors had minor differences in their definitions of complex adaptive systems theory. Studying complex adaptive systems was interdisciplinary and drew from many fields, including biology, computer science, economics, physics, and sociology. Complex adaptive systems (CAS) encompass many systems that exhibit emergent behavior, adaptation, and self- organization. These systems could be classified into three broad categories: natural life, social systems, and artificial life or systems (Holland, 2006; Mitchell, 2009).

Major external events and the dynamics of complex adaptive systems could influence a system, potentially leading to complete failure or partial disruption. This concept aligns with the nature of an edge of chaos. The use of complex adaptive systems was a foundational concept that could significantly enhance robotics, making more complex and advanced systems create robots that were more adaptive and resilient to change. Many challenges needed to be overcome to develop robots that were truly complex adaptive systems. One challenge was the need to create a robot composed of many small parts that could interact with each other. Another challenge was the need to create a robot that could learn from its environment and adapt to changes in its environment. Yu et al. (2021) conducted quantitative research to propose an adaptive fuzzy feedback control that would help improve the tracking accuracy in robot manipulation. This helped with the apparent uncertainties that were seen in the operation of robotic manipulation accuracy. This study presented an adaptive fuzzy full-state and output-feedback control scheme for uncertain robots with output constraints. They offered a new adaptive fuzzy control scheme composed of a full-state feedback control and output- feedback control combined to compensate for uncertainties and enforce output constraints. Yu et al.'s proposed scheme enabled robots to track desired trajectories while satisfying output constraints accurately. The effectiveness of the proposed control scheme was verified through simulation results.

ecosystem, which is resilient and capable of evolving and adapting to external changes and stimuli without the entire system collapsing. When humans have a drastic influence on an ecosystem, it generally starts to fail or even collapse. This led to a further point by Yu et al. (2021), in which resilience and four sub-attributes were proposed. The goal was to create that behavior that was viewed in many complex adaptive systems, developing countermeasures to failures and significant external events. When discussing complex adaptive systems, it was essential to introduce some progenitors and how their theories and work built up to complex adaptive systems. Starting with complexity, Edmonds & von Bertalanffy (1977), the creator of general systems theory, was credited with coining the term "systems thinking." Edmonds & von Bertalanffy defined it "as a complex of interacting components, concepts characteristic of organized wholes such as interaction, sum, mechanization, centralization, competition, finality, etc., and to apply them to concrete phenomena." (p. 91) In other words, a complex system had many pieces that interacted non-linearly and were well-ordered. A field that was still developing was complexity theory. It was interdisciplinary and incorporated concepts from other disciplines, including arithmetic, physics, biology, psychology, economics, and many pieces that interacted non-linearly and were well-ordered. A field that was still developing was complexity theory. It was interdisciplinary and incorporated concepts from other disciplines, including arithmetic, physics, biology, psychology, economics, and so forth. The behavior of systems with numerous interacting pieces was a topic of complexity theory. Because they were challenging to comprehend and anticipate, these systems were called "complex." Complexity theory was also used to develop artificial intelligence algorithms and design new computer networks. Complex systems were frequently "open" systems, which implied they interacted with their surroundings by exchanging matter and energy.

Complex open systems include living systems like the human body. Mathematicians like Benoit Mandelbrot and James Gleick contributed to the study of complexity (Gleick, 1987; Mandelbrot, 1977). Systems that were "self-similar" or had the same structure at many scales were attractive to mathematicians. For instance, a shoreline appeared different when viewed up close compared to when viewed from a distance, yet the general shape remained the same. Jantsch (1980) helped to lay the foundation of complex adaptive systems. Jantsch talked so forth.

could be viewed as a whole or micro-level and how parts of the system worked together, arguing that systems were complicated and complex. In contrast, complicated systems were a collection of many factors that worked together. At the same time, complex systems had many parts that interacted with each other.

Lewin (1999) explored the science of complexity and its implications for understanding life. Lewin discussed the history of the field and the work of its pioneers, as well as establishing the latest findings and theories. Lewin showed how complexity theory could help us to understand the behavior of living systems, including the human brain. Lewin offered a new perspective on the nature of evolution.

This idea laid some of the foundations for complex adaptive systems theory.

Van de Vijver's (1988) Tree of Knowledge was a philosophical work that explored the nature of knowledge and how knowledge was acquired. The biology of cognition was first covered in the book, after which the epistemology of scientific knowledge was explored. The discussion of the ontology of knowledge, emphasizing the idea of truth, served as the book's conclusion. The philosophical work supported the complex about how evolution could be viewed as a process of self-organization. Jantsch studied the paradigm of evolution and focused more on unifying values than just an updated advancement of new knowledge in evolution. Jantsch also discussed how life adapted and evolved—describing how these systems interacted and their natural dynamics. The author wrote about how systems

The foundation of chaos theory, sensitive dependence on initial conditions, was discussed in the author's work. Chaos theory states that complex systems have no cause-and-effect relationship; many possible connections could cause a particular outcome.

This meant that it was nearly impossible to predict the behavior of complex systems with 100% accuracy. Lorenz discovered that small changes in a system could result in significant, unpredictable changes in behavior. The butterfly effect was a well-known example of this principle. Chaos theory has been used to explain various phenomena, including weather patterns, stock market fluctuations, and the spread of diseases.

When coming to the conclusion of whether a system was a complex adaptive system, it was not easy to discern at first. Still, one factor all complex adaptive systems had in common was evolution. The most essential characteristic of complex adaptive systems is their ability to

adaptive systems theory and thoroughly explained how living systems were autopoietic. Chaos theory was a founding principle behind complex adaptive systems, which indicated that systems were dynamic and constantly changing (Lorenz, 1963). In 1963, Lorenz wrote a paper on the strange attractor known as the Lorenz attractor, which resulted from a straightforward set of differential equations.

response to a virus or infection. The temperature outside could drop unexpectedly, or the sun could emerge and heat the area. The thermostat had to change the temperature to maintain the desired temperature. Complex adaptive systems, however, went beyond simple adaptation and evolution. Lastly, Holland mentioned that a complex adaptive system could also be anticipated. For example, when a dog followed a command and heard a click or indicator, it expected to receive a treat.

Furthering to the point of discerning truth from complex adaptive systems, Jost (2004) stated that "complex adaptive systems try to increase their external complexity and to reduce their internal complexity" (p. 1-2). Jost (2004) formalized the concept of external complexity, positing that a system tends to minimize the influx of information from its environment. This is achieved by managing learn and adapt to a situation or event. The system was constantly learning and constantly evolving to be able to handle different situations that it encountered. Holland (1992) stated that even straightforward things could be an adaptive system. In his work, Holland discussed how a thermostat could be viewed as an adaptive system. Simple parts like a sensor to gauge the temperature, a control to set the preferred temperature, and an actuator to turn the heat on or off made up a thermostat.

The thermostat was an adaptive system because it had to adjust constantly to the shifting environment, even though it did so more superficially than an immune system evolving in.

While Gell-Mann would have said computer-based and complex adaptive systems were unified in thought, others would have said complex adaptive systems were akin to artificial life. I favor a comprehensive point of view according to which the operation of CAS encompasses such diverse processes as the prebiotic chemical reactions that produced life on Earth, biological evolution itself, the functioning of individual organisms and ecological communities, the operation of biological subsystems such as mammalian immune systems or human brains, aspects of human cultural evolution, and adaptive functioning of computer hardware and software. Such a point of view the system's internal complexity. In order to maximize information gain, the complexity of the system should ideally be maximized. This is because complex systems are more likely to contain new and meaningful information. Although the dataset can be diverse, the system should ideally select its input to maximize information gain. However, the system's ability to gain new information is limited by its need to observe external data. As such, a complex adaptive system learns from the data it has access to but cannot capture all external information. Many researchers and scientists have been divided on the whole meaning of complex adaptive systems. Gell-Mann (1994) stated that his definition of complex adaptive systems differed from his fellow researchers.

V. Complex Adaptive Systems Theory in Robotics Studies

The field of robotics has seen significant advancements in recent years, with a growing focus on incorporating complex adaptive systems (CAS) in developing intelligent robotic systems. This approach has led to the emergence of diverse types of robotic systems that exhibit complex behaviors and adapt to their environment. In this context, several studies explored the application of CAS theory in different aspects of robotics, including distributed robotic systems, multileads to attempts to understand the general principles that underlie all such systems and the crucial differences among them. The principles would be expected to apply to the CAS that must exist on other planets scattered through the universe. (p. 18) When it concerned complex adaptive systems, it was no surprise that they showed similarities in their inner workings. Lansing (2003) and Holland (1992) discussed how a city and an ecosystem could somehow support themselves. Adam Smith's "invisible hand" was briefly mentioned but was an inadequate answer. Complex adaptive systems evolved, and this adaptability ensured a system remained stable, as in the case of a city and its supply of goods or the movement and operation of an ecosystem. The question of how such systems sustained themselves was complex, and the answer was the same: their adaptability to changes within their systems. A complex adaptive system is a system that can adapt to changes in its environment by evolving and changing itself. This adaptability has been essential for the survival of complex systems. A complex adaptive system consists of multiple models, theories, assumptions, and a subset of nonlinear dynamical systems. A dynamic approach had many points of interaction, with three major factors: the first was to learn and adapt its ability to evolve, the second was its behavior of aggregation, and the third was its ability to anticipate. Complex adaptive systems can be agent robotic systems, and swarm robotic systems. The following entries provided an overview of various research papers that have considered or utilized CAS theory in their exploration of robotics.

When discussing complex adaptive systems in robotics, one must consider many diverse robotic systems, including distributed robotic systems, where each robotic system is connected to other robotic systems via a communication network. Zedadra et al. (2017) stated, "Many artificial systems such as distributed computing systems and artificial intelligence systems are characterized by complex behaviors" (p. 1). This is known as a complex adaptive system, and both Lansing (2003) and Zedadra et al. (2017) agreed that multi-agent robotic systems, where each robotic system was controlled by its own intelligent agent. Swarm robotic systems, where each robotic system was controlled by a simple set of rules that governed its interactions with other robotic systems.

human operator who was not physically present with the robot. However, even in autonomous robots, the decision-making process is set in a specific way (Fahimi, 2009).

In autonomous robotics, the robot can make its own decisions and carry out actions without any human intervention. Some robots were programmed for repetitive tasks, while others used AI to machine learning to seen everywhere, from the brain to the ocean's ecosystem to a computer simulation. It was the theory of complex adaptive systems that can be used to base many future studies, such as how it has been a foundation of thought for robotics (Jantsch, 1980; Lewin, 1999; Holland, 1992; Gell Mann, 1994; Dooley 1997; Jost, 2004).

In several cases, robotics could be considered part of a more extraordinarily complex adaptive system. According to Gell-Mann (1994), the CAS era was characterized by the growth of autonomous learning and evolving systems instead of those humans created. Contrast this with the expert system era, in which specialists created systems that did not evolve or adapt over time. The previous generation of expert systems was built using input from subject-matter experts, but it needed to learn from its experience. "The new era of CAS in robotics and other such fields is the age of constructed systems that learn by formulating schemata subject to variation and selection according to results in the real world." (Gell-Mann, 1994, p. 20). An example of a system that could learn was robotics. In this case, some combined pieces to create a complex adaptive system.

Another example was Han et al. (2019), who presented an ecological approach to intelligent healthscape for a medical service robot. A complex adaptive system composed of various make decisions and carry out actions independently (Jost, 2004). When using machine learning, robots constantly learn and improve their skills as they gain more experience—for example, using neural networks in robotics. A robotics use of neural networks would be considered a complex adaptive system because they constantly learn and adjust to new data. This means that they were continually changing and adapting to new information.

Schneider and Somers (2006) stated that artificial neural networks, usually called neural networks, were an appropriate method that contributed by clarifying the properties of complex adaptive systems. Artificial neural networks were used in many different robotic applications. The most common application was artificial neural networks for learning and control purposes. In the decision process of a robot, many different methods could be used. Artificial neural networks were one of the most popular methods that were used. Artificial neural networks were used for pattern recognition and could learn from their mistakes (Schneider & Somers, 2006). While Khayut et al. (2014) discussed fuzzy logic, among other things, which was another popular method used for decision-making, fuzzy logic could agents and resources could be made from an intelligent healthscape. In addition, the intelligent healthcape helped individuals in the community by providing opportunities for social interaction and participation. Identifying the process by which a robot decided or processed an action was essential. The three methods were autonomous, semi-autonomous, and remote. In autonomous robotics, the robot can make its own decisions and carry out actions without any human intervention. In semi-autonomous robotics, the robot can make its own decisions but still requires some human intervention. In remote robotics, the robot was controlled by a

consider many different factors when making a decision. Evolutionary algorithms were also used for optimization and could adapt to the changing environment.

Dell'Anna and Jamshidnejad (2022) presented the application of fuzzy logic systems to socially assistive robots (SARs). The authors argued that such systems could be used to create personalized robots to assist individuals in a social setting better. They presented results from a user study evaluating the system's effectiveness. With fuzzy logic, the authors created a system that could adapt to the user's needs and preferences and improve the user's experience with the SAR.

people and objects in the area and assist. Another advantage of using neural networks was that they could learn to make predictions. This means that they could predict the behavior of objects and people. This could be useful in several different situations. For example, a robot equipped with a neural network could be used to predict a person's path. The robot could make a prediction based on the person's movements and then take the appropriate action. A disadvantage of using neural networks was that they could learn slowly. This means that the robot may take a long time to learn to make predictions. Sometimes, robots may need to learn to make predictions (Jost, 2004).

It was crucial to consider the role of feedback loops in robotic systems design. Feedback loops allow a system to adapt to its environment and to learn from its experiences. Without feedback loops, a robotic system could not change its behavior in response to environmental changes (Everett et al., 2021). Feedback loops were essential for modern robotic systems to make more extraordinary advancements necessary for growth and utility. They must interact with their surroundings. For example, a robot that was designed to clean floors may need to be able to adjust its behavior based on the type

Rainer et al. (2018) discussed a decision-making algorithm using fuzzy logic. The purpose was to use it on an autonomous guide robot. The algorithm was based on the idea of a rule-based system, in which a set of rules was used to determine the robot's actions. These rules were determined by a group of inputs, which included the robot's current position, the destination, and the obstacles in the environment. The algorithm outputs the robot's actions, which were determined by the rules. The authors tested the algorithm on a simulated environment and showed that it could navigate the environment and reach the destination without collision.

Jost (2004) stated that one advantage of using neural networks in robotics was that they could learn to recognize patterns. This means that they could identify objects and react to them accordingly. For example, a robot equipped with a neural network could be used in a restaurant with many events. The robot could identify applications, such as autonomous vehicles and robotics. The paper's primary contribution was the development of a novel algorithm for computing the reachable sets of closed-loop systems with neural network controllers. The algorithm was based on a convex optimization problem that was computationally efficient and could handle sources of uncertainty, high dimensionality, of floor it was cleaning. If the robot was not equipped with feedback loops, the robot might sweep the floor in the same way regardless of whether the floor was made of carpet or tile. This could result in the robot damaging the floor or not cleaning effectively.

Everett et al. (2021) conducted quantitative research that presented a novel algorithm for computing the reachable sets of closed-loop systems with neural network controllers. The authors addressed the challenge of analyzing the safety and performance of closed-loop systems with neural network (NN) controllers. Safety verification of such systems was crucial as they were increasingly used in safety-critical time steps, capturing other uncertainties and nonlinearities, and synthesizing provably robust control policies.

Nolfi (2011) explored behavior and cognition as a complex adaptive system, focusing on insights that can be gleaned from robotic experiments. The author discussed the concept of complex systems, noting that they are composed of many interacting parts that can give rise to emergent phenomena. The author discussed behavior and cognition as a complex adaptive system, specifically due to the interactions between an organism's brain, body, and environment. Nolfi then argued that behavior and cognition could be viewed as complex adaptive systems in which agents and nonlinear dynamics. The numerical experiments showed that the proposed algorithm provided 5x better accuracy in 150x less computation time than the state-of-the-art and applied to real-world systems. Additionally, a novel backward reachability algorithm was provided to inform the design of an initial state set when only the target state set was known/specified.

The new algorithm (Everett et al., 2021) was shown to be substantially faster and less conservative than previous methods. The authors presented a new approach to formal safety analysis of systems with neural network controllers. The approach was based on a new technique called "reachable set approximation." The technique was substantially faster and less conservative than previous methods.

Everett et al. (2021) proposed a convex relaxation-based algorithm for analyzing neural feedback loops (NFLs) with neural network (NN) controllers. The proposed algorithm was computationally efficient and could account for sensor and process noise and nonlinearities in the dynamics. Results showed that this work advanced the state-of-the-art in guaranteeing properties of systems that employed NNs in the feedback loop. Future directions included mitigating the conservatism due to the accumulation of approximation error over interact with their environment to learn and adapt. Through examples of robotic experiments, the author illustrated how this complex system nature of behavior and cognition could result from the interactions between the agent's control system, body, and environment, as well as from the dynamical processes occurring within each of these elements.

The implications of this complex adaptive system of behavioral and cognitive skills were further discussed, with particular attention to the notion and role of embodiment and situatedness.

Stanescu et al. (2008) discussed the development of industrial robotics toward intelligent robotic systems, emphasizing the role of Complex Adaptive Systems (CAS) in this transition. They discussed the history of robotics and how industrial robotics has developed over time. The authors then attempt to cope with uncertainty and to gain knowledge from past mistakes (Bennet & Benne, 2003).

Errors are inevitable, but that does not mean systems cannot learn from and recover from them. The thought process should eliminate some errors and create the ability to heal and adapt from those errors to classify and recover. Kristiansen et al. (2020) conducted a many

addressed the challenges faced in making robots more intelligent and how these challenges have been overcome, particularly through the incorporation of CAS. Finally, the authors discussed the future of robotics and how intelligent robotic systems, enriched by CAS, could play a crucial role. They envisioned a world where these advanced systems can seamlessly integrate into various industries, improving efficiency, productivity, and safety while reducing the need for human intervention in hazardous or repetitive tasks.

VI. UNCERTAINTY, ERROR HANDLING, AND MECHANICAL LIMITATIONS IN ROBOTICS AND CAS

If the basis of current and expanding robotics is complex adaptive systems, then uncertainty is apparent. Since a complex adaptive system operates at the edge of chaos, a complex adaptive system will certainly have uncertainty in an environment. Sengupta (2016) stated that there is a clear relationship between uncertainty and complex adaptive systems. Complex adaptive systems are, by definition, systems that are constantly changing and evolving in response to their environment. Complex adaptive systems are inherently uncertain, and any attempt to predict their future behavior is fraught with uncertainty. This does not negate the possibility of comprehensive quantitative study, employing a systematic approach to develop an automatic error classification and recovery strategy for robot assembly tasks. Utilizing a combination of advanced algorithms, machine learning techniques, and experimental data, the researchers aimed to improve the adaptability and efficiency of robotic systems in various settings, including food service. The strategy can also be replicated for robots in other settings, such as food service. A dominant theme in the author's work was the inability of robots to accommodate change and errors. For example, suppose a customer wants ketchup on their bun. In that case, the robot must be programmed to account for this customization. If the customer wants more ketchup than what is available, the robot may need help to fulfill this order.

Kristiansen et al. (2020) stated that this could lead to customer dissatisfaction and even cause them to stop using the service. Companies need to consider human factors when designing and implementing robotic systems. The system should consider human limitations such as vision, hearing, and strength. For example, if a robot is designed to lift heavy objects, it should be designed in a way that will

Wang et al. (2021) employed a mixed

understanding and modeling complex adaptive systems. However, it underscores the need for awareness of the inherent uncertainty in any such endeavor. Complex adaptive systems abound with uncertainty. This is a result of the systems' ongoing evolution. There is no ideal method to carry out any task or resolve any issue. The best course of action is to not injure the user. There are many benefits to using robotic systems, such as improving efficiency and accuracy. Robotics can also reduce costs. However, companies must be aware of these systems' limitations and consider human factors when designing and implementing them. Kristiansen et al. (2020) found that this strategy was highly successful, with a 99.6% success rate for error classification and a 98.8% recovery rate. However, all failed attempts at recovery were resolved in the next cycle. Kristiansen et al. provided a strategy that can be replicated in other settings. Suppose the customer requests a change or customization to their order. In that case, it is difficult for the robots to respond since they are not adaptable.

Jarrar et al. (2020) conducted a systematic literature review on agent-based modeling in complex adaptive systems. The review aimed to synthesize the current state of knowledge and identify the key challenges and limitations associated with agent-based modeling in these systems. The study did not involve a meta-methods research design that incorporated theoretical analysis and empirical data collection, allowing the authors to understand various aspects of uncertainty in robotics applications. The key components of the research design included theoretical analysis, experimental design, data analysis, and strategy development.

The study by Wang et al. (2021) focused on geometric and physical uncertainties in robotics applications, discussing how they could make it difficult for a robot to handle unfamiliar objects. Two main types of uncertainty can exist in robotics applications: geometric uncertainty and physical uncertainty. Geometric uncertainty refers to situations where the robot does not have complete information about the shape or size of an object. In contrast, physical uncertainty refers to situations where the robot lacks complete information about the object's material properties or weight. Through a comprehensive approach combining theoretical analysis and empirical data collection, Wang et al. (2021) provided valuable insights into the challenges posed by uncertainty in robotics applications. They offered practical strategies for addressing these issues. This study contributed significantly to the field of robotics by enhancing the understanding of the role of analysis but focused on a qualitative synthesis of the existing literature. The authors briefly mentioned the errors that occur in complex adaptive systems. Errors and uncertainty in a complex adaptive system are possible due to the complexity of the system and external factors surrounding it. The authors stated that a good way to overcome some of these issues is to address these issues before the construction phase.

Uncertainty is a fundamental challenge in robotics, particularly when dealing with complex systems and operating in intricate environments. temporal requirements in robotics. Even when solutions to uncertainty and error handling are available as viable options for situations, it comes down to cost, as in the cost of process and computation. Kanazawa et al. (2019) mentioned, "GPR-based approaches can also model human trajectories and express its uncertainty with high precision" (p. 819). Other considerations need to be made besides calculation cost, such as other internal and external variables. The authors discussed many details and methods to maximize efficiency and improve safety as well as decision-making or, in this case, predictions and optimal solutions to movement. Using these methods and approaches, they looked at dealing with the relationship between collision avoidance and temporal requirements and uncertainty in complex robotic systems and suggesting ways to mitigate its impact on robotic performance. Kanazawa et al. (2019) conducted a quantitative study on human trajectory modeling using Gaussian process regression (GPR) for collision avoidance and

based on the information they gather. This behavior, studied by Garcia-Saura et al. (2021), can serve as a model for robotic systems. Analogous to animals, robots use sensors to collect data about their surroundings and base their actions on the information received. "Likewise, autonomous robotic search problems always face some level of uncertainty regarding the environment, sensor performance and reliability, the motor plant function, the possible location of the search targets, the latency in which they may appear/disappear, or move, etc." (Garcia-Saura et al., 2021, p. 1). In short, the goal is to implement natural strategies reflected in what is found in nature.

Giberti et al. (2022) conducted a quantitative study on the transition of robotics from traditional manufacturing to commercial use, focusing on the need for flexibility and personalization. Robotics has transitioned from traditional repetitive manufacturing to commercial use, such as food service, hospitality, and operations. With that shift came the need for more flexibility and personalization (Giberti et al., 2022, p. 3). As how this tradeoff works. Kanazawa et al. (2019) stated, "By planning the trajectory in consideration of the predicted trajectory of the worker, this strategy enables to simultaneously satisfy two requirements: collision avoidance and the reduction of the waste time" (p. 820).

Garcia-Saura et al. (2021) conducted a qualitative study on animal search behavior and its potential applications in robotics. The researchers aimed to implement natural strategies observed in animals to improve autonomous robotic search performance in uncertain environments. Drawing parallels with the animal kingdom can enhance our understanding of how robotics should operate in environments characterized by high uncertainty. One such parallel can be seen in animal search behavior. Animals in nature, faced with varying degrees of environmental uncertainty, must decide on their next move

VII. GENERAL KNOWLEDGE FRAMEWORK

Integrating robotics into various aspects of modern society has brought significant advancements and transformative changes. From industrial settings to our homes, robots are playing an increasingly crucial role in performing tasks and assisting humans. However, with the rise of robotics, ensuring the safety of both humans and robots has

such, the environments in these settings are typically more complex than, for example, a clean and organized factory. Additionally, as the complexity of tasks required for robots has increased, so has the potential for errors. One approach to mitigate these errors is the implementation of a correction strategy. Even if each skill is standardly programmed, and the robot thus knows how the required activities or manipulations must be carried out, the specificities of each different workstation may cause some errors that make the task not properly executable. Built-in correction strategies are then preliminarily implemented so the machine can guide a non-expert user in this correction (Giberti et al., 2022, p. 3).

robots, safety protocols are usually built in with extra caution. Safety measures can sometimes be added for noncollaborative robots, but many lack such efforts (Bi et al., 2021).

Commonly used protocols include stop buttons or emergency shutdown procedures that allow humans to halt a robot in an emergency. Other protocols involve setting speed and distance limits to ensure a robot does not move too quickly or get too close to a human (Johnson et al., 2006). However, advancements in robotics have created better forms of safety protocol to allow the robots to work with us. Studies have proposed become a critical concern. This section explored the concepts of robotics, machine learning, and safety. The challenges posed by uncertainty in robotics, the occurrence and impact of errors, the importance of robotic vision, touch, and mobility, and the integration of machine learning into robotics. This provided a general knowledge framework when discussing robotics' impact on food service.

VIII. ROBOTIC AND HUMAN SAFETY

Robotic and Human safety is a critical issue in modern society, particularly with the increasing use of robots in industry, food service, and even our homes. When discussing robotics and robot safety, we should first identify the difference between cooperative and noncooperative robots. Cooperative or collaborative robots are designed to work with humans and assist them in performing tasks to help people. Noncooperative or noncollaborative robots, on the other hand, are autonomous and programmed to complete a task without human assistance. Safety measures should be in place for both robots to minimize any risk of injury or damage. For collaborative automation in many areas, such as slaughtering, textiles, weeding, fruit and vegetable picking, and many more tasks that would typically need to be done manually or guidelines to ensure safe interaction between humans and robots. These include designing robots with features that reduce risk, such as sensors to detect humans in the vicinity or bumpers to prevent collisions (Vasic & Billard, 2013). In addition, haptic feedback systems can be used so that robots can physically respond when they come into contact with humans (Fritzsche et al., 2011).

IX. AUTOMATION OF FOOD PRODUCTION.

Robotics have been used to automate various aspects of food production for decades. Machines such as robotic arms can be programmed to perform specific tasks, such as cutting vegetables or mixing dough, more accurately than humans (Bader & Rahimifard, 2020). Agriculture is the basis and starting point for all food production; automating growing, maintaining, and harvesting at this level allows further progression and expansion. (Le et al., 2020; Sparrow & Howard, 2021). Food production from an agricultural perspective has seen many studies with a focus on robotic

Instead of producing a single, definitive value for a quantity observed through sensors, robots must often rely on making a single best guess based on available data (Thrun, assisted by machines (Sparrow & Howard, 2021). Robotics can also automate processes such as packaging and labeling, which are traditionally labor-intensive activities (Accorsi et al., 2019).

Current robotic advancement has also enabled robotic systems to do more complex work, such as sorting and food inspection, which allowed for increased food quality and safety (Khan et al., 2021). Automation allows for improving current KPIs, efficiency, costs, safety, and quality. Not only is the benefit of cost saving critical to continued growth but the ability to work in more dangerous areas and climates, as well as having remote access or even systems that require very little supervision, allowing continuous operation without the need for breaks (E Fatima et al., 2022). Furthermore, robots can be programmed to detect defects or impurities in manufacturing to minimize waste in ingredients or products and ensure quality control during production (Azamfirei et al., 2023). These automated processes reduce the need for manual labor while improving consistency and accuracy in food production.

and objects are affected by environmental factors like temperature and humidity (Xu et al., 2019).

X. UNCERTAINTY IN ROBOTICS

2000).

Industrial robots are increasingly designed to collaborate with human workers in the same workspace to improve productivity and product quality. This raised the question of improving worker safety and work-time efficiency while accounting for the unpredictability of human behavior. Because of the worker's erratic behavior, motion planning for the robot becomes difficult, increasing the risk of collisions (Kanazawa et al., 2019). To plan collision-free trajectories and maximize task efficiency, robots interacting with humans must predict human nuanced movements. However, predicting human motion is inherently difficult because of the non-linearity and stochasticity of human behavior and individual differences. Prediction models that are accurate and robust enough for real-world applications are still a work in progress (Cheng et al., 2019). It is challenging to guarantee precise motion control for robots in human-robot interaction and multi-robot cooperation, as they must be compliant with the contact forces exerted by the external environment. Despite successes in force control, uncertainties remain a challenge when dealing with redundant manipulators. Other values are not accounted for, such as the stiffness of contact surfaces and how material and objects are affected by environmental factors like temperature and

Robots are limited in their ability to accurately assess the state of their environments due to sensor limitations, noise, and unpredictability.

dissertation: complex adaptative systems. These systems are inherently unpredictable and nonlinear, making it difficult to predict outcomes and control their behavior (Holland, 1992). This makes it difficult to program robots to act in specific ways, as they are in an environment that increases those uncertain factors. This is not to say we cannot program a robot to do a task, but say, for example, a chef robot makes food. Now the ingredients are missing, a human is in the way, or even the ingredients have been moved to the side. These changes can create a higher level of uncertainty on top of other factors (Esfahani & Malek, 2013). There is always a certain degree of uncertainty. Some environments contain a much higher number than others. One example is stock trading. In a market, public companies have stocks that are bought and sold. We make predictions using the information to buy or sell to make a profit, but there is risk involved and no guarantee that profit could be made. This is based on the uncertainty apparent in the market and all the factors and information that affect the price of a stock or company.

XI. ERRORS IN ROBOTICS

An error in a program is a bug or defect that

humidity (Xu et al., 2019).

A cause for such uncertainty in robotics can be rooted back to the theory mentioned in this environment. An example of this type of error could be a robot not responding to changes in the environment it is operating in or failing to recognize the presence of a new component, which can cause an error (Correll et al., 2022).

According to Tian & Oviatt (2021), error or failure in Human-Robot Interaction (HRI) can be defined as any behavior exhibited by a robot that deviates from the desired or normal expectations of the user. Such errors can be either technical, in which the robot fails to deliver its designed function, or perceived, in which it can provide its function but is not accepted by the user. When discussing errors in robotics, especially those developed as a complex adaptive system, it is vital that we see how errors work in humans. Errors in humans can help show us errors in other complex adaptive systems more straightforwardly (Senders & Moray, 2020). Wright et al. (2020) found that robot errors can cause long- term effects on one's perception of a robot's reliability. A considerable issue in robotics is errors; what does a robot do when an error occurs? Robotic errors are partly from a robot's uncertainty about its surroundings and causes the program to produce an unintended or undesired outcome or behave unexpectedly. Errors can be caused by syntax errors, logical errors, improper design, or incorrect data (Pressman & Maxim, 2020). Driving from the concepts of uncertainty in complex adaptive systems, many errors can occur because of the lack of knowledge of how the system works and responds to various inputs. This is due to the large amount of data in an ever-changing

precise and fast grasping comparable to humans. Robot vision can come in many forms, such as infrared or light-based technologies. It can be used to identify and track objects or aid in navigation. Vision is critical for every aspect of the operation of a complex robot or bioinspired. If the tasks required are complex in nature, they require more input to work (Mazzola & Laschi, 2020). For instance, Wan & Goudos (2020) discussed an improved vision method for fruit detection. Still, it has many areas of effect: "Fruit classification isnt only mainly applied to fruit quality detection, sorting by classifications, maturity identification, defect detection, and robot picking." (p. 2) This can be applied to other areas, such as food service in management and vision control of different foods and the environment around them. Other sensors play a part in the determination of task completion. Faisal et al. (2020) developed a method to detect the maturity

information.

XII. ROBOTIC VISION, TOUCH, AND MOBILITY

Machine learning-enabled vision is one of the most important aspects of robotics that should be addressed. According to Bai et al. (2020), as machine learning develops, its ability to be used in machine vision is becoming increasingly evident. Object detection and recognition are required for a robot's ability to perform

XIII. THE INTEGRATION OF MACHINE LEARNING INTO ROBOTICS

"Robotic learning lies at the intersection of machine learning and robotics" (Ibarz et al., 2021, p. 698). Using machine learning in robotics is vital to fulfilling the need for more complex and modern robotics (Mosavi & Varkonyi-Koczy, 2017). Most traditional robotics can achieve simple tasks in known environments that do not change. However, when creating social robots among other more sophisticated robots, they are required to do more complex tasks, and the information from the environment is continuously changing. However, it is more complicated than just adding machine learning to a robot. More information adds complexity and layers of new decision-making (Chaudhuri & Bose, 2020). According to Singh and weight of date food. A study by Salim et al. (2021) discussed robots' ability to identify food and have a high level of certainty about the item in question. Touch and movement are other aspects needed for complex tasks; when at optimal levels, the combination of the three allows for highly complex tasks to be done. According to Xiao et al. (2022), robots need to be able to navigate complex environments in order to be intelligent. Many years of research and development have gone into creating efficient navigation systems for mobile robots. Robotic haptic feedback allows the perception and interaction with elastic and deformable objects in their environment, allowing for additional sensory input (Bednarek et al., 2019).

demonstrated promise in enabling physical robots to learn complex skills in the real world. When using deep reinforcement learning, a robot can achieve complex behaviors based on the input of raw sensory data. This could enable robots to demonstrate complex skills (Ibarz et al., 2021).

XIV. ARTIFICIAL LIFE

Artificial intelligence is concerned with developing machines that think and reason like humans or other living things. In contrast, machine learning is focused on developing algorithms that can learn from data. The goal et al. (2019), robotic reinforcement learning, combined with deep neural networks, allows robots to learn from raw sensory inputs, such as camera images or feedback sensors. This combines estimation and control into a single model. For practical use of reinforcement learning in real-world applications, a reward function must be manually programmed to indicate the objective of the task. Simply put, the robot will learn as it works, gaining experience. Deep reinforcement learning (RL) has emerged as a promising approach for autonomously acquiring complex behaviors from low-level sensor observations (Mnih et al., 2015). Although a large portion of deep RL research has focused on applications in video games and simulated control, which does not connect with the constraints of learning in natural environments, deep RL has also such as cellular automata (Langton, 1986). An organism is composed of intrinsically inanimate cells. If this is the case, then artificially created cells with similar properties could be used to construct complex life.

Both machine learning and living organisms rely on the ability to learn and adapt. Machine learning focuses on developing algorithms that can learn from data and improve performance over time, while living organisms rely on their ability to learn and adapt to new information. Artificial life forms of artificial intelligence is to expand human growth. Still, as a by-product, it can be the means to create artificial life. Although there is no universally accepted definition of life, it is generally defined by shared characteristics, such as the ability to grow, reproduce, respond to stimuli, and maintain homeostasis (Margulis et al., 2000; Buddingh' & van Hest, 2017). Living organisms comprise cells with a metabolism that converts energy and matter. Consider the following aspects to understand how artificial intelligence may contribute to the creation of artificial life:

Artificial life forms, for instance, might be capable of reproducing and evolving through digital means. This is exemplified by genetic algorithms and other evolutionary computation techniques, which are inspired by natural selection. They can be used to optimize AI systems. These methods allow for new generations of AI systems that inherit traits from their predecessors and evolve over time. Alternatively, they could consist of artificial cells within the organism's system. AI systems, particularly those based on neural networks or other distributed architectures, can exhibit emergent behavior and complexity. By developing AI systems that can generate complex, adaptive behaviors, we come closer to adding the ingredients needed to create life (O'Connor, 1983; Carmichael & Hadžikadić, can exhibit this adaptive behavior by incorporating machine learning techniques. Various forms of machine learning exist that best suit different conditions of incoming data. Some are designed to simulate life, such as the NeuroEvolution of Augmenting Topologies (NEAT), which is a genetic algorithm that evolves artificial neural networks by combining the optimization of network weights and the discovery of new network structures (Stanley & Miikkulainen, 2002). This approach allows for creating increasingly complex and adaptive behaviors in artificial life forms, enabling them to learn and adapt to new tasks and environments. NEAT has been successfully applied to various domains, including robotics, game- playing, and optimization problems (Stanley et al., 2005; Stanley, 2007). Newer variations of NEAT have also been developed, such as CoDeepNEAT, which combines NEAT with deep learning techniques to evolve the topology and weights of deep neural networks.

Living organisms, which are typically autonomous, often exhibit complex emergent behavior. This behavior arises from the interaction of many fundamental components software and hardware tested in 15 fast-food restaurants in Taiwan. Existing food service robot systems in Thailand and current perceptions of limitations were outlined.

2019).

Artificial intelligence, with specific reference to machine learning and deep learning, employs bio- mimicry. These technologies mimic how biological life forms work. For instance, neural networks are inspired by the structure and function of the human brain. Such as the human brain which is a massive network of neurons with connections between them, while in a neural network, artificial neurons or nodes are interconnected with weights to process and transmit information. These artificial neural networks aim to learn from data and adapt their performance over time, much like the human brain learns from experience. Bio-mimicry AI leverages the principles of biological systems to create more efficient, adaptive, and resilient artificial intelligence algorithms and architectures (Guan et al., 2021).

XV. Qualitative studies

Chen et al. (2022) developed an experimental food service robot in 2018 and a qualitative survey of employees exposed to the system in 2019 and 2020. Chen et al. noted that the aging population and declining birth rate in developed nations had caused high costs and drop-out in labor. The experimental design included

data. The first study looked at secondary data, These limitations included using waitpersons to serve customers' items once the robot had reached a table. Operational challenges for robots in the food service environment include "robot performance, high-level understanding, resource awareness, and task-driven perception" (Chen et al., 2022, p. 31467).

Chen et al. (2022) identified four key areas of operational challenges for food service robots, including the complexity of the operating environment, crowd levels during peak hours, spacing between tables in service areas, and the level of perceived friendliness of the robot interaction with customers. These operational challenges were discussed regarding software and hardware development design concepts.

XVII. Quantitative studies

Tuomi and Ascenção (2021) conducted a quantitative research study investigating robotics and automation in food service. The goal was to see how robotics and automation in food service affect specific sectors and, most importantly, address the relativity of a task or job that can be automated trying to fill the current research gap. The authors discussed automation, AI, and robotics and how they are becoming crucial to frontline tasks and responsibilities.

while the second was preliminary. The first study aimed to list all possible tasks commonplace in food service. The second study was to establish the automatability of food service.

Findings from Tuomi & Ascenção (2021) indicated that the tasks discussed in the study under food service showed that "58.8% are found to require mechanical, 26.8% analytical, 11.3% intuitive, and 3.1% empathetic intelligence" (Tuomi & Ascenção, 2021, p. 15).

Following results indicate that the automatability of tasks is broken down into three sources of development: (a) autonomous navigation, (b) object manipulation, and (c) natural language processing" (Tuomi & Ascenção, 2021, p. 15).

Ivanov et al. (2019) explored the state of robotics in hospitality and tourism and identified gaps in the literature. The authors discuss the history of robotics, how it was first coined, and its late arrival in the service sector. The authors identified several themes, including but not limited to the following:

1. The design of the robot.
2. Issues by consumers and employees.
3. The robot manufacturer.
4. The need to manipulate services capes to accommodate robots.

Tuomi & Ascenção (2021) focused on a quantitative method by employing an exploratory study using primary and secondary home appliances to make a meal. Before moving into the methodology, the authors used a mixed-method approach and a SWOT analysis.

Fonseca et al. (2019) deployed both quantitative and qualitative instruments. They used two questionnaires, a focus group, and two semi-structured interviews. The questionnaires were distributed via a convenience sampling directed to consumers (over 95% women) using technology via Facebook and Messenger. In comparison, the interviews were conducted with clients, professional chefs, and a robot supplier. Quantitative analysis was done on 300 answers, half from robot users and the other half from non-robot users. When visualizing the results, the researchers could easily associate the quality of life with using robots.

Findings Fonseca et al. (2019) study indicated that kitchen robots currently available from multiple manufacturers have revolutionized the way of cooking. They are supplemental and proven aids when creating a meal and were considered by users to be intuitive, time-saving, and simple to use. The data from the qualitative analysis shows that participants agreed that it would be difficult

XVII. MIXED STUDIES

Fonseca et al. (2019) conducted a 2018 Portuguese research study investigating multifunctional kitchen robots, their use in the kitchen, and how they can support users. The focus is on regular users, such as those who use to improve the efficiency and quality of restaurant service. Tuomi discussed the challenges and opportunities and provided recommendations for how restaurants can best take advantage of this technology. The methodology used in Tuomi's (2021) research is a mix of qualitative and quantitative methods. Tuomi used surveys, interviews, and observations to collect data from restaurants and customers. Tuomi also used a variety of analytical methods, including factor analysis and regression analysis, to analyze her data. Her study employs three stages of research. The first is a set of interviews and observations across the US, Japan, and the UK with 28 sites and 16 informants. The second stage used the LEGO® Serious Play®, and the final stage is an empirical evaluation. However, several challenges had to be addressed when implementing robots into hospitality services. These include the potential for job loss, customer resistance, and technical issues.

XIX. THEORY TIE-IN AND SUMMARY

for a robot to replace human beings. A limitation of the study was time and content length. Of particular note by participants was the value of using these devices for routine processes such as essential food preparation, cutting, weighing, or kneading. Robots were seen as facilitating the cooking process rather than replacing the cook.

Tuomi (2021) explored the potential for robots to be integrated into hospitality service in order

Lansing, 2003; Jost, 2004). Continued research and construction of more advanced robotics can propel the world towards the future. The ability to have robots take over tedious and time-consuming work along with dangerous jobs could create a safer and optimized work environment for humans.

XVIII. PROCEDURES AND METHODOLOGY

The problem this a comparative research study aimed to address is the potential discrepancy in food service performance and safety when comparing human and robotic service providers, as well as the implications of integrating robotics into the food service industry. This study employed a survey to compare a rollup of several scales from Song & Kim (2022), Bartneck et al. (2009), and Qin

The underlying theory and some of the supporting theories are used as the foundation for this study. Complex adaptive system (Holland, 1992; Gell-Mann, 1994; Dooley, 1997; Lansing, 2003; Jost, 2004), which is built on many models and theories such as chaos theory (Lorenz, 1963) builds on the importance and significance of the systems that surround us. Complex adaptive systems theory was chosen based on the current advancements of research and development that build on explaining more realistic models. There are many examples of complex adaptive systems, such as a market, an ecosystem, the brain, and even artificial life (Holland, 1992; Gell-Mann, 1994; Dooley, 1997;

considerations, limitations, and delimitations associated with the study before concluding with a summary.

XX. RESEARCH PARADIGM

This study adopted a quantitative approach to explore the impact of robotics on food service. Quantitative research was employed to gather and analyze numerical data, measure trends, evaluate opinions, and draw conclusions about a population (Creswell, 2013). The goal was to derive generalizable insights from the data collected, which could inform practices in the food service industry (Farrelly, 2013).

& Prybutok (2009). Researchers have called for further exploration of this topic (Wang et al., 2022; Grau et al., 2020). There has been a lack of quantitative research on the opinions on the potential impacts of robotics on the industry (Zemke, 2020). This study aimed to fill this gap by gathering empirical data from experts, including software engineers, data scientists, machine learning experts, those in the field of robotics, and those who have knowledge of IT in food service to find potential impacts of robotics on performance within the food service industry. This chapter described the method and design for this study, which used quantitative data to study the impact of robotics on food service performance. It outlined research questions, study population, sample size, source of data used in the study, data collection methods, and data analysis techniques. Furthermore, it discussed ethical 2015). By using quantitative methods such as surveys, researchers were able to collect factual information regarding attitudes toward robotics in food service, identify any trends or patterns, and measure how different factors may influence participants' responses. Additionally, these methods allowed researchers to compare their findings with those from other studies to gain a more comprehensive picture of the effects of robotics in food service. Quantitative research is often used to identify

The survey method allowed researchers to gather large amounts of data quickly and enabled them to draw generalizations from their findings. Furthermore, this methodology enabled the accurate comparison of experts' opinions on the potential impacts of robotics on the food service industry. The method was chosen because it allowed for an unbiased collection of information from a large sample size that could be used to make generalizations about the population being studied. Quantitative research involved the collection and storage of numerical data in an electronic database, as well as the analysis of this data using statistical methods (Watson, 2015).

A quantitative study was an appropriate approach for a research project focused on understanding the impacts of robotics on food service. Quantitative studies provided a valuable method of collecting and analyzing data to generate results that could be used to make decisions and assess changes (Leedy & Ormrod,

relates to the assumption of normality and claims that 'Before parametric statistical analysis is appropriate... the study sample must be drawn from a normally distributed population [italics theirs]' and (2) the sample size must be large enough to be representative of the population" (p. 626). It enabled the patterns and relationships between variables by examining data from multiple sources (Taherdoost, 2022). The results of quantitative studies can be used to explain relationships between variables and make predictions about future trends. Moreover, quantitative methods allowed researchers to compare different groups or populations on a variety of characteristics (Taherdoost, 2022).

This study employed a quantitative methodology due to the need for objective measurement and statistical analysis of the data collected. The nature of the research questions, which involved comparing performance and safety between food service robots and human employees, necessitated a quantitative approach. Quantitative methods allowed us to measure these variables in a way that qualitative methods could not, providing numerical data that could be analyzed to draw statistically valid conclusions. The Wilcoxon sign rank test was the primary statistical method used in this study. This non-parametric test was chosen since Likert scale survey responses are ordinal and non-parametric. As Norman (2010) stated, "Sin 1 is using parametric statistics on ordinal data. Sin 2

XVI. RESEARCH DESIGN

comparison of two related samples or repeated measurements on a single sample, which was useful in this study, given that we were comparing the performance scores of the same subjects under two different conditions.

Several other statistical tests were used besides the Wilcoxon sign rank test. Cronbach's alpha was used to confirm the survey instrument's reliability, ensuring it consistently measured the intended constructs. A confirmatory factor analysis (CFA) was performed to validate the survey instrument's factor structure, ensuring that each item loaded onto the intended factor. Spearman's rank correlation and Kendall's tau were used to measure correlations between ordinal variables, providing further insight into the relationships between different aspects of performance and safety. The correlations between scales were measured using Spearman's rank correlation and Kendall's tau, which provided additional insight into the relationships between various aspects of performance and safety. An analysis of variance (ANOVA) was also conducted to determine the impact of factors such as the highest level of education and organization size on the performance of service robots. This test allowed for the comparison of means across multiple groups, revealing whether these factors had a significant impact on

The research employed a comparative research design to assess the performance and safety of service robots versus human employees in the food service industry. This design was chosen as it allowed for the direct comparison of two groups (service robots and human service employees) on the same variables (performance and safety). This comparative design was deemed more appropriate than other possible design options such as non-experimental correlational, predictive correlation, quasi-experimental, and experimental designs. Non experimental correlational design, which determines if the variables are related, was deemed inappropriate for this study as it does not determine the influence of one variable upon another (Salkind, 2010). Predictive correlation design, which determines the predictive value of predictor variables on other criterion variables, was also not aligned with the intent of this study (Creswell, 2017). Quasi-experimental design, which requires equivalent groups and examines one group with an applied intervention and a control group, was not considered appropriate due to the lack of a control group in this study (Shadish, Cook, & Campbell, 2002). Lastly, the experimental design, which includes independent variables to be manipulated to determine the causal influence on dependent performance control group.

XXI. SAMPLING PROCEDURES AND DATA COLLECTION SOURCES

The population for this study consisted of experts in the development of robotics, including software engineers, data scientists, machine learning experts, those in the field of robotics, and those with knowledge of IT in food service. These experts were typically found in technology-focused organizations, such as universities, research centers, and software engineering companies.

The sample frame for this study comprised Survey Monkey Audience and the Prolific Audience panel. Survey Monkey Audience is an online panel that provides access to a diverse range of professionals and experts in various fields, including robotics, software engineering, data science, machine learning, and those who have interacted with robots, as well as employees and managers in the food service sector. This platform allowed researchers to target specific demographics and industries, ensuring that the sample frame accurately represented the target population. In addition to Survey Monkey Audience, the study also leveraged the Prolific Audience panel. Prolific is a platform connecting researchers with individuals actively participating in research studies. The inclusion of the Prolific variables, was also not suitable as this study did not involve any manipulation of variables (Fraenkel, Wallen, & Hyun, 2012). Therefore, the comparative research design was best suited for this study as it allowed for the direct comparison between service robots and human service employees in terms of performance and safety, without requiring any manipulation of variables or the need for a Appendix E. This analysis considered factors such as the desired statistical significance level, effect size, and power. The power analysis estimated the minimum number of participants required to detect meaningful differences or relationships within the data while minimizing the risk of Type I and Type II errors. Participants were randomly selected from the Survey Monkey and Prolific Audience panels' pool. This expert sampling technique ensured that qualified individuals were included in the study.

The desired sample for this study included experts in the development of robotics and individuals with IT knowledge applicable to robotics. These professionals encompassed software engineers, data scientists, machine learning experts, and those working in the field of robotics. They were typically found in technology-focused organizations like universities, research centers, and software engineering companies. The study utilized

Audience panel expanded the sample and engaged individuals with relevant expertise and knowledge. A power analysis was conducted to determine the appropriate sample size for this study. Using G*Power, it was determined that 57 participants were needed, with the results detailed in

the study. To access the target audience and survey data, the researcher contracted an account with Survey Monkey. A fee was paid to Survey Monkey and Prolific to obtain the desired audience and data for the survey. This fee covered the cost of accessing the panel and collecting the necessary information from the participants.

The desired sample for this study included a diverse group of individuals representing various aspects of the robotics and food service industries. This group comprised experts in robotics development, software engineers, data scientists, machine learning experts, as well as individuals who had interacted with robots in a food service setting, such as employees, managers, and consumers. Including participants with a wide range of experiences and perspectives, the study was better equipped to capture the full scope of potential impacts that robotics may have on the food service industry. The SurveyMonkey Audience panel and Prolific Audience panel served as powerful tools for accessing a diverse both Survey Monkey Audience and the Prolific Audience panel to ensure a diverse and representative sample. Survey Monkey Audience is an online panel that grants access to a wide range of professionals and experts in various fields, including robotics, software engineering, data science, and machine learning development. This platform enabled researchers to target specific demographics and industries, ensuring that the sample frame accurately represented the target population. Additionally, the researcher leveraged the Prolific Audience panel. By utilizing the Prolific Audience panel, the study further expanded the sample and engaged individuals who possessed expertise and knowledge relevant to

1. machine learning specialists, data scientists, and IT professionals working with robotics-related technologies. This helped gather diverse opinions on the development and deployment of robots in the food service industry from individuals directly involved in these fields.
2. Company size: Participants came from companies of varying sizes, from small startups to large multinational corporations. This provided insights into the adoption and impact of robotics in

and representative sample. As the sample frame for this study, these panels offered several advantages: access to a large, diverse pool of participants, customizable targeting, quota management, quality control, and efficient data collection. The study considered the following demographic factors to ensure the sample was representative of the target population:

1. Job title: Participants held job titles that aligned with their expertise in robotics, artificial intelligence, or data science. Examples of relevant positions included robotics engineers, AI developers,

information technology, programming, robotics, and machine learning who possessed experience and knowledge of automation robotics technology, along with its industry implications. The researcher used Survey Monkey Audience and Prolific Panel to identify potential respondents. These platforms allowed for recruiting professionals with expertise in the relevant areas of robotics and machine learning in the food service industry. A screening process was developed to ensure that only qualified individuals participated in this research project. Potential participants had to meet certain criteria before gaining access to the survey. These criteria included demonstrating expertise or knowledge in

food service within different organizational structures and resource levels.

3. Level of education: Individuals with diverse educational backgrounds in technology, robotics, artificial intelligence, and related fields were included in the sample. This aided in gathering a range of perspectives and views on the potential consequences of robotics in the food service business.

4. Years of experience: Participants had varied years of experience working in areas such as robotics development, artificial intelligence or machine learning development, and data science or IT related to robotics. This range of experience ensured a comprehensive understanding of the potential impact of robotics on the food service sector and provided a variety of perspectives on the challenges and opportunities associated with integrating robotic systems in the industry.

The study employed an expert sampling technique to recruit participants. The target population for this survey included experts in

incorporated questions that assessed the performance and safety of robotics in the food service industry, as well as compared robotics technology or machine learning and having some understanding of its potential application within the food service industry. Participants were asked to provide evidence of their qualifications or work experience via Survey Monkey before being granted access to the survey. Once identified and screened, eligible participants were provided with access to the survey through Survey Monkey. Before answering the survey questions, all relevant information necessary for participants to make an informed decision was provided. This included details about the purpose of the study, confidentiality measures, and any other relevant information (see invitation to the study in Appendix H).

By employing expert sampling and implementing a screening process, the study aimed to ensure that the participants were qualified and knowledgeable in the specific areas of robotics and machine learning within the food service industry.

This quantitative descriptive study encompassed a single comprehensive survey. The survey difference in the mean scores would suggest a disparity in performance between the two groups.

To assess the performance of food service robots and employees, various subscales, including usefulness, social capability, anticipated service quality, perceived these measures to the performance and safety of human employees working in the same industry. Several of the scales used in the survey had been adapted from previously tested instruments to ensure their validity and reliability. This process contributed to the development of a robust and comprehensive survey that accurately captured the perspectives of food service industry professionals on the performance, safety, and overall implications of robotics in their field. The survey outline of variables is in Tables 1 and 2 below.

XVII. STATISTICAL TESTS

The research questions were designed to compare the performance and safety of food service robots with human employees across various metrics or subscales: Usefulness, Social Capability, Anticipated Service Quality, Reliability, Responsiveness, Assurance, and Perceived Intelligence. Each subscale is operationalized through a series of Likert scale items. For example, the "Usefulness" subscale includes items such as "The food service robot would be useful" and "Using the food service robot would save me time." Respondents rate their level of agreement with these statements on a 7-point scale, and the mean score for intelligence, reliability, and responsiveness, were evaluated. Safety is a crucial factor in the food service industry, directly impacting the well-being of employees and customers. The study acknowledged that if food service robots cannot maintain a high level of safety, their performance in other areas may be overshadowed by safety concerns.

This analysis is crucial for determining the feasibility of adopting food service robots and evaluating whether they can be considered a safe and reliable alternative to human employees. The operationalization of these subscales and the method for comparing them are based on established research methods in the field of service quality and customer satisfaction. The specific items used in this study were adapted from previous research by Song & Kim (2022), Qin & Prybutok (2009), and Bartneck et al. (2009), with permission, to ensure the validity and reliability of the constructs measured.

Table 2

First Set of Scales

Category	Scale Item

each subscale is calculated. This process is repeated for all seven subscales. The comparison between food service robots and human employees is made by comparing the mean scores for each subscale. A significant

Category	Scale Item
Usefulness (Humans)	• The food service employee would be useful. • Using the food service employee would save me time. • It would be easy to dine in/get food with the food service employee. • Using the food service employee would improve my meal/dining experience. • Using the food service employee would enhance my effectiveness during my meal/dining experience.

• Usefulness (Robots)	• The food service robot would be useful. • Using the food service robot would save me time. • It would be easy to dine in/get food with the food service robot. • Using the food service robot would improve my meal/dining experience. • Using the food service robot would enhance my effectiveness.

Anticipated service quality (Robots)	• Overall, I would be pleased with the services provided by the food service robot • Overall, the service quality of the food service robot is excellent. • Overall, the food service robot would meet my expectations of what makes a good food service provider.

Social Capability (Robots)	• The food service robot appears to listen attentively. • The food service robot appears to say appropriate things. • The food service robot listens without interrupting when the customer is talking. • The food service robot seems to remember the detailed information about the customer's questions.
Social Capability (Humans)	• The food service robot appears to be polite. • The food service employee appears to listen attentively. • The food service employee appears to say appropriate things. • The food service employee listens without interrupting when the customer is talking.

Anticipated service quality (Humans)	• Overall, I would be pleased with the services provided by the food service employee. the service quality of the service employee is t. • Overall, the food service robot would meet my expectations of what makes a good food service provider.
Reliability (Robots)	• Overall, I would be pleased with the services provided by the food service robot. • Providing service as promised • Sympathetic and reassuring• Dependable • On-schedule service

Table 3

Second Set of Scales

Category Rating	**Category Rating Scales**
Reliability (Humans)	• Providing service as promised • Sympathetic and reassuring • Dependable • On-schedule service Accurate charge
Responsiveness (Robots)	• Telling exact service time • Robot employees available to requests • Prompt service Robot employees willing to help
Responsiveness (Humans)	• Telling exact service time • Employees available to requests • Prompt service • Service employees willing to help
Assurance (Robots)	• Trust robots • Feel safe for financial transactions • Friendly robots Knowledgeable

Scales	
Perceived Intelligence	• Incompetent (1 2 3 4 5) Competent • Ignorant (1 2 3 4 5) Knowledgeable • Irresponsible (1 2 3 4 5) Responsible • Unintelligent (1 2 3 4 5) Intelligent
Perceived Safety	• Foolish (1 2 3 4 5) Sensible • Anxious (1 2 3 4 5) Relaxed • Calm (1 2 3 4 5) Agitated • Quiescent (1 2 3 4 5) Surprised

Note. Scale items adapted from Bartneck et al. (2009). Please rate your impression of the food service robot and your emotional state during interactions with the robot and service employee on these scales. Scale Items (5-point Likert-type scale: 1 - 5 based on left to right)

Table 4

Demographic Variables

Variables Description	**Variables Description**

	employees
Assurance (Humans)	• Trust employees • Feel safe for financial transactions • Friendly employees • Knowledgeable employees

Note. This table presents scale items based on a 7-point Likert-type scale (1 = Strongly Disagree, 7 = Strongly Agree). Respondents are asked to rate their level of agreement with statements related to the service of robots and employees in food service.

The survey instrument was meticulously crafted by integrating Likert scale items from established surveys in the field, specifically those developed by Song & Kim (2022), Qin & Prybutok (2009), and Bartneck et al. (2009). Permission for the use of these items was secured prior to the survey's deployment, ensuring adherence to ethical standards of research and intellectual property rights. The chosen items were selected for their proven reliability and validity in measuring user perceptions and attitudes toward robotics and technology in service settings.

Job Title	Description of job title
Size of company	Size of the company that is worked at
Experience	Highest level of education completed by the participant
Education	Number of years of experience in field

Song and Kim (2022) constructed their scales by reviewing literature on human-robot interaction, service quality, and technology acceptance, adopting scales from seminal studies to create an instrument for assessing performance in the context of humanoid retail service robots. Minor modifications were made to these scales to adapt them to the food service robot context, ensuring the preservation of their validity and reliability.

Data collection and management procedures were meticulously implemented:

1. IRB Approval: Institutional Review Board (IRB) approval was secured from the University before the study commenced.
2. Question Development: The survey

Song & Kim (2022) reported that Cronbach's alpha values for the scales ranged between 0.78 and 0.89, indicating good reliability. Confirmatory factor analysis (CFA) was conducted to assess the convergent and discriminant validity of the scales. The results showed that all factor loadings were significant and above 0.5, indicating good convergent validity. The average variance extracted (AVE) values were above 0.5, and the square root of AVE for each construct was greater than its correlation with other constructs, indicating good discriminant validity.

Qin & Prybutok (2009) reported Cronbach's alpha values for the scales ranging between 0.72 and 0.88, suggesting acceptable to good reliability. Their study also utilized CFA to assess convergent and discriminant validity. The factor loadings were significant and above 0.5, and the AVE values were above 0.5, indicating good convergent validity. The square root of AVE for each construct was greater than its correlation with other constructs, supporting discriminant validity.

Inferential statistics are based on probability theory, which allows researchers to use knowledge of a sample to make general statements about a population (Asadoorian & Kantarelis, 2005). Inferential statistics are questions underwent approval by an expert panel and were field-tested to eliminate bias.

3. Participant Recruitment: Participants were sourced via Survey Monkey and Prolific.

4. Participant Screening: A screening process was conducted to confirm participant eligibility.

5. Formal Consent: Informed consent forms were provided and signed by all participants.

6. Interview Selection: Interviewees were chosen from the pool of participants who met the screening criteria.

7. Anonymity: The anonymity of participant information was maintained, with identifiable information redacted from any study-related reports or publications

between the means of multiple groups. In this case, the performance scores of food service robots and humans were compared using ANOVA, derived from the composite scales for usefulness, social capability, anticipated service appropriate for making inferences about populations from samples using the data to draw conclusions and gain insight into what the data means and how it connects. They involve using sample data to make inferences and predictions about a larger population. This can help businesses and organizations make better decisions based on insights gleaned from the data (Marshall & Jonker, 2011).

Data was analyzed using Jeffrey's Amazing Statistics Program (JASP, 2023). Descriptive statistics, such as frequencies and means, were used to analyze demographic information. Inferential statistics like ANOVA were also used to determine significance. Correlation analyses were conducted to evaluate any relationship between variables. The survey responses were coded and analyzed using JASP. The survey results were analyzed using descriptive statistics, such as frequencies and means, to determine how participants responded.

Specific tests were conducted for each hypothesis to analyze the relationships between variables and compare the performance of food service robots and service employees. An analysis of variance (ANOVA) was conducted to compare the performance of food service robots and humans. ANOVA is a statistical technique quality, perceived intelligence, reliability, and responsiveness. This analysis provides insights into the overall performance and acceptance of food service robots compared to human employees. For the safety aspect, an independent samples t-test was conducted to compare the perceived safety of food service robots and humans. The t-test is a statistical method used to determine whether there is a significant difference between the means of two groups. By comparing the mean safety scores for robots and humans, researchers can identify significant disparities in the perceived safety between the two and investigate potential factors contributing to these differences. This analysis is crucial in understanding the concerns and preferences of customers regarding safety when interacting with food service robots and humans, which can guide the development and implementation of food service robots to ensure a safe and comfortable experience for customers.

Multiple variables were assessed to understand the overall perception of food service robots and service employees. Most questions were rolled up to measure the overall performance, except safety. This allowed for a more streamlined comparison between service robots and employees regarding their perceived usefulness, social capability, used to determine whether there are any significant differences the individual scores for each question within a specific category (e.g., usefulness, social capability, etc.) were averaged to obtain a single score representing the overall performance in that category. For example, the five questions related to the usefulness of robots are averaged to generate a single usefulness score for service robots. The exact process is applied to the questions pertaining to service employees and other categories. By rolling up the questions into a single scale for each class, the analysis is more straightforward to interpret. On the other hand, safety is rolled up onto a single scale, as it is a distinct aspect that warrants separate analysis. This is because safety is crucial in adopting and accepting new technologies, particularly in the food service industry. By analyzing safety separately, researchers could better understand the participants' emotional states when interacting with food service robots and service employees and identify any potential concerns or areas for improvement in the design and implementation of food service robots. This information could be valuable for manufacturers and food service providers, as it can guide them in ensuring that their robotic systems are safe, user-friendly, and well-received by customers.

anticipated service quality, reliability, responsiveness, and perceived intelligence. A composite scale was created, and

There are not only morally correct actions that researchers are held up to but also laws and regulations that can affect how studies are conducted when using personal information is considered. When conducting research involving human subjects, researchers must adhere to the ethical principles of respect for persons, beneficence, and justice. Respect dictates that individuals should be treated with respect, and their autonomy should be respected by allowing them to make their own decisions (U.S. Department of Health and Human Services, 2018). Beneficence requires the researcher to maximize the research's benefits while minimizing risks (U.S. Department of Health and Human Services, 2018). Finally, justice requires that the researcher allocate study resources fairly (U.S. Department of Health and Human Services, 2018). In addition to ethical principles, researchers must also comply with laws and regulations such as the Common Rule (45 CFR 46), designed to protect human subjects' rights and safety throughout a research study (U.S. Department of Health and Human Services, 2018). The Common Rule provides guidance on informed consent, confidentiality, data protection, and compensation for injury or harm (U.S. Department of Health and

Understanding ethical considerations is very important when involving human subjects in a study. There are not only morally correct actions that researchers are held up to but also laws and regulations that can affect how studies are conducted when the use of personal information is considered. Understanding ethical considerations is very important when involving human subjects in a study. There are

industry. Specifically, the study investigated the potential effects of integrating robotics into food service performance and safety. Several quantitative tests were done to investigate the connection between robots' performance and safety and service employees' performance and safety. The hypotheses tested in this study revolved around two main research questions: the extent to which food service robots' performance differs from that of human employees and the differences in expert opinions on safety between food service robots and human employees. The chapter presents the specific hypotheses tested and summarizes the results obtained from the analysis.

In addition to presenting the study's findings, Chapter Four provided a comprehensive description of the sample used in the

Human Services, 2018). Researchers need to adhere to ethical principles and laws when conducting research involving human subjects to protect the integrity of the research study and the rights of the individuals involved in the study.

XXIII. RESEARCH FINDINGS

Chapter Four presented the study's findings, which focused on examining the impact of robotics on various aspects of the food service researchers to verify the findings and build upon the work done in this study.

The graphics for the study were generated using JASP (JASP Team, 2023), an open source statistical software package designed with an emphasis on user-friendliness, simplicity, and flexibility. JASP is known for its ability to produce APA (American Psychological Association) style figures, which are commonly used in social sciences research. Using JASP ensured that the graphics were clear, concise, and adhered to the standards of the APA. The use of R and JASP in this study aligns with the current trend in research towards open-source tools, which promote transparency, reproducibility, and accessibility in scientific research (Prlić & Procter, 2012; Stodden et al., 2018). These tools also facilitate peer review and research collaboration, fostering a more inclusive and dynamic research community (Lee et al., 2013).

research. This description includes details about the limited demographic variables of the participants, as well as a discussion on a priori and post-hoc power calculations, effect size, and aggregate sample size included in the study. Furthermore, the chapter offers a thorough summary of the hypotheses that were tested, along with a detailed analysis of the results obtained from these statistical tests.

XXIV. TOOLS AND ENVIRONMENT

This study's quantitative tests and statistical analyses were performed using R (R Core Team, 2023), a powerful statistical programming environment. R is widely recognized for its robustness and flexibility in handling various types of data and performing a wide range of statistical tests. It also provides a platform for reproducible research, enabling other relationships within the data. This expert sampling technique helped to reduce selection bias and enhance the external validity of the research findings. The sample included individuals with varying job titles, representing different company sizes, educational backgrounds, and years of expertise in the field. The sample was recruited through Prolific Audience, and participants were screened to ensure they met the eligibility criteria for the study. This screening process helped to ensure that only

XV. Participants and Research Setting

The sample for this study consisted of experts in IT with exposure to robotics, machine learning/software engineers, and those who work on robotics. The sample was recruited through Prolific Audience, an online panel providing access to various field professionals and experts. The sample frame for this study was representative of the target population with an expert sampling of the panel on a first-come, first serve. This study's desired sample size was 57 participants based on a power analysis conducted using G*Power located in Appendix E. This analysis considered the desired statistical significance level, effect size, and power to estimate the minimum number of participants required to detect meaningful differences or bachelor's degrees, 19% (23 participants) had certifications or associate degrees, and 5% (6 participants) held no degrees. The size of the participants' organizations varied, with 26% (32 participants) working in organizations of 1 to 49 employees, 20% (25 participants) in organizations of 50 to 249 employees, 22% (27 participants) in organizations of 250 to 999 employees, and 32% (39 participants) in organizations with 1000 or more employees. Participants' years of experience in the field also varied. 18% (22 participants) had 1-2 years of experience, 41% (51

qualified individuals with expertise or knowledge of robotics technology or machine learning and some knowledge of its potential application within the food service industry were included in the study.

The sample for this study was drawn from the Prolific Audience, a pool of approximately N = 6,000 potential candidates involved in the information technology sector. Of these, N = 140 participants started the study's questionnaire, with a participation rate of 2.33%. Of the initial 140 participants, N = 123 completed the survey, resulting in an 88% completion rate. The integrity of the study was maintained by verifying each participant's IP to remove duplicate responses. Afterward, a request was sent to Survey Monkey and Prolific to remove any remaining link information, such as IP addresses. This step was crucial to protect the participants' privacy and maintain the data's anonymity. In the survey itself, no PII was collected. Participants also answered demographic questions related to their professional backgrounds. The data revealed that 12% (15 participants) held master's degrees or higher, 64% (79 participants) held industry could potentially enhance overall performance or is at least viewed as comparable to their human counterparts. This enhancement could take the form of participants) had 3-9 years of experience, 25% (31 participants) had 10-19 years of experience, and 15% (19 participants) had 20 or more years of experience. This aggregate data provides a comprehensive overview of the professional characteristics of the study's participants. Demographic data was intentionally omitted as it was not purposely collected or used to analyze the results.

XXVI. IMPLICATIONS FOR FUTURE STUDY

Several significant implications for the food service industry have emerged from the present study. Although the overall performance and safety of robots and human employees did not significantly differ, the analysis of individual performance scales highlighted specific areas where robots were perceived to outperform human employees. Such findings could suggest that a balanced approach that leverages the strengths of both robots and human employees may be the most effective strategy for the food service industry.

Firstly, the positive correlation between robot and human employee performance implies that integrating robotics into the food service

unexpected situations.

Given the findings that robots and human employees performed equally well in overall performance and safety based on expert opinion, it is recommended that food service

increased efficiency, precision, or service speed. Secondly, the absence of a significant difference in perceived performance and safety between robots and human employees indicates that the current state of robotics technology in the food service industry is competitive with human performance. Such a finding suggested that the industry is nearing a tipping point at which robotics become more prevalent. Thirdly, the statistically significant differences in the 'Responsiveness' scale indicate that robots are perceived as more useful and responsive than human employees in this area. This implies that integrating robots may be most beneficial in areas where these characteristics are critical. In high- volume or fast-paced environments, for example, robots' ability to work continuously and respond quickly could significantly improve service delivery.

Moreover, the absence of statistically significant differences in the 'Social Capability,' 'Reliability,' 'Assurance,' and 'Perceived Intelligence' scales indicates that human employees continue to outperform machines in these areas or that certain tasks are comparable between the two. Such a result suggest that, while robots are useful in some ways, humans possess unique skills and abilities that machines cannot easily replicate, such as strong emotional and social businesses consider a balanced integration of robotics into their operations or at least consider how robotics can support the continued growth of the business. This could involve deploying robots for tasks where they are perceived to be more useful and responsive, such as repetitive tasks or tasks requiring precision and speed, while retaining human employees for tasks that require more social interaction, assurance, and adaptability. This is known as collaborative robotics, where instead of replacing employees, robots are used to lower the load of work that needs to be done while maintaining employees to improve efficiency and speed, which in turn can improve customer happiness. Many robots have been developed to clean dishes, clean and even make food and act as serving staff.

The research identified a variance in anticipated service quality, yet no difference in medians was observed. A notable distinction in responsiveness emerged when compared to human employees, indicating a perception of robots as more responsive, as evidenced by the data. Therefore, it is recommended that businesses consider deploying robots in roles that can fully utilize their strengths. For instance, robots' ability to work continuously and respond quickly in high-volume or fast-paced environments could significantly improve service delivery. Even though robots constructs. These could include complex social interactions, customer assurance, and the ability to adapt to suggested that a collaborative model, where robots and humans work together, leveraging their respective strengths, could be highly beneficial. For instance, while robots can handle high-volume, routine tasks, human employees can focus on customer service, problem-solving, and other tasks that require a high degree of social interaction and assurance.

The findings relative to the difference between safety was a positive result as the progression of robotics in public environments requires the public to feel safe. Although the study found no significant difference in the perceived safety of robots and human employees, it is recommended that businesses investing in robotics also invest in appropriate safety measures. This could include regular maintenance and inspection of robots, safety training for staff, and the implementation of safety protocols and procedures when working with robots.

As robots are integrated into the food service industry, it is recommended that businesses invest in continuous training and skill development for human employees. This could help them adapt to the changing work environment, work effectively alongside were found to be more responsive, human employees held their ground in areas such as social capability, reliability, assurance, and perceived intelligence. This

integration of robotics into their operations.

While the present study provides useful information, more research is needed to build on its findings. For example, similar studies in different contexts or sectors of the food service industry would be beneficial to determine whether the findings of the present study are generalizable. A larger sample size is recommended, as it measures the actual performance of test participants between service robots and service employees, to generate concrete data on some of the differences between the two. Additionally, qualitative research could be conducted to understand better employees' and customers' perceptions and attitudes toward integrating robots in the food service industry. This could provide more nuanced insights into this integration's potential advantages and drawbacks. More research could also investigate the long- term effects of incorporating robotics into the food service industry. This could include research into the effects of robotics technology on employment, customer satisfaction, and overall competitiveness. Given the findings of the present study, it is recommended that further robots, and focus on tasks where they can add the most value. The goal is to improve education so as robots become mainstream and overtake repetitive and simple tasks, human employees can increase wages and knowledge creating new jobs such as those which work on the robots. Such recommendations are based on the data and findings from the present study and aim to guide the food service industry in making informed decisions about the service, time to clean area or load, speed, and quality of food. Before full-scale implementation, it is recommended to conduct pilot tests of robotic systems in select areas of the food service operations. This allowed for the identification of potential issues and adjustments to be made before widespread deployment. New research is needed to match the trend in the growth of robotics, as discussed early in the present study.

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research be conducted to explore the long-term effects of integrating robotics into the food service industry. This could include studies on customer satisfaction, employee job satisfaction, cost effectiveness, and the impact on business performance. More importantly, more physical and monitored tests evaluate several aspects of performance on live real-time data, such as having a study in which a restaurant has both robots and humans, and their metrics are captured and compared, such as speed of

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