NEW FRONTIERS IN SERVICES: A TASK-ORIENTED CLASSIFICATION OF SERVICE ROBOTS

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ABSTRACT

During the past few years, the service industry has been hit by a wave of automation, technology, and artificial intelligence. Robots that traditionally were used in the manufacturing industry started to move into dynamic human environments, assisting humans in work and private lives (Chuah, Aw & Yee, 2021; Nelson, 2017). The need for innovation, labor shortages, and the isolation imposed after COVID-19 have driven the use of emerging technologies that lead to the visualization of service robots as support or substitute for humans in situations such as providing services. services (Bowen & Morosan 2018; Wirtz, Kunz & Paluch 2021). This market development brings a unique opportunity for entrepreneurs to enter untapped markets.

The service industry is relatively broad, and robots have been well received so far, especially for repetitive tasks such as checking guests in hotels, providing information at airports, serving in restaurants or hospitals, and even entertaining customers (Tuomi et al., 2021). The combination of technology and artificial intelligence has allowed service robots to go from performing repetitive tasks to performing simple and complex tasks based on three basic skills essential for dealing with customers. As technology development speeds up, entrepreneurs must comprehend customers' and employees' expectations and perceptions in various service encounters in order to develop well-accepted robots.

To better understand service robots and to provide a common language within the entire domain, this study summarizes and proposes a table with different types of robots, including their definitions, possible classification labels, and examples (Nassiraei & Ishii, 2007; Huang & Rust, 2021; Vujovic et al., 2017). It also proposes a classification model for task-oriented physical robots based on three skills, social/emotional, cognitive/analytical, and physical, for performing simple and complex tasks during service deliveries.

KEYWORDS: *Service robots, artificial intelligence, customer satisfaction, task-oriented classification.*

INTRODUCTION

Humanity has experienced the birth of various technological inventions that have changed lifestyles. They have gone from horse-drawn cars, steamboats, and railways to electric vehicles, motorboats, and subway lines, from telegraphs and physical letters to mobile devices and emails. The appearance of steam engines and the use of electrical energy transformed society and strongly impacted the economy, quadrupling the world's per capita income with the industrial revolution (Sorooshian & Panigrahi, 2020; Bloem et al., 2014). Industry played a vital role in the economy of the time, producing highly mechanized and automated material products. The manufacturing sectors, together with agriculture and textiles, were the most impacted, as technology made possible mass production and the division of labor through the use of the conveyor belt and the assembly line (Sorooshian & Panigrahi, 2020; Duarte et al., 2018). The implementation of technology in production prompted companies worldwide to constantly upgrade and automate their production processes to stay competitive in their fields.

Consumers live in an era of dizzying changes where the constant appearance of new technologies such as big data, the internet of things, artificial Intelligence (AI), and 5G communication have forced us to continually reinvent the way we live, especially organizations due to its remarkable dynamism and competitive field of business (Sheng et al., 2021). Technologies are getting smarter and more powerful, offering the possibility of quick machine setup and more efficient production processes. The use of lighter materials also makes them cheaper and driven by AI; they have become more desirable and adaptable to customer requirements, improving customer experience and quality of service in the service industry (Paluch & Wirtz, 2020). Some organizations have already started innovating AI alongside physical robots to take their service to another level, like Amazon's Prime Air, which uses drones to automate shipping and delivery. Domino's Pizza is experimenting with self-driving cars and delivery robots, and RedBalloon is using Albert's AI marketing platform to discover and reach new customers (Huang & Rust, 2021).

Factors like COVID-19 are accelerating innovation and change in the service field, encouraging the use of virtual reality and remote work in education. Even in health services, for instance, the demand for medical service robots that check people's temperature or take over disinfection work has increased during the last months, all due to the social distancing and nonphysical contact that has been imposed (Wirtz et al., 2021). The pandemic led to the visualization of service robots as supports or substitutes for humans in service encounters. The combination of technology and human capabilities can effectively improve service encounters, especially when used to perform tasks relatively simple and repetitively related to customer-facing. These repetitive tasks include "taking orders, dealing with payments, providing more product information, managing restaurant queues, and performing hotel customer check-ins" (Tuomi et al., 2021, p. 237).

Robots have moved from the industrial sector into dynamic human environments, increasingly supporting humans both at work and in their private lives, becoming service robots. The global service robotics market is growing at an annual compounded growth rate of 22.6% and is projected to increase from USD 37 billion in 2020 to USD 102.5 billion by 2025 (Chuah et al., 2021). This growth is due to factors such as positive profitability, improved resource utilization, demand forecast accuracy, quality control, process management, and disposal of human errors (Ivanov et al., 2017). In particular, recent years have seen rapid development in service robots for the hospitality industry, robots that cook complex meals, and robots that serve customers in hotels or airports. Bowen and Morosan (2018) believe that the main reason for the increase of robots in most industries is the labor shortage, which has pushed the use of emerging technologies to fill the need.

Japan, a pioneer country in the implementation of service robots, was forced to include service robots in hotels due to the increase in the proportion of elderly people, the drop in the birth rate, strict immigration policies, the expected significant growth of the demand for services, and the decrease in costs since robotic labor being usually less expensive than human labor. Henn-na Hotel was the first hotel in Japan to employ robots in all its operations without human intervention, from check-in at the front desk to automated bag drop, since 2015 (Tussyadiah & Park, 2018). Hotel robotics implementations are often integrated with other AI technologies, such as facial recognition, automatic checkout, and self-driving cars, to improve the experience. The success of service robots depends on the satisfaction of users. Some characteristics of robots induce positive reactions in consumers, for example, their level of anthropomorphism or the complexity level of cognitive/analytical tasks they perform (Wirtz et al., 2021; Tussyadiah & Park, 2018). Previous studies (Jia et al., 2021; Chuah et al., 2021; Park & del Pobil, 2013) indicate that human appearance induces positive perceptions and attitudes in consumers, so humans may judge humanoid robots favorably in terms of appearance and similarity with sociability required to perform complex tasks (Belanche et al., 2020).

The fast-paced development of service robots and frequent failure incidents led us to the research problem. There is a need for an organized effort in research and development. Moreover, these efforts should reflect the human element's expectations, both customers and employees. A classification framework will enable developers, policymakers, and academicians who wish to investigate human-robot interactions.

The service industry is relatively vast, as are the different robots that can be used in this industry, such as in hotels, airports, restaurants, hospitals, and even deliveries (Wirtz et al., 2021). Classifying them to better understand their similarities, differences, and possible combinations is necessary based on service robots' abilities and the complexity of the tasks they can perform. The abilities of service robots involve their social/emotional, cognitive/analytical, and physical skills. Thus, classification is necessary to understand the phenomenon as it provides a common language within the entire domain of service encounters (Lambert 2015)**.** This research aims to propose a classification of robots in the service industry based on three main characteristics and abilities, as well as the level of task development. This classification may help academic researchers develop theories about human-robot interactions, practitioners identify design specifications, and policymakers conceptualize regulations. Our research objective is to review the theoretical and practitioner literature to explore the phenomenon as it is occurring and organize the knowledge around a framework.

LITERATURE REVIEW

Technological transformation has been evidenced since the Industrial Revolution at the end of the 18th century. Humanity has experienced different scientific-technological innovations such as steam engines, electric power, production lines in the manufacturing industry, and transformations in the service industry with transitions from full personal service to self-service technology (Bloem et al., 2014; Anitsal et al., 2002). The economic benefits of technological innovations were evident. Since the beginning of the 19th century, the income per capita grew at an average of 0.9 percent per year, eight times faster than the growth before the Industrial Revolution. The era of constant economic growth began when consumers got used to constantly growing in production, pushing technology to continually reinvent itself with either new products or reductions in the cost of making existing products around different industries (R. C. Allen, 2006; de Steiguer, 1995; A. Khan, 2008). The service industry, for example, was motivated to increase sales and reduce labor costs, which led it to implement self-service systems in the 1930s. At that time, technology-based self-service came to the service industry with options such as self-price checkers, self-service checkouts in grocery stores, and automated teller machines (ATMs) (Anitsal et al., 2002).

The service sector has positively impacted the Gross Domestic Product (GDP) and promoted employment in the economically active population. The growth of this industry and its dominance in developing economies during the last decades has generated curiosity for research purposes (Stoshikj et al., 2016; Iglesias, 2018). Academics in North America and Europe are taking a new approach to services, viewing them as part of science for their ability to invigorate the economy. In the US alone, 75% of workers work in the service sector. According to the US Bureau of Labor Statistics (BLS), the service sector encompasses many industries. In 2020, the top four employment sectors in the US were education and health services, professional and business services, leisure and hospitality, and retail. The service sector also includes finance, communications, wholesale, insurance, transportation, real estate, logistics, postal operations, etc. (Hidaka, 2006; Holusha, 1989; Günay & Kurtulmuş, 2021). The breadth of the services sector makes it a dynamic, competitive, and attractive field for technological innovation.

Events such as the COVID-19 pandemic have also forced innovation within this sector. During this pandemic, the world economy experienced the worst crisis since the Great Depression of 1930. According to the International Monetary Fund (IMF), in 2020 alone, GDP fell by 3.5% worldwide, primarily due to significant losses in income from the service sector businesses such as bars and restaurants, hotels, educational institutions, and airlines. An impact similar to that of the Spanish flu at the end of the 20^{th} century is estimated to have caused a GDP decline of 6% after its onset. (Açikgöz and Günay, 2021; Kurtulmuş, 2021).Technology led the situation during the 2020 pandemic, particularly in health and education. In the field of health care, most of the activities supported by technology and AI were the provisions of health services remotely, the prediction, detection, and monitoring of diseases in real-time around the world, and the analysis and visualization of disease spread trends (Vargo et al., 2021; Dananjayan & Raj, 2020). While in the educational system, schools had to provide emergency remote teaching to students from all over the world through electronic learning management systems such as Blackboard Learn, Moodle, ATutor, Sakai…, or cloud communication platforms such as Zoom, Microsoft Teams, WebEx, etc. (Jia et al., 2021; Gladilina et al., 2020; A. M. Khan et al., 2021).

While technology is leading, AI is taking a prominent role in customer service, increasing significantly due to isolation and restrictions imposed during the pandemic. Free virtual assistants such as Hyro are examples where through AI, technology helps healthcare companies and their patients to assist them using a database compiled by the World Health Organization (WHO) and other trusted sources of information to answer questions from customers, helping to regulate the increasing flow of online users (Abuselidze & Mamaladze, 2021). AI, combined with other technology, is revolutionizing companies worldwide in different sectors by providing competitive and innovative products and services while executing mechanical and analytical tasks. In the service sector, AI and technology can be used as self-automated algorithm processors that can perform complex tasks to support customers and employees. Examples are used to predict customer behavior and generate personalized recommendations based on past data, such as customer behavior or preferences (Paluch & Wirtz, 2020).

Automation and AI have also made customers "active participants" in service encounters and how they want to experience them through introducing technology-based self-service (TBSS) options and service robots. According to the American Banking Association, in 2013, 56% of customers preferred to use mobile bank apps or ATMs rather than traditional services. Anitsal, Moon, and Anitsal (2002) stated that within service encounters, three characters, namely customer, employee, and technology, interact with one another in different interactive service options, evidenced from the beginning of the service transformation. For service marketing professionals, it's essential to understand the interactions that occur from various perspectives. The customer has always been part of these interactions. For example, customer-employee interaction denotes a complete service, which is known as a traditional encounter that requires low cognitive and emotional complexity. With the injection of technology in recent years, technology has become a new participant in these interactions. It has been observed from customer-technology, which is called self-service technology, to technology-employee interaction, which is known as service robots to serve employees and customers in tasks that require developing highly cognitive and analytical skills (Anitsal et al., 2002; Scherer et al., 2015; Wang et al., 2013).

Traditional services served as a development niche for service robots since the activities carried out there require low cognitive and low emotional complexity, such as carrying objects and undertaking monotonous assembly jobs. Technology and AI development have bet for top-of-the-line robots within the service industry to improve the service experience and reduce operating costs, goals the marketing field has been fighting for years to increase customers' standard of living. Now, it is sought that service robots also serve in services that require developing highly cognitive, analytical, and physical tasks within service encounters, such as assisting in medical surgery through voice-activated robotic arms or humanoid robots in hotel lobbies that welcome guests, carry the luggage to the guest room and even entertain them (Fusté-Forné & Jamal, 2021; Wirtz et al., 2021).

The ability of AI technology to execute mechanical, repetitive tasks cheaply and with no room for human error will disrupt service jobs, making it likely that service workers will gradually be replaced by robots in the future. Frey and Osborne (2017) estimate that 47% of jobs in the US are vulnerable to automation, and Lu et al. (2020) calculate this will happen by 2055. Empirically, it is believed that this wave of automation and AI technology was caused as a compensatory response to labor shortages, an aging population, and competitive needs in the industry. The New York Times estimates that by 2030, only 59 percent of adults aged 16 and older will be in the US workforce, down three percentage points from 2015 (Schneider et al., 2018; Nelson, 2017). Authors such as Fauxet (2021) estimate that by 2025, robots will substantially impact the market, reaching 1.5 billion dollars. In the United States, a robot has already been developed to cook complex meals and serve customers by replacing an entire staff of employees. In California, a hamburger robot has been designed to fulfill up to 120 orders per hour. For its part, Café X, located in some airports, has robotic baristas that can produce up to three drinks in 40 seconds (Fauteux, 2021; Koster & Brunori, 2021; Tuomi et al., 2021).

Service robots can adapt to different environments, unlike other technologies in producing and delivering services, such as (TBSS) options, service kiosks, or pre-programmed tablets. According to Wirtz et al. (2018), a "service robot" is an autonomous system that has the capacity to adapt while interacting, communicating, and delivering services to customers. Jörling et al. 2019, for its part, add that this autonomous system can provide personalized assistance in performing physical and nonphysical tasks. Two definitions agree with the International Federation of Robotics, which describes a service robot as an autonomous robot that performs tasks without human intervention. Bowen and Morosan (2018) also add that autonomous machines could have a human, animal, or object functional morphology. For this research, service robots would be defined as adaptable, highly autonomous machines that develop physical and cognitive/analytic complex tasks during service encounters (Fusté-Forné & Jamal, 2021; Paluch and Wirtz, 2020).

Advances in AI have fueled the development of machine capabilities in response to its popularity. Autonomous machines are highly complex AI-powered systems that integrate different technology segments without human intervention (Liu & Gaudiot, 2022). These systems are widely used in various industries and customers' daily lives. For example, autonomous vehicles, smart manufacturing robots, and service robots (Chen et al., 2021; Ignatious et al., 2022; Zhang et al., 2020). These autonomous machines must also include cognitive/analytical and social/emotional skills to effectively and naturally collaborate or assist humans. Features such as action, perception, and reasoning of language, gestures, touch, and facial expressions must be built into robots to support human-robot interaction, especially in service encounters. For example, in the health care industry, a nursing robot capable of feeding patients must be able to follow the movements of the patient's head but must also understand the subtle clues that indicate when the patient is ready for the next bite through interpretation of voice, facial expressions, and patient gestures (Ahn, 2018; Lange, 2019). Cognitive/analytical skills are mental abilities that must function correctly, such as memory to retain information, processing speed, and logic to solve problems. Social/emotional skills mean the ability to analyze and regulate human emotions and display them. What authors like (X. Liu et al., 2015) call emotional Intelligence (X. Liu et al., 2015; Manivannan, 2019).

Service robots can adopt human capabilities to perform simple or complex tasks depending on the requirements of the service encounter. Service robots, such as holograms or mechanically designed robots, can be designed virtually or physically. Mechanically designed robots (physical robots) must develop their designs considering a particular environmental niche in which they are to perform. When establishing the design, the expected behavior the robot will adopt during physical tasks within the service industry should be determined, such as the social/emotional and cognitive/analytical skills necessary for customer satisfaction (Nassiraei & Ishii, 2007; Vujovic et al., 2017). Customer satisfaction is the primary goal of a service encounter. The consumer-machine interaction must be considered when deciding the most relevant mechanical design, as well as the morphological representation of the robot, such as human, animal, or object appearance.

Anthropomorphism in robots seems to be a determining factor in consumer-machine interaction, where imitating male or female characteristics in a robot increases consumer confidence and influences decision-making related to automation technology (Belanche et al., 2020; Singh & Sellappan, 2008). Robots that include human physical characteristics such as eyes, nose, hands, arms, legs, and mouth, and nonphysical human features such as gestures, voice, or personality appear to be physically, cognitively, and socially accepted by consumers. Singh and Sellappan (2008) identified robots that mimic humans through perception, processing, and action as humanoid robots. Humanoid robots can be deployed in sensitive environments to interact with fragile service encounters such as health and in intense environments such as military usage (Chuah et al., 2021; Lyons et al., n.d.; Singh & Sellappan, 2008). While human physical features have already been developed in robots, nonphysical human parts are starting to be incorporated for their importance to customer satisfaction in the service industry. For example, an engineering company based in the UK has developed a robot named AMECA that physically looks like a person and displays human expressions such as surprise, wonder, curiosity, and happiness (Engineered Arts, 2022).

As with technology in the industrial revolution, customers have seen the evolution and growth of intelligence in robotics and AI. Robots are destined to become a pervasive aspect of modern society because of their growing ability to support the performance of human tasks while improving customers' lives (Lyons and Nam, 2021). In 1959, the first industrial robot was developed and introduced in the US as a hydraulic machine programmed in joint coordinates. Industrial robots are intended for simple tasks such as device transport, assembly, welding, and painting due to the design and purpose that have been determined according to the industry in which they work. Service robots, meanwhile, are intended for complex tasks, so they must be flexible, autonomous, and easy to operate (Savin et al., 2022; Singh & Sellappan, 2008). We listed various types of robots, their definition, possible classification labels, and examples below. This table may help entrepreneurs to identify needs and gaps in design and development efforts.

TABLE 1 – TYPES OF ROBOTS AND EXAMPLES

NAME	DEFINITION	LABEL	EXAMPLES
Delta robots[1]	Its configuration includes arms with rotating or concurrent prismatic joints that can execute precise and minute movements.	Industrial robot	High-precision assembly operations robots. Packaging industry robots. Operating room assistant robot.
Polar coordinate robots[1]	Its configuration includes an arm with two rotating joints and a linear joint connected to a base with a rotating joint. The robot axes work together to form a polar coordinate, allowing the robot to work spherically.	Industrial robot	Surveillance robots. Environmental monitoring robot. Underwater and planetary exploration robot.
Articulated robots[1]	Its configuration contains a rotary joint, simulating the rotation of a human arm. It can move on flat terrain and narrow spaces.	Industrial robot	Welding robot. Assembly robot. Material handling robot.
Teleoperated robots[1,2]	Its configuration allows it to be teleoperated by a human operator who controls the robot's movements from a distance through devices such as personal digital assistant (PDA) systems or cell phones.	Industrial robot	Robots with multi-panel displays with control devices like joysticks, wheels, and pedals.
Hybrid[3,4]	Its configuration is based on automatic systems that use a combination of wheels (or tracks) and legs in different formations to perform locomotion.	Human server and cobot	Wheels are attached to the end of the legs. Combination of wheels and legs operated independently.
Pre-programmed robots[5,6]	They are autonomously preconfigured, so they cannot change their behavior while working and are not supervised by humans.	Human server and cobot	Roomba Robot Vacuum[7]
Animatronics[8,9]	They physically look like real people or animals. They are generally used in movies and other entertainment industry settings.	Humanoid robot	Disney show/movie performance robots.
Bipedal[10,11]	They are configured to mimic the gait of a human being. It can be scheduled to perform some tasks as needed.	Humanoid robot	The locomotion of a bipedal walking robot with six degrees of freedom.
Autonomous mobile robots[12]	Its configuration allows navigation in environments without needing physical or electromechanical guidance.	Robot	Hospital assistance robots. Agriculture assistance robots. Services robots.
Automated guided robots[13,14]	Its configuration is automated and guided by a contactless guidance system that moves and transports items in production, storage, and distribution centers.	Robot	Guided carts. Tow tractors. Mobile picking robots.
Android / Gynoids	It is configured as a humanoid robot. Its design will resemble a male human (Android) or a female human (Gynoid).	Humanoid robot	Sophia[20]: Female humanoid robot capable of displaying humanlike expressions and interacting with people.
Humanoids[16]	It was configured to mimic the general appearance of the human body, its movements, and human interaction.	Humanoid robot	Eva: Adult-sized humanoid with emulation of human facial expressions, head movements, and the ability to speak, using 25 artificial muscles.[15]

Cobots[17,18]	Its configuration allows one to physically interact with humans in a shared workspace.	Humanoid robot	Object position robot. Bar code identification machine.
Augmenting robots[19]	Its configuration generally allows for enhancing a person's capabilities or replacing abilities that a person has lost.	Humanoid robot	Robotic prosthesis in medicine.
Social robots[22,23]	Its configuration is the same as a humanoid robot but programmed to "socially" interact with humans and provide physical and emotional support.	Humanoid robot	Asimo[22]: Can understand and respond to simple voice commands and recognize the faces of a select group of individuals.
Biohybrid robots[24]	They are composed of biological and synthetic components that have the potential to be fully autonomous, intelligent, and self-assembled. Capable of learning from previous experience and repairing their damage or injury.	Humanoid robot	Biologically inspired manta ray-shaped robot.
Sources: [1] Process Solutions (2018), [2] Valero-Gomez and De la Puente (2011), [3] IGI Global (2022), [4] De Luca et al. (2021), [5] Gottlieb and Anderson (2011), [6] Das (2022), [7] Forlizzi and DiSalvo (2006), [8] Stan Winston School of Character Arts (2015), [9] Baradwaj (2020), [10] Perkins (2021), [11] Lim and Yeap (2012), [12] Jacoff et al. (2002), [13] Bore et al. (2019), [14] Lin et al. (2021), [15] Faraj et al. (2021), [16] Song and Kim (2022), [17] Biton et al. (2022) and Beuss et al. (2021), [18] & [19] Gottlieb and Anderson (2011), [20] Hanson Robotics, (2022), [21] Sakhineti and Jayabalan (2020), [22] Okita et al. (2009), [23] Piçarra and Giger (2018), [24] Mestre et al. (2021)			

Table 1 highlights the different types of robots based on their design and programming. Industries have been a niche for robot technology and development. In the manufacturing industry, for example, robots with a mechanical structure capable of performing complex tasks with high precision, such as delta and polar coordinates, and articulated robots are the most used and demanded. The retail industry, for instance, has adopted robots to perform repetitive tasks performed by teleoperated, hybrid, and pre-programmed robots. At the same time, the service industry has adopted robots such as autonomous mobile robots, automated guided robots, cobots, social robots, and humanoids to be the most flexible regarding the environment or task adaptability. The variety of robot combinations has become a very popular and demanded market in recent years, which is why Reshetnikova and Pugacheva (2022) expect the robot market to exceed 61.4 billion dollars by 2025, while Chuah et al. (2021) forecast just $102.5 billion for service robots by 2025. The use of AI is growing, and despite its relevance and current popularity in customers' lives, finding other robot developments was not easy. Table 1 summarizes the most popular robots, but the spectrum is even broader, so more research is needed for better insight.

The current study proposes a task-oriented physical robot deployment model by skills (Figure 1), including social/emotional, cognitive/analytical, and physical skills. As Moon and Anitsal (2002) did with the TBSS, this article presents a helpful classification of service robots to understand the possible combinations, interactions, and full potential of skills based on the complexity of the tasks. According to their complexity, the tasks are performed based on three different types of AI: Mechanical AI, Thinking AI, and Feeling AI (Huang & Rust, 2021). The types of AI provide a better understanding of the possible tasks performed by service robots covered in this article. Mechanical AI focuses on tasks with standardized, consistent, and reliable results. Some examples would include high-precision object positioning, packaging, and assembling. Thinking AI focuses on tasks that provide customer personalization, for example, voice and face recognition, weather-based outfit suggestions, and memorizing customer preferences (Huang & Rust, 2021; Klein et al., 2020). Feeling AI focuses on tasks based on emotional intelligence, such as recognizing and responding to customer emotions, displaying own emotions, and empathy (Huang & Rust, 2021; Sayed & Gerwel Proches, 2021).

Service robots that share a work domain with customers should be able to handle multiple tasks simultaneously with real-time responses. Service robots cannot fully satisfy all customer demands with autonomous decision-making. Service robots currently lack emotional intelligence and inference mechanisms to predict customer requirements. So far, task-oriented service robots have been developed based on human skills (Kim & Yoon, 2014; Letheren et al., 2021). The classification of robots in the service industry can be represented by interactions between customers, employees, and robots with three types of skills. (1) social/emotional skills, such as emotional intelligence or expression of emotions; (2) cognitive/analytical skills, such as communication or long-term memory; and (3) physical skills, such as lifting weights or moving steadily. The skills of service robots are based on three types of AI (Mechanical, Thinking, and Feeling) and are tied to the simplicity or complexity of the assigned task (Wirtz et al., 2021).

Social/emotional skills for simple and complex tasks: ***(1a and 1b)***

The use of social/emotional skills to perform simple tasks is shown as (1a) in Figure 1 by human servers and collaborative robots (cobots) based on Feeling AI. Cobots are designed to work with humans simultaneously in the same workplace. For example, in the health industry, cobots are integrated into simple surgical processes, such as routine oral and maxillofacial interventions (Chromjakova et al., 2021; Huang & Rust, 2021). The cobot is programmed to predict the doctor's activities based on different parameters using systems that have copied the movements of the human assistant to transfer them to the robot. In this scenario, the human-robot social/emotional interaction is as simple as a movement assistant (Beuss et al., 2021). When complex tasks are combined with social/emotional skills, it is determined as (1b) and performed by a partial employee. The customer acts as a partial employee by performing some tasks by themselves, replacing specific tasks performed by service providers, improving customer satisfaction (Hsieh et al., 2004). In the retail industry, self-checkout systems have been implemented to provide a good experience for customers, allowing them to scan items and pay for them without interacting with human employees and providing more privacy during service delivery. Hence, the quality of service falls mainly on the customer (Aquilina & Saliba, 2019).

Cognitive/analytical skills for simple and complex tasks: ***(2a and 2b)***

The use of cognitive/analytical skills to perform simple and complex tasks is shown in (2a) and (2b), respectively, based on Thinking AI and performed by robots. Robots with cognitive/analytical capabilities based on thinking artificial intelligence are mainly programmed to perform personalized tasks for the client according to their preferences. In simple tasks, for example, the robots are programmed to recognize the commands of a customer through their voice (Gundogdu et al., 2018). Robot programming uses a metaprogramming approach that allows customers to customize simple commands such as move, select, and drop with their voices. While in complex tasks, the robots are programmed, for example, with an algorithm for recognizing orders and customer habits, which can open various types of doors in a house in the same way and at certain times based on the daily routine of the client, without the need for the client to command it (Li & Meng, 2015; S. Park, 2020).

Physical skills for simple and complex tasks*: (2a and 2b)*

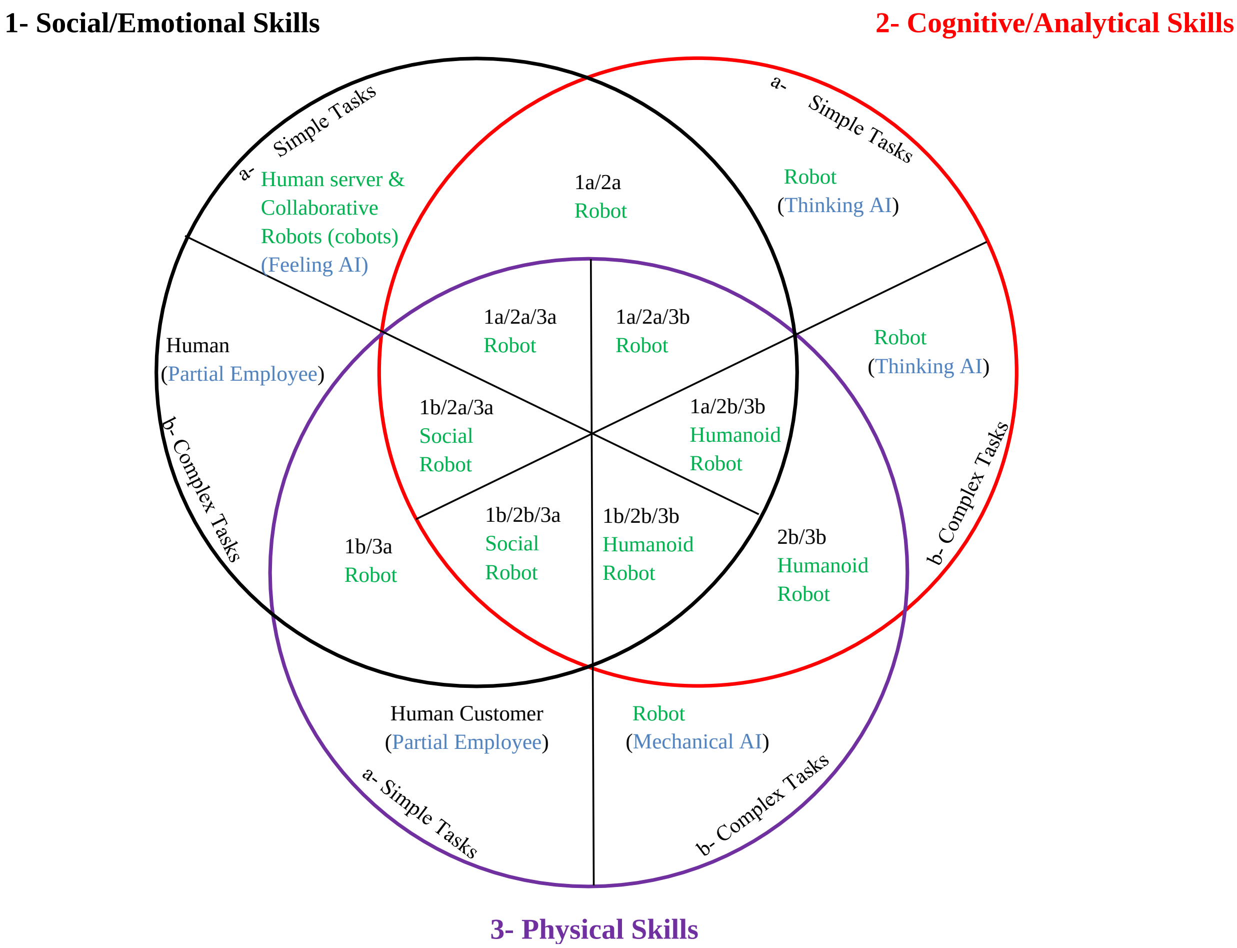
When physical skills and simple tasks are combined, as seen in (3a), they are performed by a Human Customer (Partial Employee). A simple job with physical skills could be seen in the self-checkout example. Customers are expected to scan each product on the scanner, pack them in bags, and pay manually (Aquilina & Saliba, 2019; Considine & Cormican, 2016). The use of physical skills to perform complex tasks is denoted as (3b) and performed by mechanical AI-based robots focused on precision and standardized results. For example, the Roomba robotic vacuum cleaner is capable of moving autonomously around any surface, such as wood, ceramic, or carpet. Its programming allows it to brush and vacuum even the most minor dirt and dust in seconds, while a human would take hours. (Forlizzi and DiSalvo, 2006).

Intersections of social/emotional and cognitive/analytical tasks

At intersections, we see lots of opportunities for robot development. Simple tasks performed with social/emotional and cognitive/analytical skills are represented as (1a/2a) and are performed by a robot. The robot can assist a human employee in simple tasks based on feeling AI and thinking AI. For example, in a laboratory where SARS-CoV-2 tests are carried out, the assistants were helped by automation, where a robot assumed the role of laboratory technician. The robot assists in simple activities such as sample preparation, pipetting, and liquid handling under the supervision of the human employee as a simple human-machine interaction (Zanchettin & Facciotti, 2022). Robots can also develop physical skills to perform simple and complex tasks. The performance of simple duties in this type of robot is denoted as (1a/2a/3a). This means the robot can move autonomously in an austere environment like a laboratory. Performing complex tasks with physical skills in the same scenario is denoted as (1a/2a/3b) and means, for example, the robot can take and transport the samples for later processing stably.

The utilization of social/emotional skills to perform complex tasks and physical skills to perform simple tasks is denoted as (1b/3a) and performed by a robot. The robot can interact with customers, but its physical skills are simple. For example, in self-checkout systems, the machine is capable of interacting with the customer by giving visual and voice instructions through the screen but physically is capable of weighing the fruits or vegetables once the customer places them on the scale (Aquilina & Saliba, 2019; Considine & Cormican, 2016). (1b/3a) based robots can also develop cognitive/analytical skills to perform simple and complex tasks and become social

FIGURE 1 - A MODEL OF TASK-ORIENTED PHYSICAL ROBOT DEPLOYMENT BY SKILLS



Sources: Extended from Wirtz et al. (2018), Wirtz, Kunz, and Paluch (2021); Colgate et al. (1996); Huang and Rust (2020); Belanche et al. (2020); Chromjakova et al. (2021); Beuss et al. (2021); Stipancic et al. (2021); (Hsieh et al. (2004) robots. Social robots are explicitly designed to be "social" and improve human-robot interactions (Coeckelbergh, 2021; Zonca et al., 2021).

The involvement of cognitive/analytical skills to perform simple tasks is denoted as (1b/2a/3a). This means that social robots, for example, process the product's price based on its weight while giving instructions to the customer (Coeckelbergh, 2021). Performing complex tasks with cognitive/analytical skills is denoted as (1b/2b/3a). Here, the social robot can reach a higher level of AI, and for example, the PLEA robot was designed as a teaching social robot. PLEA is an autonomous humanoid head capable of teaching and interacting with students in a classroom just as a teacher. PLEA can also assess and predict students' emotional states and alter the teaching process by changing the tone of voice or asking questions about the student's state of mind and self-understanding. (de Montfort University, 2021; Stipancic et al., 2021).

The performance of complex tasks using cognitive/analytical and physical skills is denoted as (2b/3b) and is performed by a humanoid robot. The humanoid robot is designed to mimic the general appearance of the human body and its movements. Physically, humanoid robots look like humans and can mimic simple physical tasks, such as head movements and facial expressions, and their cognitive/analytical skills are as complex as a robot (Faraj et al., 2021; Pepito et al., 2020). The entertainment industry has pioneered the use of humanoid robots, but they have been cataloged as animatronics because they are designed to entertain customers rather than interact with them. When social/emotional skills get involved, the scope of tasks performed by humanoid robots changes (Baradwaj Yellenki, 2020; Stan Winston School of Character Arts, 2015).

A humanoid robot programmed to perform complex tasks with cognitive/analytical and physical abilities but simple tasks with social/emotional skills is denoted as (1a/2b/3b). Examples of this combination of skills and tasks can be seen in the entertainment industry, such as casinos. Some casino owners in Las Vegas have started using a robot prototype to replace the dealers. The humanoid robot is a prototype called Min, which physically looks and mimics a dealer, can perform card dealing functions, and even detect cheating during gameplay, but still without social interaction with customers. (McCoy, 2019). In the past few years, authors such as (Chiang et al., 2022) state that humanoid robots have begun to be designed under experimental conditions to perform complex tasks with social/emotional skills, such as recognizing facial emotions, movements, or sounds of customers. For example, a robot named Ameca has been popularly listed as the world's most advanced and realistic humanoid robot. The robot has been designed by Engineering Arts, a company dedicated to manufacturing humanoid entertainment robots for companies, theme parks, and science centers (Alfonso, 2022; Gomez, 2021). Ameca is currently a prototype with an artificial intelligence and machine learning platform that stores data in the cloud while interacting effectively with customers. Ameca has a combination of artificial limbs and ligaments that simulate human movements. The robot can smile, blink, show surprise, and scratch its nose. Ameca can also detect people, track their faces, detect objects, and even have fun looking at a customer (Osmond, 2022; Yi Joey, 2022). This humanlike robot aims to bridge the gap between customers and digital life. Its current software makes the humanoid robot ideal for customer service; however, its developers seek to improve its software to be constantly reprogrammed and updated by adding new functions (Alfonso, 2022; Gomez, 2021).

MANAGERIAL IMPLICATIONS AND FUTURE RESEARCH AVENUES

Robots have moved from the traditional manufacturing industry into human environments such as work and personal life (Savin et al., 2022). Combining technology and artificial intelligence has allowed robots to respond to different environments and adapt to various industries, such as the service industry. The changing nature of the industry and factors such as COVID-19 have driven services such as hotels, restaurants, and health centers to rely on technology to meet their needs. The imposed distancing and labor scarcity as pandemic consequences have pushed robots to take jobs with repetitive tasks. Authors such as Paluch and

Wirtz (2020) point out that AI and robots have also begun to take a dominant role in customer service in response to said isolation and restrictions. Robots have started to develop more abilities that allow them to perform mechanical and analytical tasks beyond the traditional ones used by industrial robots.

The service industry has been cataloged as an industry of high quality in customer satisfaction (Choi et al., 2020; Lu et al., 2020). Today, we see robots capable of performing complex tasks to serve customers in restaurants and hotels or as a human-machine team in technology-based self-service trying to bring an excellent experience to customers (Anitsal et al., 2002; Wirtz et al., 2021). However, El-Said and Al-Hajri (2022) argue that many researchers in the "customer service" field conclude that there is a general preference for human service in the service industry. AI has not yet reached the point of fully satisfying the service industry. Robots cannot match the quality of service characterized by personalized service, the human touch, and authentic customer-employee interactions. The key to successful service delivery is to ensure pleasant interactions for those involved. A pleasant interaction with a customer includes empathy and emotional intelligence from the service provider (Ho et al., 2020; Prentice et al., 2022; Sayed & Gerwel Proches, 2021).

In order to reach customer satisfaction, the goal of service delivery, robots should include natural human basic skills. According to Turja et al. (2022), in addition to physiological requirements, customers have basic psychological needs, such as feelings of competence, autonomy, and social relatedness. Huang and Rust (2021) have identified three types of AI, Mechanical AI, Thinking AI, and Feeling AI, to which service robots are adaptable and on which they are based to perform simple or complex tasks according to customers' requirements. Service robots have been dispersed into different categories to meet customers' needs, based on the combination of human skills and artificial intelligence to carry out various tasks within the service industry.

Considering the necessity of social/emotional, cognitive/analytical, and physical abilities, in combination with AI and the complexity of their tasks, a classification of robots according to a specific environment and purpose is needed (Huang and Rust, 2021). For example, conversational agents or chatbots use a combination of social/emotional skills and cognitive/analytical skills to perform simple tasks, such as conversing verbatim or with voice. Also, recognize customer requests by predicting customer behavior through feeling and thinking and thus propose solutions. When the physical capability, the ability for autonomous mobility, is added to the chatbot, we are no longer talking about a virtual assistant but a physical assistant. This physical assistant can be used, for example, in the care of the elderly, not only providing them with company through conversations but also helping them with physical tasks such as making their bed (Biton et al., 2022). The robot with the three abilities moves to another environment where its social/emotional and cognitive/analytical skills are needed. Still, its physical ability takes it to a more advanced level, reaching another audience and performing different tasks.

Japan, South Korea, the United States, and some European countries have been pioneers in implementing service robots and investing in their development (Ward and Ashcraft, 2010). There is a distinction in the adoption of robots in advanced and developing countries, as discussed by De Vries et al. (2020). Investment in robotization is closely linked to the economic capacity of the country's industries where it is implemented. Therefore, it is inferred that since developing countries have an emerging economy with a lot of inexpensive labor available, investment in technological structure is not as significant as in advanced countries (Awnan and Ali Khan, 2015; Vo et al., 2017). To facilitate the implementation of robots in the service industry in countries with emerging economies, this study suggests developing and implementing policies that allow the identification of the economic and structural benefits after adopting service robots in companies. Companies will adopt service robots as long as they show technical and economic feasibility. Once implemented, robots improve the provision of services and, therefore, generate benefits above costs (Berg et al., 2016; Miller, 2017). Investing companies are also invited to assess the potential of markets in emerging economy countries for possible technology investments, considering the potential of these economies mentioned by (Awnan and Ali Khan, 2015). Regarding expectations, such as steady economic growth in the future due to a younger active population, the development of consumer markets, the expansion of the middle class, and the increase in exports may influence the adoption of service robots in emerging economies as well as the post-implementation economic benefits.

Once robotization reaches multiple countries with different economic structures, a wave of robots could spread into the markets and customers' personal lives, providing them many options, just as the internet did (Castells, 2013; Hackl, 2020). The current study shows how different skill combinations rank robots. Until now, the most advanced service robots are humanoid robots. In addition to having the three social/emotional, cognitive/analytical, and physical abilities, they can perform complex tasks while mimicking humans. Humanoid robots look not only physically similar to human beings but also display similar psychological states by recognizing customers' facial emotions, movements, or sounds under experimental conditions (Belanche et al., 2020). Söderlun (2022) points out that even several existing robots seem to recognize themselves in a mirror, an ability that requires a relatively advanced form of intellect. Researchers such as Saegusa et al. (2014) and Stoytchev (2011), mentioned by Söderlund (2022) in his paper, have noted that once robots are truly capable of recognizing themselves, this would improve their abilities to interact with customers, use new tools, self-repair or even become a customer.

LIMITATIONS AND CONCLUSION

Service robots are a fast-developing area in the services industry, especially gaining momentum after the COVID-19 experience, so much so that market development is way ahead of academic business research. In this conceptual paper, we intend to explore, summarize, and organize the recent developments in automation and artificial intelligence pertaining to the service industry. We recognized a gap between academic discovery and marketplace applications regarding service robots.

Our research enabled us to design a framework to direct research to analyze customer-employee-technology interactions based on the skill sets of related parties. As far as we know, this framework may be one of the first attempts to organize robot development activities around the necessary skills in service marketing. The framework is definitely not exhaustive, as the research is moving very fast. We focused on the social/emotional, cognitive/analytical, and physical skills as the most relevant in customer, employee, and technology relationships in multitude of service situations. There may be other variables that are worth considering. Development of such variables, data collection, and analysis methods are beyond the scope of this paper.

As indicated in the future research avenues section, the design and development of service robots and their impact on customer-employee-technology interactions are wide open for new research. Even though we have not approached this topic from any existing research philosophy perspectives in mind, the framework may help researchers from positivist or relativist paradigms design their investigations better. Indeed, the opportunities for further research make this topic very exciting.

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