A Review of Identity and Roles of Robotics in the Healthcare Industry

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Abstract – Robotics is a branch of engineering that deals with the design, construction, operation and application of robots to perform some physical tasks on behalf of human beings with varying degrees of autonomy. Generally, robots are used to perform jobs that are highly repetitive or have a high risk towards human's life. This article seeks to critically examine various classifications of robots used in the healthcare industry and their specific applications. This paper looks at advances made in the field of artificial intelligence (AI) and robotics mainly focusing on notable progress by key players like IBM Watson and Google's DeepMind. The study explores robotic applications in different medical setups such as surgical operations, telemedicine, rehabilitation, radiation, telepresence, socially useful activities, and pharmacy services. Besides that, this article discusses how potentially imaging nurse robots, cleaning robot and delivery/transporting robot can change health care sector in future. The article underscores the need for more research and development efforts to enhance comprehension of the functionalities and potential uses of robots within the healthcare sector.

Keywords – Surgical Robots, Rehabilitation and Mobility Robots, Radiotherapy Robots, Telepresence Robots, Interventional Robots, Socially Assistive Robots, Disinfection Robots, Delivery, Transport Robots.

I. INTRODUCTION

Based on data provided by the World Health Organization (WHO) [1], it is anticipated that the proportion of individuals aged 60 years and older in the worldwide population would see a significant increase from 12% to 22% between the years 2015 and 2050. This indicates that the pace of growth of the aging population is much higher than to previous periods. Consequently, several nations have substantial challenges pertaining to the well-being of elderly individuals, necessitating adequate preparedness of health and social institutions to effectively address this demographic transition. Due to this rationale, several nations have implemented the incorporation of technology that possess the ability to engage in human contact, exemplified as robots equipped with artificial intelligence (AI). The technologies have shown to be very beneficial within the context of hospital environments, where the overall demand for healthcare services often leads to a scarcity of healthcare professionals.

In the last decade, the area of AI and data science has seen a significant proliferation of technical advancements. Even though research in AI for many applications has been persistently pursued over the course of several decades, the present surge of AI enthusiasm distinguishes itself from its predecessors. The fast advancement of AI tools and technologies in the healthcare sector may be attributed to the synergistic effects of enhanced computer processing speed, expanded data gathering libraries, and a substantial pool of AI expertise. This development has the potential to bring about a significant transformation in the field of AI technology, as well as its widespread acceptance and influence on society. The emergence of deep learning (DL) has significantly influenced the contemporary perception of AI tools, hence generating considerable enthusiasm for AI applications. DL enables the identification of intricate relationships that were previously unattainable with conventional machine learning techniques. The foundation of this approach primarily relies on artificial neural networks.

In contrast to previous iterations of neural networks that included a limited number of connections spanning 3 to 5 layers, deep learning networks exhibit an increased depth with over 10 layers. This pertains to the simulation of artificial neurons on a scale of millions. Several prominent businesses, like as IBM Watson and Google's Deep Mind, are leading the way in this field. These firms have shown the superior performance of their artificial intelligence systems in various jobs and activities, such as chess, Go, and other games, surpassing human capabilities. Google`s Deep Mind and IBM Watson are now used in several applications of healthcare [2]. The use of IBM Watson is now being explored in the domains of diabetes management, advanced cancer treatment and modeling, and drug development. However, its clinical efficacy in benefiting patients has not yet been shown. DeepMind is now being investigated for several applications, such as serving as a mobile medical assistant, enabling diagnostics using medical imaging, and facilitating the prediction of patient deterioration.

Several computation and information-based technologies have shown exponential growth patterns. One well recognized illustration is Moore's law, which elucidates the exponential advancement in the efficacy of computer chips. Several consumer-oriented applications have shown comparable exponential expansion via the provision of cost-effective services. In the fields of healthcare and life science, the potential for significant development exists due to the mapping of the human genome and the digitalization of medical data. This growth may be attributed to the decreasing costs associated with genetic sequencing and profiling, as well as the use of electronic health records and similar platforms for the purpose of data collecting. While first seeming insignificant, these places will eventually experience exponential expansion. Humans often struggle to comprehend exponential trends and tend to overestimate the immediate influence of technology, often within a span of one year, while simultaneously underestimating its long-term effects, spanning a period of ten years.

The utilization of robots in health care environments is anticipated to experience a surge due to the advancement of technology, the decrease in associated expenses, and the rising need to control expenditures. Nevertheless, the advent of robotics has significant potential for disruptive innovations, necessitating a comprehensive comprehension of the sociotechnical obstacles that are expected to arise throughout the implementation of robots. It is essential to identify and develop solutions to address these issues. Sociotechnical approaches to the examination of technology deployment see social and technical elements as mutually influencing one another over the course of time. The prevailing assumption posits that technologies are influenced by their social contexts, as seen by the modifications made to their designs. Additionally, it is acknowledged that social settings are also influenced by the characteristics inherent in technologies, leading to changes in the work practices of users with the introduction of new technologies.

Robotic systems have been widely acknowledged as having the potential to mitigate manpower demands, particularly within the healthcare sector. The user's message does not contain any data to be rewritten academically. These systems may include remote robots' presence designed for real consultations, as well as movement of robots intended for automated delivery of items inside medical settings. Furthermore, robotic systems have the potential to provide assistance for clinical practice across several disciplines, in addition to their use in hospital settings. Illustrative instances include exoskeletons designed to facilitate the movement of stroke victims and surgical robots enabling doctors to conduct procedures from a distant location. Gaining a comprehensive understanding of the many functions that robots play in the healthcare sector is crucial for informing future research and development endeavors.

The objective of this article is to ascertain the many categories of robots used in the healthcare sector and determine their specific applications via a qualitative examination of the existing literature. By using this approach, it becomes possible to provide forecasts on the future trajectory of robots. The subsequent sections of the article have been organized as follows: Section II presents a review of previous literature works related to the research. Section III focuses on the methodology employed in composing this paper, which follows the rules outlined in the Cochrane Handbook for Systematic reviews of Interventions. Section IV presents a discussion of the results, which focus on defining the participants and search results, and identified robots and their roles within the healthcare sector. Lastly, Section V presents a conclusion to the research, and recommends directions for future research.

II. LITERATURE REVIEW

During the early 20th century, as argued by Hockstein, Gourin, Faust, and Terris [3], robots had not yet been a prominent element in popular science fiction narratives. The notion of robotics gained recognition in the public mind with the publication of Joseph Capek's short novel Opilec in 1917 and the subsequent release of Karel Capek's play Rossum's Universal Robots (RUR) in 1921 [4]. The attribution of the word "robot" to its original creator is a subject of scholarly debate within the Czech literary sphere. The etymology of the name "robot" may be traced back to its Czech origin, specifically the word "robot," which denotes the concept of a serf or worker. Karel Čapek's play, RUR, was crafted with the intention of expressing a critique towards the fast advancement of contemporary technology. As such, the playwright portrays a progressive development of robots, highlighting their expanding powers, and ultimately depicting a rebellion by these robots against their human creators. The Capek brothers unintentionally coined the word "robot" in contemporary lexicon, hence igniting widespread public intrigue about their inventions.

According to Blair [5], the first use of live surgical applications was the deployment of active robotic equipment that operate autonomously, relying on pre-programmed data and computer-generated algorithms, without requiring real-time input from operators. The first use of industrial robotic technology for surgical purposes was documented in 1985, when a modification was made to an industrial robotic arm to enable the performance of a stereotactic brain biopsy with a remarkable precision of 0.05 mm. The technological entity served as the prototype for Neuromate, a medical device developed by Integrated Surgical Systems in Sacramento, CA, USA. Neuromate subsequently obtained clearance from the Food and Drug Administration (FDA) in 1999 [6]. The Robodoc (Integrated Surgical Systems) was first launched in 1992 as a tool for doing hip replacement surgery (see Figure 1). The Robodoc is a computer-assisted milling device used for the purpose of coring the femoral head to facilitate the insertion of a hip replacement prosthesis.

According to Trimpe and Buchli [7], the notion of remote robotic operation has been widely acknowledged for its advantageous implications across several domains. Several possible uses include defusing explosive devices, conducting surveys in outer space and the deep sea, and providing medical treatment to war victims from a secure location behind the front lines. The first iteration of the DaVinci surgical system had a console for the surgeon to operate remotely and a system for controlling instruments with three robotic arms (see **Fig 1**). The surgeon's console is equipped with two viewers, each dedicated to one eye, that provide a three-dimensional perspective of the surgical site. The surgeon assumes a seated position at the console, placing his hands on the control grips that facilitate arm, wrist, and pincer movements (see **Fig 2**). The hands of the surgeon are positioned in alignment with the visual axis and are responsible for manipulating the wristed equipment, which offers seven degrees of freedom (see **Fig 3**). The instrument drive system, which is operated by a robot, consists of a tower with three articulated arms. Two of these arms are responsible for manipulating various surgical instruments with a diameter of 8 mm, while the third arm is used to operate a binocular video endoscope (see **Fig 4**).

Fig 1. The da Vinci S surgical robot. On the left is the control panel for the surgical robot, and on the right is where the surgeon will stand.

Fig 2. Application of grips that are perpendicular to the binocular viewers' optical axis.

Fig 3. Multiple 8 mm enchanted instruments

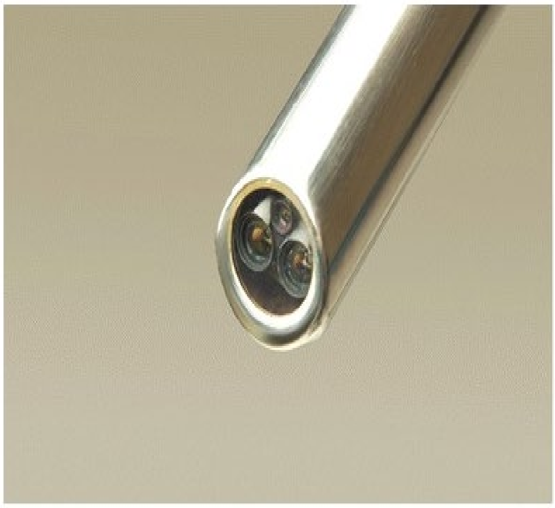

Fig 4. The binocular endoscope consists of two parallel glass rods, each of which transmits a picture to its own camera head.

According to Habuza et al. [8], the area of AI and robotics has made significant advancements in addressing the urgent requirements of the healthcare industry during the ongoing epidemic. Scholars and inventors are offering novel remedies for the escalating difficulties encountered in the healthcare industry because of the COVID-19 pandemic. This section examines the various areas in which Robotics and AI have made significant contributions towards improving the circumstances during the ongoing pandemic. These areas include disinfection, diagnosis, service automation, risk assessment, supply chain management and delivery, tele-healthcare, surveillance, and the acceleration of drug and research development.

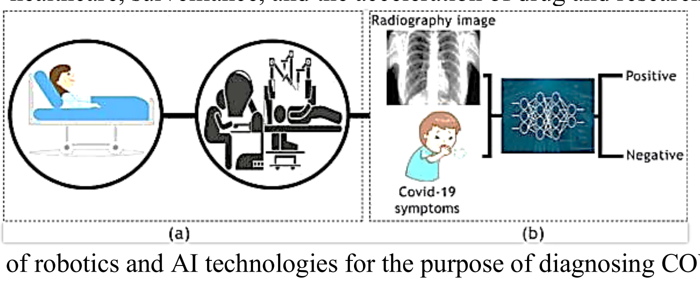

Fig 5. The use of systems of robotics and AI technologies for the purpose of diagnosing COVID-19. (a) The usage of robotic systems for the purpose of contactless sample collecting. (b) The use of AI for the identification of COVID-19.

According to Hope-Simpson [9], there has been an increased emphasis on prioritizing quick testing as a means of mitigating contagion and curbing the transmission of a virus. Nevertheless, this task presents difficulties because of the limited availability of medical services and the heightened risk of transmission via close proximity. Robotic technologies have the capability to acquire samples in a non-contact manner. Robotic technology is being used as a means for physicians to remotely diagnose patients, therefore reducing the risk of contamination. AI algorithms play a crucial role in expediting the patients suspected and accelerating the testing procedure with minimum human intervention. **Fig 5** depicts a selection of AI and robotics technologies used in the context of COVID-19 diagnostics.

The objective of this article is to ascertain the many categories of robots used in the healthcare sector and determine their specific applications via a qualitative examination of existing literature. The robots that were discovered have been classified into several tasks, including: **s**urgical robots, rehabilitation and mobility robots, radiotherapy robots, telepresence robots, interventional robots, socially assistive robots, pharmacy robots, imaging aid robots**,** disinfection robots, delivery, and transport robots. This study presents a comprehensive examination of many research and applications pertaining to each distinct type of robots.

III. METHODOLOGY

The scoping review procedure was implemented following the rules outlined in the Cochrane Handbook for Systematic Reviews of Interventions [10]. A comprehensive search was performed in the databases of bibliography listed below: The databases Scopus, CINAHL, Embase, Cochrane Library, and MEDLINE were queried utilizing MeSH (medical subject headings), the corresponding thesaurus specific to each database, in addition to text keywords. The database search query encompassed two unique browse concepts, namely the utilization of robots for intervention purposes and the particular context of a healthcare setting.

The intervention was characterized using specific terminology, namely “socially assistive robot*”, “service robot*”, and “surgical robot*”. These phrases were related with the MeSH term “Robotics”. The investigation also included the identification of certain robot systems. The terminology used within the given excerpt included the below expressions: “Field hospital,” “outpatient setting,” “geriatric hospital,” “pharmacy,” “rehabilitation hospital,” and “acute centre.” These terms were classified under the MeSH category “Hospitals.” The asterisk symbol (*) usage allows for the word to be regarded as a prefix. As seen in Supplementary Material A, the term “elder*” is used to include many related terms such as “elderly” and “eldercare.” Additional papers were identified using a comprehensive search strategy that included the use of Springer, and Elsevier as well as the examination of reference lists from chosen articles and pertinent reviews.

The papers were subjected to a three-step evaluation procedure by two independent reviewers, namely AM and MS. This approach included screening the full text, abstract, and title of each publication, and choices were made based on predetermined exclusion and inclusion criteria. The concept of inclusion refers to the integration of a physical robot into a healthcare environment. Exclusion criteria were applied to the study selection process. These criteria included the following: studies that were reviews or meta-analyses, published studies in languages apart from English, studies that were technical reports, studies conducted in settings that were not relevant to the research question, studies that used interventions unrelated to the topic (e.g., artificial intelligence instead of robotics), and studies for which the whole text was not accessible.

The articles obtained via the reference list, and database search harvesting were evaluated using a 3-point scale (0, not relevant; 1, perhaps relevant; 2, highly relevant). Only those publications that received a cumulative score of 2 from both evaluations were considered for further evaluation. Publications that had a cumulative score of zero were omitted from the analysis. A publication with a cumulative score of 1 indicates a divergence of opinions among the reviewers, necessitating resolution via deliberation and discourse. Following the completion of the full-text screening phase, an overall selection of articles to be inserted into the review was obtained. The coefficient of Cohen kappa was computed to assess the level of agreement among the reviewers throughout the screening steps of abstract, full-text, and title evaluation.

The information extraction form was developed in accordance with the OPCI framework, which encompasses the key elements of outcomes, participants, comparator, and intervention. The procedure was carried out by four reviewers, namely JA, AM, GE, and MPV, in accordance with a standardized pro forma extracted. The outcome measures that were reported in the chosen trials were retrieved. The process of data extraction included several elements, such as the outcomes of interest, the total number of participants involved, the age range to which the participants belonged, the exact type(s) of robot used, the venue in which the research took place, the design of the study, the comparators utilized, and the specialty under investigation.

Multiple instances of the same research may be found in various conference proceedings, journals, or publications, with each iteration potentially emphasizing different measures or including more follow-up information. The procedure of extracting data was performed on the report that provided the most thorough information on certain research. The robots that were found in this study were categorized based on their primary function. The authors of the research established these groups, which are not explicitly referenced or specified within the studies themselves. Data that lacked clear definition in the research, such as the name of the robot, were designated as “n/a”.

IV. RESULTS AND DISCUSSION

Participants and Search Results

The studies had a collective sample size of 5,173,190 people. Most articles, namely 53%, had a sample size of less than 45 participants. Notably, publications that drew data from national databases tended to have bigger sample sizes. Most of the publications, namely 89%, were centered upon adult populations, while a much smaller proportion, specifically 7%, exclusively focused on paediatrics. The areas of expertise that exhibited the highest number of publications were stroke (n = 194, 21%), general surgery (n = 137, 15%), and urology (n = 149, 16%). Various clinical settings were used, with the rehabilitation unit (n = 353) and the surgery theatre (n = 498) being the two most prevalent. Seventeen catheterization labs, sixteen pharmacies, and ten general wards were subsequently prioritized. Among the papers analyzed, a small proportion of 4% included studies related to aged care units (n = 7), pathology laboratories (n = 4), and outpatient clinics (n = 6).

Table 1. Tabulated PRISMA Process Determining Selection Process

Process		N = ?	Exclusion	
1.	Free search and harvesting of references	96	n/a	
2.	Database search	3836	n/a	
3.	Records after duplicates removed	3834	n/a	
4.	Assessment of Titles	3834	Virtual interference	n = 484
			Review or Meta-analysis	n=231
			Wrong setting	n=59
			Wrong language	n=55
			Diagnostic AI Software	n=31
			Technical report	n=11
			Other	n=48
5.	Assessment of Abstracts	2915	Virtual intervention	n=413
			Review or meta-analysis	n=221
			Wrong setting	n=65
			Technical report	n=24
			Diagnostic AI software	n=23
			Other	n=114
6.	Full manuscrits assessed	2055	Review or meta-analysis	n=141
			Manuscript unavailable	n=106
			Technical report	n=99
			Virtual intervention	n=93
			Wrong setting	n=69
			Wrong language	n=34
			Diagnostic AI software	n=6
			Other	n=382
7.	Data Extraction	1123	Excluded	n=196
			Inadequate and Unusable data	n/a
			Not clinical	
			Reviews	
			Duplicate	
8.	Final publications	927	n/a	

The first database search resulted in the identification of 3836 articles. Additionally, 96 publications were obtained via the free search and reference harvesting process. Ninety-eight duplicate articles were excluded from the analysis. After undergoing three screening rounds, a total of 1123 publications achieved the criteria for inclusion in the study. During the process of information extraction, an additional 196 articles were excluded from the analysis. These exclusions were made based on criteria such as non-clinical assessment, duplication, reviews, and missing data, or insufficient data to facilitate extraction. Consequently, the final dataset included a total of 927 original studies. The method of doing a literature search is visually shown in **Table 1** using the PRISMA process. This process effectively demonstrates the many stages of the review process as well as the criteria used for excluding certain studies.

The agreement of inter-rater among the reviewers was 0.23 for screen title, 0.53 for the final report, and 0.46 for the abstract screen. These values indicate a moderate, and fair correlation among the reviewers, as measured by coefficient of Cohen Kappa. The studies included in this analysis span from 1994 to 2022, exhibiting a variation in the number of publications each year, ranging from 0 to 152. The publications median number each year was found to be 16, with an interquartile range (IQR) of 46. The quantity of published works reached its zenith in 2021, exhibiting a substantial increase of 585% compared to the same figure from a decade before.

Identified Robots and Their Roles in Healthcare

A total of 165 robots with distinct names were detected. The most extensively researched robotic systems in the field of medical technology were the da Vinci System of Surgical advanced by Intuitive Surgical in the US, which was the subject of 291 studies. Following this, the Lokomat® manufactured by Hocoma in Switzerland was investigated in 72 research papers, while the Hybrid Assistive Limb (HAL) developed by Cyberdyne in Japan was the focus of 46 studies. The comprehensive compilation of detected robots may be seen in Supplementary Material C. The robots that were detected were classified based on their respective roles, resulting in the establishment of ten distinct groups. These groupings include the ten broad tasks that robots have been identified to fulfill in the healthcare sector. **Fig 6** illustrates the quantity of articles associated with each category of robots.

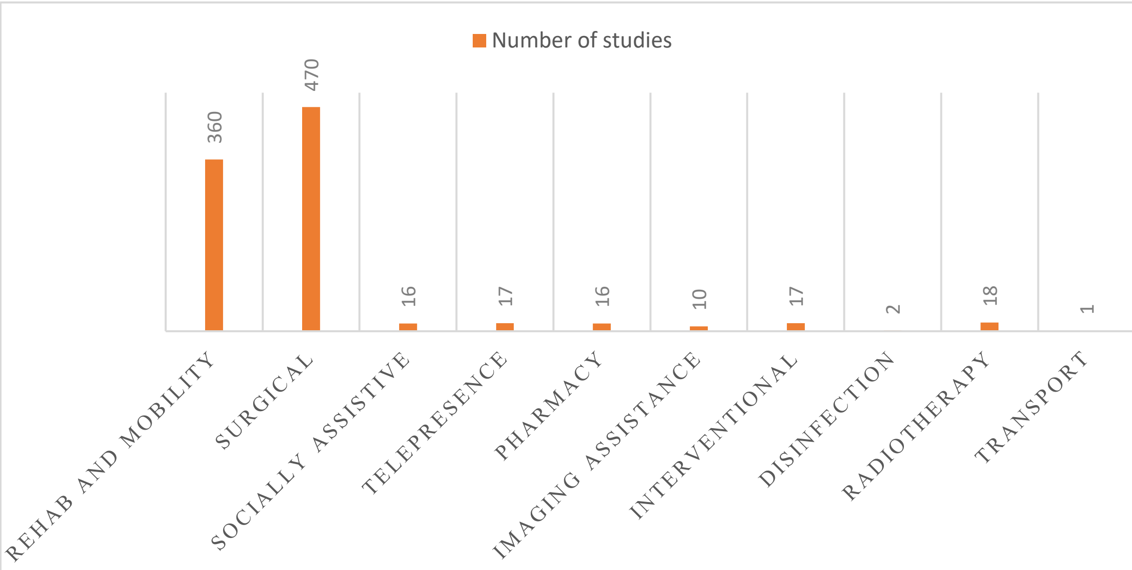

Fig 6. The Quantity of Research Conducted Inside Each of the Ten Robot Groups

Surgical robots

Surgical robots have the capability to provide assistance during the execution of surgical operations. The precise responsibilities they undertake within the field of surgery include a wide range of tasks, spanning from the management of surgical instruments to the automation of movements on surgical tables. The function in question has been extensively investigated, constituting 51% of the research included in the analysis. Furthermore, a total of 19 specific robots have been recognized and named within these investigations. The majority of studies conducted in this particular area are of an observational character, accounting for around 90% of the research conducted.

The Surgical System of da Vinci is widely recognized as the leading robotic platform in current use, consequently boasting the most extensive body of literature dedicated to its study and application. The system offers a range of equipment that may be used by a surgeon through a console to do minimally invasive surgical procedures. It has the potential to be used in many surgical operations such as cholecystectomy, pancreatectomy, and prostatectomy. An illustration of this may be seen in the research conducted by Capili and Anastasi [11], where a retrospective cohort design was used. The study included 103 patients and aimed to compare the results of robot-aided anti-reflux surgery using the Surgical System of da Vinci with those of traditional laparoscopy. The focus of the evaluation was on outcomes. Additional systems of robots that have been investigated include the system of Surgical of ROBODOC®, an USA-based Curexo Technology, which has been utilized in the field of orthopaedics for the purpose of planning and executing total knee arthroplasties. Another notable example is the

ROSA® (Robotized Stereotactic Assistant), a France-based Zimmer Biomet technology, which has demonstrated its potential in assisting with neurosurgical procedures, specifically in the realm of intracranial electrode implantation.

Certain robots that have been found are capable of providing assistance in doing biopsies as well. One instance of a robotic system that may aid in seeing and guiding needles during prostate biopsy is the Mona Lisa iSR'obot™, established in Singapore-based Biobot Surgical technology. A publication that was included in the study examined this robot in a prospective manner, focusing on a cohort of 86 men who were having prostate biopsy. The primary objective of Li, Zhang, Wang, Hou, Zhang, and Chen [12] was to assess the robot's ability to identify clinically important prostate cancer.

Mobility and rehabilitation robots

Mobility and rehabilitation robots refer to a category of robotic systems designed to provide physical assistance or assessment to patients, hence facilitating the attainment of certain objectives. These devices have the capacity to enhance manual dexterity, facilitate the attainment of rehabilitation objectives, or assist in the process of mobilization. These robotic systems have the potential to be used in both inpatient healthcare facilities and community-based rehabilitation centers. Robotic systems have a significant role in healthcare, particularly in the domain of rehabilitation, as shown by the analysis of evaluated articles which indicates that rehabilitation constitutes 39% of the total. The aforementioned cluster of robots exhibited the most significant percentage of interventional research, accounting for 75% of the total interventional studies conducted by this group. Within this particular category, there exists a total of 102 robots that have been assigned distinct names. These robots possess the capability to fulfill a diverse range of duties. The primary function of most medical devices is to provide physical support to patients, therefore aiding in the rehabilitation process. This may include either whole-body or single-joint support. Robotic tilt tables and robotic wheelchairs are used by individuals for posture training and mobility purposes.

One widely used robotic device for rehabilitation in conditions such as stroke is the Lokomat®, which functions as a gait orthosis robot. The main function of this activity is to enhance the strength and range of motion in the lower extremities. A research conducted by Palazzolo et al. [13] examined the effectiveness of a robot in the context of stroke rehabilitation. The researchers conducted a randomized trial involving 30 patients with acute stroke. The participants were divided into two groups: one getting conventional physiotherapy alone, and the other getting conventional physiotherapy in addition to Lokomat therapy. The study aimed to evaluate the effect of the interventions on results related to ambulation ability. One of the robots that has garnered significant attention in academic research is HAL, a powered exoskeleton that has been extensively investigated. HAL is available in many iterations, including versions designed for lower limb assistance as well as those equipped with single-joint functionality. The primary focus of scholarly investigations is in the examination of its application within the realm of neurological rehabilitation. However, scholarly inquiry also encompasses the exploration of its utilization in other domains, including post-operative rehabilitation.

Two studies have shown the use of robots in the evaluation of several patient characteristics, including gait speed. One such robot, known as Hunova and developed by Movendo Technology in Italy [14], is designed for both trunk and lower limb rehabilitation as well as sensorimotor assessment, specifically in terms of limits of stability. Bang and Lee [15] presented an instance of employing this robot, wherein it was utilized to acquire patient parameters for the purpose of constructing a model of assessment of fall risk within the community with elderly. The underlying concept was to enhance clinical evaluation through the integration of robotic assessment, thereby yielding more reliable and comprehensive data.

Radiotherapy robots

Cancer, being responsible for a considerable number of fatalities, emerged as a prominent cause of mortality in 2020, with an incidence exceeding 19 million cases [16]. Radiotherapy (RT) has historically been a highly used and effective therapeutic modality, necessitated in most instances, accounting for around 60-70% [17]. Nevertheless, the administration of ionizing radiation, which forms the fundamental basis of radiotherapy, may potentially have significant adverse effects on both patients and medical personnel. As a result, ensuring the safe and automated distribution of radiation doses represents a critical obstacle in the field of radiation therapy. One intriguing aspect is to the localization of the target, which is often situated deep inside the patient's anatomy and not clearly discernible. Additionally, it is important to consider patient movements during therapy. Mazzoleni et al. [18] have suggested a variety of solutions based on robots and robotics approaches in response to the demanding environment, the need for automation, and the complexities associated with patient movements.

Radiation robots have the capability to provide assistance in the administration of radiation treatment. In this analysis, a single robot named Cyberknife (Accuracy, USA) was found among the group, with a total sample size of 18. The use of this robotic system enables the facilitation of radiation application and picture guiding for the purpose of managing medical disorders, including liver and orbital metastases. All the papers consisted only of observational studies, without any comparative groups. One publication that examined the safety and effectiveness of Cyberknife usage in patients with renal tumors was conducted by Bal, Łabuz-Roszak, Tarnawski, and Lasek–Bal [19]. They conducted a 40 patients case study and assessed the aforementioned aspects.

Telepresence robots

One fundamental characteristic of the telepresence robotic collective is its capacity to enable humans to establish a distant presence by using the robot. The use of robots may include a range of applications, including but not limited to doing remote ward visits, providing remote surgical mentorship, and facilitating remote inspection of histology slides. The group included a total of 17 articles, with the prevailing robotic systems being remote presence (RP) robots, namely InTouch Technologies from the United States, and Double Robotics, also from the United States. The Double robot is an autonomous mobile platform equipped with a pair of wheels and a visual interface. Klodmann et al. (20) used robotic systems for surgical ward visits when rural consultant surgeons were present and then compared this experience to conventional ward practices.

Interventional robots

Unlike their surgical counterparts, robots in this category are meant to assist during the intervention process, which includes a variety of medical treatments such as ablation in atrial fibrillation context, neuro-endovascular intervention and percutaneous coronary intervention (PCI). The possible uses for these instruments are very wide including catheter guiding and stent placement among others. In total, 17 studies were included that evaluated nine different robotic systems. The most commonly mentioned robotic systems were Niobe System (made by Stereotaxis in the US) and the Hansen Sensei Robotic Catheter model (produced by Hansen Medical in the US). Also mentioned were Corpath's systems (200 and GRX) manufactured by Corinda's, from USA. Magnetically controlled mechanisms enable Niobe system to move the catheter precisely. Jia et al.'s study [21] compares case-control analysis that was conducted to evaluate the safety and efficacy of Niobe system for AF treatment through conventional manual catheter navigation. Many cases have used Corpath 200 for different medical procedures including PCI [22]. Moreover, it has been reported that GRX system is used in endo-neurovascular procedures.

Social robots

Health can be improved only if there is a social life. In most cases, persons with bad health find it hard to build and maintain supportive social relationships. A damaging cycle emerges from this situation where physical health and mental well-being are both weakened. This statement holds true particularly for those who have serious ongoing illness management requirements. The effect of social limitations on people's well-being differs depending on the nature of the disability such as, among others, neuromotor disabilities (involving physical impairments), dementia (relating to cognitive impairment), depression (which refers to emotional difficulties), and autism (that entails neurodevelopmental disorders). These limits gravely affect health and lead to reduced quality of life and lifespan.

Due to this, there has been an increase in robotic presence in the medical sector that has led to possible ways through which they can be involved in managing patients' social health aspects. Cockerham et al [23] described "Social self-management of health" as a term used for adopting practices of self-care that promote both good mental and physical condition as well as comforting in a society. These activities include participation in meaningful social activities, developing satisfying personal relationships, and seeking support from competent individuals. Socially assistive robots are devices made primarily to assist humans through providing social interaction instead of performing actual acts on them physically. These SARs which originated from blending between assistive robotics and social robotics are constituted with an intention of offering the main assistance required by people while interacting socially with them too. In healthcare field, various roles are expected for SARs (Socially Assistive Robots).

These functions encompass conducting medical interviews, monitoring, and documenting symptoms, assisting with the organization of pills and medication schedules, guiding individuals through therapeutic tasks, offering companionship, serving as stress reducers and mood enhancers, and facilitating social interactions among humans.

Pharmacy robots

A cohort of robotic entities has been developed with the explicit purpose of aiding in the administration and provision of pharmaceutical services. This encompasses the processes of medication storage, dispensation, and compounding. As an example, a robotic system might be used to aid in the compounding of cytotoxic medications, aiming to decrease mistakes and mitigate potential risks to operators. A total of sixteen papers, each including ten robots, were included in the study. The robots that were most often examined in the literature were the Rowa™ Vmax, manufactured by Germany-based BD Rowa, and the Italian APOTECA Chemo. The automated system of BD Rowa™ Vmax is designed for the storage and administration of medicine in response to user requests. The system in question was implemented by Morgan [24] inside a teaching hospital pharmacy setting, where its investment return was assessed, specifically in relation to the rate of dispensing mistakes. The system of APOTECA Chemo is capable of automating the manufacturing process of chemotherapy treatment. In their study, Iwamoto, Morikawa, Hioki, Sudo, Paolucci, and Okuda [25] investigated the environmental pollution associated with APOTECA Chemo in comparison to traditional medicine compounding methods.

Imaging aid robots

Robots within this category have been used for their distinct capability to aid in the execution of imaging procedures across several domains within the field of medicine. A total of eight robots were included in the analysis, which included ten papers. The use of robotic camera handlers in theatrical settings is prevalent, while their application extends to other domains such as neurosurgery, where robotic microscopes are employed, as well as the use of transcranial magnetic stimulation robots. The robotic camera controllers that are often mentioned include Freehand® (Freehand, UK) and Solo assist® (AKTORmed, Germany). Robotic camera holders can be controlled through various input modes such as voice commands and moving a joystick. The publication undertook a comparative analysis to assess the efficiency of Solo assist in colorectal cancer context and analyze its safety and usability. Additionally, the research paper evaluated how well Solo assist was able to perform when compared to a human scope assistant.

Disinfection robots

The use of robots for the purpose of disinfecting clinical spaces, such as hospital wards or outpatient clinics, is a possibility that is currently being explored. The group included two experiments that assessed the efficacy of two robotic systems: Ultra Violet Disinfection Robot® (manufactured by Clean Room Solutions) and Light Strike™ (manufactured by Xenex, USA). Both systems use ultraviolet (UV) radiation as a means of disinfecting rooms, while the UVD-R has the additional capability of independent movement. The efficacy of UVD-R in disinfecting waiting rooms in hospital outpatient clinics was investigated by Astrid et al. [26], who conducted a comparative analysis with standard manual disinfection methods.

In recent years, there has been notable advancement in the rate at which robotic technologies are being adopted. The integration of robotics has potential for enhancing several aspects of infectious illness management in the present, such as disinfection. Traditional ultraviolet germicidal irradiation (UVGI) systems [27] use stationary equipment that often call for human oversight and handling. These devices can be made more employable by using mobile or autonomous UV robots. However, these types of machines can make decontamination operations more efficient with less labor force because they have greater self-reliance. They also permit monitoring from a distance through smartphones and tablets so that one can know how far along they are in the process of disinfecting and even uncover any problems that might be there. In this regard, this section provides an extensive overview of UV robots; it describes their operation as well as evaluates their effectiveness. At last, this section gives the scope of present generation of robots.

Ultraviolet (UV) robots provide automated and consistent disinfection. This makes the traditional UVGI tools more effective when they incorporate ultra violet lamps on movable surfaces allowing them to work autonomously. The ability by these machines to take decisions on their own is enabled through sensor inputs. Cadena et al. [28] use simultaneous localization and mapping (SLAM) as a means to construct a comprehensive representation of the surrounding environment. This map is then utilized to provide a potent ultraviolet (UV) dosage. Numerous empirical investigations substantiate the efficacy of ultraviolet (UV) equipment and robotics. A two-year randomized cluster experiment was done in the United States, including nine hospitals. The research aimed to evaluate the impact of incorporating UV-C robots into disinfection of quaternary ammonium on reducing the likelihood of acquiring future infections. Mehta, Hsueh, Kourtzanidis, Brylka, and Saeedi [29] have designed a mobile robot for UVC disinfection, which has the capability to effectively eradicate microorganisms. Nevertheless, a comprehensive analysis conducted by Dancer and King [30] examined the effectiveness of automated devices of decontamination using UV light. They concluded that more study of UV autonomous robots on efficacy, including the inclusion of control groups, is necessary prior to implementing any significant changes to current cleaning and disinfection protocols.

Delivery and transport robots

The use of robots in the transportation of objects between different locations is a viable proposition. A study was included in the research that examined the use of a delivery robot inside the confines of the ICU. The TUG Automated System of Delivery, developed by Aethon in the United States, is a robotic device designed to transport medications from the department of pharmacy to the Intensive Care Unit (ICU) without human intervention. Despite sharing comparable advantages, autonomous aerial drones and ADRs possess distinct operational strengths and disadvantages.

Nevertheless, Autonomous Delivery Robots (ADRs) exhibit superiority over unmanned aerial vehicles (UAVs) in several dimensions. For instance, it has been noted by Jennings and Figliozzi [31] that ADRs include more compartments, a greater cargo capacity, and a longer operating range. These features allow for numerous deliveries to be carried out in a single trip, compensating for their relatively slower speeds. Similarly, although drones and ADRs contribute to the reduction of carbon emissions in transportation, it is worth noting that drones spend around 4-10 times more energy compared to electric ground vehicles (specifically relevant to ADRs in high from medium wind factors. Moreover, it has been shown that drones may exhibit higher energy consumption compared to diesel delivery trucks in situations with a greater number of stops and consumers, such as densely populated metropolitan areas. In addition to the aforementioned design and operational advantages, the use of ADRs is also seen positively within legislative frameworks due to the perception that drones pose more risks to public infrastructure and humans. In a similar vein, it is worth noting that drones also make a significant contribution to the problem of noise pollution, which has the potential to evolve into a pressing public health concern. Conversely, it is important to highlight that ADRs provide the advantage of being both safer and producing less noise.

The Automatic Delivery Robots (ADRs) now used for delivery applications may be categorized based on their design and operating characteristics. According to Srinivas, Ramachandiran, and Rajendran [32], there are three types of Automated Delivery Systems: Road Automatic Delivery Robots (RADRs), Sidewalk Automated Delivery Robots (SADRs), and ADVs. Additionally, deliveries based on ADR may also be facilitated by traditional vehicles such as motherships. These deliveries rely on infrastructures such as robot depots and robot stations.

V. CONCLUSION AND FUTURE SCOPE

This article presents an evaluation of the notion of robots within the healthcare domain. The study presents a comprehensive analysis of 165 distinct robots, among which the da Vinci Surgical System emerges as the most extensively examined. The robots are classified into ten distinct categories according to their respective tasks within the healthcare sector. The aforementioned categories include several types of robots, such as surgical robots, rehabilitation and mobility robots, radiotherapy robots, telepresence robots, interventional robots, socially helpful robots, pharmacy robots, imaging aid robots, disinfection robots, and delivery and transport robots. The article presents several instances and research findings pertaining to each category, in order to exemplify the efficacy and practical applicability of these robotic systems within healthcare environments. Based on the analysis conducted on the identified robots within the healthcare domain, it can be inferred that surgical robots, rehabilitation and mobility robots, and telepresence robots are the prevailing subjects of study and implementation in healthcare environments. The da Vinci Surgical System, Lokomat®, and Hybrid Assistive Limb (HAL) are the robots that have been extensively researched and analyzed within their respective categories. Surgical robots are mostly used to provide assistance during surgical operations, whereas rehabilitation and mobility robots are utilized to support physical therapy and mobility training. Additionally, telepresence robots provide remote presence for tasks like ward rounds and surgical mentorship.

Extensive scholarly investigations have been undertaken pertaining to surgical robots, rehabilitation and mobility robots, and telepresence robots within the healthcare domain. However, it is worth noting that some categories of robots in healthcare have not garnered equivalent levels of scholarly scrutiny. Future research should prioritize the investigation of the possible uses and advantages associated with many types of robots, including radiation robots, interventional robots, socially helpful robots, pharmacy robots, imaging support robots, disinfection robots, and delivery and transport robots. It is essential to conduct further inquiries to evaluate the effectiveness, safety and cost-effectiveness of different types of robots in healthcare; as well as to undertake comparative studies that evaluate the performance of various robots or compare robots to traditional techniques in order to provide more comprehensive data about the advantages and constraints associated with the robots usage in healthcare settings. Moreover, it is imperative that future research places emphasis on the seamless incorporation of robots inside established healthcare systems and operational processes. This research encompasses an examination of the perceptions and beliefs held by healthcare professionals and patients about the robot's usage in healthcare settings. Additionally, it aims to explore the ethical and legal implications that arise from the deployment of robots in healthcare.

In general, the topic of healthcare robotics has a diverse array of prospects for future investigation. Delving further into these domains will serve to propel the progress and integration of robotic technologies inside healthcare environments. The body of data supporting the use of robots in the healthcare field is growing, leading to their increasing application in many specializations and environments. A total of ten distinct functions for robots were identified, with particular emphasis placed on the comprehensive exploration of surgical and rehabilitative applications. Nevertheless, further rigorous study is required, specifically focusing on less proven functions of robots, such as disinfection. The future trajectory of robots is anticipated to be centered on the concepts of distant presence and the capacity to perform activities in demanding settings. The realization of this vision relies upon the advancement of resilient network and infrastructure capabilities, which are crucial for facilitating the widespread acceptance and use of such technologies.

Data Availability

No data was used to support this study.

Conflicts of Interests

The author(s) declare(s) that they have no conflicts of interest.

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