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# Issues and Research Fields of Medical Robotics: A Review

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**Abstract**
***The goal for collaborative robots has always driven advancements in robotic technology, especially in the manufacturing sector. However, this is not the case in service sectors, especially in the health sector. Thus, this lack of focus has now opened more room for the design and development of service robots that can be used in the health sector to help patients with ailments, cognitive problems, and disabilities. There is currently a global effort towards the development of new products and the use of robotic medical devices and computer-assisted systems. However, the major problem has been the lack of a thorough and systematic review of robotic research into disease and epidemiology, especially from a technology perspective. Also, medical robots are increasingly being used in healthcare to perform a variety of functions that improve patient care. This scoping review is aimed at discovering the types of robots used in healthcare and where they are deployed. Moreover, the current study is an overview of various forms of robotic technology and its uses the healthcare industry. The considered technologies are the products of a partnership between the healthcare sector and academia. They demonstrate the research and testing that are necessary for the service of robot development before they can be employed in practical applications and service scenarios. The discussion also focused on the upcoming research areas in robotic systems as well as some important technologies necessary for human-robot collaboration, such as wireless sensor networks, big data, and artificial intelligence.***

**Keywords**
**Robotics, Medical Robotics, Healthcare, WSN, and human-robot collaboration.**

## I. INTRODUCTION

The use of service robots has improved considerably over time in the industrial sector, while less attention has been given to the technology in the healthcare industry due to the difficulties in providing interpersonal care and the kind of service rendered in the sector, which is believed to have hampered the invention of robots that can assist in patient care [1] [2] [3]. Previously, researchers [2] [4] [5] provided a summary of robotic applications during a pandemic. A study presented by [6] classified robot use in healthcare as the receptionist, ambulance, nursing, telemedicine, surgical, serving, cleaning, spraying/disinfesting, radiologist, outdoor delivery, rehabilitation, and food robots. Zeng et al. [7] further analysed the use of robots on the basis of the desired places, such as robots in communities, transportation, hospitals, airports, hotels, restaurants, recreation, attractions, and picturesque sites. These studies have offered a worthy summary of robotic advancements to date.

Numerous studies in the field of medical robots have focused on specialised medical robots for the improvement of robot deployment in the medical sector as well as improving the outcome metrics following their utilization. Some of the specialised robot services in the medical sector include robotic wheelchairs [8] and robot nursing assistants [8] [9].

Our public healthcare systems had to be reevaluated in light of the COVID-19 pandemic and made more adaptable to shifting end-user trends and needs. Consequently, medical robots may no longer be viewed as an alternative but as an advancement in the standard of medical care [10] [11]. Moreover, there has been relatively little in-depth research into medical service robotics. Therefore, it is critical to focus on the critical robotic technologies employed to fight the pandemic and to predict future research trends [12].

This study investigates the use of service robots in the healthcare sector, emphasising those that can benefit patients, medical personnel, customers, and organisations during the pandemic. The present study also focuses on things of increasing importance, such as hospital sanitary procedures, ensuring provision of patients' supplies, reducing mistakes, and monitoring patients remotely.

The rest of this article is organized thus: Section II is an overview of healthcare service robots. Section III describes the several types of robots that have been implemented in the healthcare sector. Section IV discusses the research directions, and finally Section V outlines the conclusion of the study and the research limitations.

## II. A REVISIT OF HEALTHCARE SERVICE ROBOTS

The section is focused on the service robots that have been developed for specific use in the healthcare sector. A medical service robot is described as one that performs duties in medical and clinical settings in either semi-automatic or fully automatic modes. Even though service robotics is still in its early stages, it is expected that by the coming few years, 38 billion USD will be spent on highly qualified service robots to help healthcare workers [13]. This is because robots will not only make healthcare workers' jobs easier, but they will also facilitate difficult tasks that need to be performed [14].

In 1993, the first definition of a service robot was provided by the Fraunhofer Institute for Manufacturing Engineering and Automation (Fraunhofer IPA). The institute defined a service robot as ”a freely programmable kinematic device that performs services semi- or fully automatically.” Services are defined as ”tasks that do not contribute to the industrial manufacturing of things but are the execution of valuable labour for persons and equipment” [15]. Since the first definition of service robots by the Fraunhofer IPA, many definitions have been suggested; for instance, the International Standardization Organization defined a service robot as ”a robot that performs useful tasks for humans or equipment, excluding industrial automation applications” [16]. The International Federation of Robotics emphasized the level of autonomy of the robot in their definition by suggesting that a service robot is ”a robot that operates semi- or fully autonomously to perform services useful to the well-being of humans and equipment, excluding industrial automation applications” [17].

As the phrase ”Service Robot” has evolved, the convergence of the service and industrial sectors has introduced some degrees of haziness in its definition. For instance, industrial automation devices utilize mobile robots and automated guided vehicles (AGV) while service robots are mostly employed in new environments such as hospitals [18].

There are numerous challenges in the domain of healthcare robots, such as the continuous phobia of robots taking the place of humans, thereby causing job losses [19]. Hence, the promotion of positive views and acceptance of medical service robots requires public engagement initiatives that will introduce and train healthcare personnel on how to operate these robots [1]. Additionally, the visibility of healthcare robots should be increased by making them available in everyday settings [17]. On the one hand, medical service robots can ease the stress on healthcare workers by aiding them with daily tasks, giving them more time to focus on higher-priority jobs. The greater employment of service robots could lead to decreased person-to-person contact among patients. This is more crucial during the COVID-19 pandemic since deliberate measures have been taken to reduce person-to-person contact, despite the resulting patient isolation [20].

Another major concern with medical service robots is reliability; as they interact with humans, service robots require detailed safety features as well as the internet that can handle the problems associated with remote communication, such as data breaches and unauthorised access. In addition to safety, there must be efforts to ensure no generation of false negative or positive results when using service robots to detect or diagnose ailments because this could be a significant risk to public health [21] [22]. As a result, there is a need for sustained technological improvement in sensor and actuator development. In addition, more studies should focus on human-deep learning interaction.

The following sections describe in detail the state-of-the-art of various types of medical care robots.

## III. TYPES OF MEDICAL ROBOTS.

Robotics in medicine and healthcare has progressed well beyond its humble beginnings in the operating room more than 30 years ago. Nowadays, robots can be employed to assist in a variety of medical fields as discussed below.

### A. *Examination Robot*

Robotics may first be used during patient testing, when it may check for COVID-19 symptoms [12]. For instance, an oropharyngeal swab robot may be developed for the collection of swabs from patients. Cross-infection between health workers and patients could be avoided with an oropharyngeal swab robot. Li et al. demonstrated that oropharyngeal swab robots detected pathogens at the same rate as a manual swab. The oropharyngeal swab robot witnessed high patronage during the COVID-19 pandemic [23]. Another kind of examination robot is one that performs robotic ultrasonography. During robot-assisted ultrasonography, exposure to illness between the patient and the sonographer is restricted by separating them using remote robotic ultrasound instruments. Network robotic ultrasound is necessary for remote or low-volume facilities because it helps patients in getting ultrasound services more quickly without having to travel to distant imaging centers [24]. Demand for radiologist robots is also high due to the issue of human exposure to high radiation levels and other safety concerns [6].

### *B. Medicine Production and Sample Test Robot*

Following the sample collection, the next stage is to immediately test them and acquire the results. A robotic technique that can perform high-throughput screening for the discovery of critical therapeutic targets against the COVID-19 virus has been described [25]. The virus and its related drug targets are typically detected using a robot and an automated platform. Once the virus has been identified and the sickness has been confirmed, it is vital to provide treatments and immunizations as soon as feasible. Robots and automated machines are used to manufacture medicines and vaccines for such clinical interventions [12].

Medical robotics have only recently begun to expand in patient-facing scenarios, despite their immense potential in SARS-CoV-2 situations. The robot's expensive price, limited patient-facing functionality, and potentially detrimental effects on patients, medical personnel, and interactions between them are the main causes of concern. On the contrary, the lab-based robot is anticipated to provide appreciable advancements in sample extraction and amplification [26].

Another study is [27], where the researchers showed two examples of robot-assisted ankle rehabilitation after equinus surgery in children utilising the HAL-SJ. Case 1 was an 8-year-old child, whereas case 2 was a 6-year-old boy. After they were able to walk without braces, they received postoperative training with the HAL-SJ for 20 minutes per session, a total of eight times (2–4 sessions per week). Assessments were carried out both before and after HAL-SJ training. Case 1 showed improved joint angles during the stance phase on the operated side during gait analysis, whereas case 2 had improved joint angles during the stance and swing phases. The co-activation index values of the medial gastrocnemius and tibialis anterior muscles dropped following training and approximated the standard value. The HAL-SJ is thought to have motor learning effects and may give systematic feedback regarding voluntary ankle dorsiflexion and plantar flexion.

### *C. Surgery and Rehabilitation Robots*

Surgery robots are designated for complicated and minimally invasive operations. During the epidemic, surgery robots attained notable success at reducing the length of patient care and boosting the availability of other patients. The benefits of surgical robots, including less interaction and contamination, a shorter hospital stay, less blood loss, and smaller incisions, promote surgical use, particularly in a pandemic [28] [29]. Patients and medical staff could securely use surgical robots. The study by [28] tested sixty members of the medical team who came into direct contact with patients during robotic surgery for COVID-19 virus transmission and found no evidence of virus contamination among them. Similar research by Zemmar et al. showed that pre- and post-surgery contamination can be reduced using surgery robots [29].

Surgery and rehabilitation robots are needed to prevent the spread of infection during a pandemic. Patients with disabilities can benefit from rehabilitation robots through reduced patient-caregiver contact, decreased infectious disease transmission through home rehabilitation equipment, and assistance for patients with impairments [7] [30]. Additionally, as the elderly population grows and the number of people with disabilities increases, there is a growing demand for rehabilitation robots. These rehabilitation robots come in a variety of forms, including autonomous collaborative robots, teleoperated robots, exoskeleton robots, hand-held robots, smart wearable mechatronic systems, and social robots [31].

### *D. COVID-19 Monitoring Robot*

The ways of minimizing COVID-19 infection includes regular use of face masks, social distancing, and regular hand washing. Infected persons often come down with a fever which is the most common sign of COVID-19 infection [32]. Remote monitoring of public spaces for early signs of the disease and ensuring the maintenance of social distancing may therefore help guarantee public safety and reduce the workload on medical workers. Also, if a person displays signs of an infection, they should be examined promptly, but the administration of swab sampling for testing could be dangerous to healthcare professionals due to close person-to-person contact [33]. To tackle this, nasopharyngeal and oropharyngeal swabbing robots can limit infection spread while also allowing healthcare workers to focus on higher-priority activities. The COVID-19 pandemic elicited a high demand for robot-based tests and diagnosis of cases related to the virus [34]. A good research study on robotics-based COVID-19 testing has recently been published by Shanti & Lugli [35]. The study defined the concept of robotic ”liveliness” following their increased usage during the COVID-19 pandemic, thereby contributing to robot geographies. Their conceptualization, which is influenced by contemporary materialism, came up with the idea of liveliness by considering the agential capabilities of robots in three different ways: seemingly autonomous technologies, perpetually incomplete and contingent things, and inorganic and mechanical bodies. They postulated that this concept of liveliness provides a method that can further criticize their use in ”caring” roles, an application that is rapidly emerging in the area of social robotics. They considered numerous instances of their usage even during the pandemic to decipher the potential for the emergence of robots as ”caring subjects.” They reasoned that the claim to ”care” inside robotics remains a major reason for more studies to be conducted on its liveliness. Furthermore, Yang et al. [36] published a study in which the authors offered a new telerobotic system for remote care management in isolation wards. That system is made up of two parts: a teleoperation system and a telepresence system. They expect to prevent infections by limiting interaction between infected individuals and medical personnel. In a study provided by [37] the authors built a novel device, designed using Unifed Modelling Language (UML) schemes and was informed by a risk analysis, which highlighted some of its critical requirements and specifications. As a result, the robotic system preferred constructive solution, a robotic-arm framework, was built and manufactured utilising computer-aided design and 3D printing.

### *E. Remote Surgery Robot*

The Research Center for Biomedical Technologies and Robotics (RCBTR) has begun a large project on the development of a laparoscopic telesurgery system. The robot system is comprised of a master console that can be operated directly by the surgeon, as well as three slave robots that are involved in carrying out the procedure on the patient. The master console also contains two master robots with a mechanical interface shaped in the form of a common laparoscopic surgery instrument [38]. These mechanical connectors are used by the surgeon to convey force or motion commands to the slave system. While using the robot, the haptic capabilities of the master robots ensure that the robot provides the surgeon with the force input that facilitates the interactions between the patients and the slave robots. There are three spherical robots in the slave system, each with four degrees of freedom and the gripping capability of the laparoscopic tool. The laparoscope is manipulated by one of the slave robots. It provides the surgeon with visual feedback via the master console. Also, a specific laparoscopic end tool is created for the slave robot, which is completely instrumented to allow for automatic grasping and safe tissue manipulation. Furthermore, a novel grabbing mechanism is used, allowing large as well as small organs to be handled. The prototype of the telesurgery system has been built and is undergoing technical testing, which will be followed by animal clinical trials [39] [40].

### *F. Cleaning and Disinfection Robots*

Cleaning robots are also recommended as a way of preventing human-to-human contact [41]. They have been shown to perform ultraviolet surface disinfection in some nations, achieving 99.99 % disinfection rates within 15 minutes in hospital wards rooms [12]. Hence, the orders for such cleaning robots are increasing as their efficiency, safety, and efficacy are anticipated to reach 400 – 600 % [41].

The GermFalcon robot was originally developed for aviation hygiene to improve travel safety has UltraViolet-C (UVC) light [12] that can eliminate superbugs, bacteria, and viruses. The UVC light also serves as a germicidal add-on for cleaning and disinfection of both civil and industrial areas [42]. The central column of the robot also has eight UVC lights with two extra lamps on top [43]. The mobile base has several sensors that can avoid obstacles and measure things like the temperature and humidity of the working environment.

A study by Cresswell & Sheikh [44] focused on the evaluation of the current generation of robots for cleaning and disinfecting purposes in healthcare settings. The study noted inefficiencies in the effectiveness of these robots, especially in dealing with the complex environment in schools and care homes during the pandemic. To improve the performance of cleaning robots, a fuzzy logic-based wall-cleaning robot was developed [45]. The evaluation study showed that the created fuzzy logic-based robot performed better than the conventional ones in various wall settings.

An indoor adaptive robotic disinfection method was developed by Hu et al [46] in which the deep learning-based object affordance idea was used to map and separate areas with potential contamination. The potentially contaminated area directs the robot’s path, and its short-wavelength UV light executes the required disinfection operation.

## IV. RESEARCH DIRECTIONS

As described in Section 3 (Types of medical robots), a significant portion of the literature to date consists of conceptual research concepts or proposals, including robotics during the pandemic. Only a few of them succeeded in developing viable approaches and implementing them on real robotic systems. Robotic arms have been widely used in research achievements as manipulators and duplicates of human actions, whereas mobile robots provide the required mobility to facilitate moving processes such as disinfection, cleaning, distribution, etc. Naturally, communication technology is crucial for the human-robot interface. Numerous applications, such as medicine and vaccine development, sample testing, logistics, etc., require some levels of automated instruments and controls.

In general, robots in the post-pandemic environment are predicted to become increasingly autonomous, versatile, and cooperative. Future studies are expected to focus on the following technologies to advance research on robotics during and after pandemic eras:

### *A. Wireless sensor network:*

In addition to potential problems, the literature lacks significant research on monitoring the robots' environment. It is essential to monitor the environment and work conditions, such as air quality, patient temperature, and other factors, and to activate the robot process accordingly. Effective communication and connectivity can be established by connecting the wireless sensor network to the 5G network.

### *B. Artificial Intelligence (AI):*

It is expected that AI will soon influence every sector of life, from domestic applications to automated robot-assisted medical providers. It is suggested that robot applications be integrated with AI technology to achieve intelligence and adaptability in a complicated working environment [47]. AI algorithms will be crucial in fields such as image processing, data analytics, and decision-making.

## V. DISCUSSION

Around the world, numerous R&D initiatives have been made to produce cutting-edge technologies and clinical applications for medical robotic and computer-assisted systems. The research activities entail a broad range of clinical problems. The current study defines the concept of service robots and examines the challenges to their adoption and reliability. Following that, a description of cutting-edge applications in healthcare systems is given, with an emphasis on emerging disease prevention. Furthermore, the proposed research is limited to medical robots and focused entirely on the topic indicated in the majority of papers. The limitation of this research is that it failed to provide a comprehensive perspective by including other types of medical robots, such as those that assist in drug prescription and administration, delivery of medical supplies, sanitation, and clinical management.

## CONFLICT OF INTEREST

The authors have no conflict of relevant interest to this article.

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