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Robots Exploration in Healthcare Support for Infectious Disease Scenarios: An overview

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ABSTRACT

The development of semi-autonomous and autonomous robotics fields has grown significantly in a variety of applications. One essential aim of existing robots is to operate and interact in a dangerous environment that is inconvenient for humans. It is estimated that by 2030, millions of workers worldwide will be replaced by robots, and this is evident of a robotic revolution taken place in healthcare worldwide wherein procedures and tasks have been made more safe and efficient. The literature review is on existing and the advancement of robotic technology in healthcare and beyond. healthcare robots are required to work safely in the human environment and interact closely with humans during operations unlike their industrial counterpart. This paper provides the state of the art of robotic technology, ethical consideration of robot deployment and future direction toward the fight against infectious disease such as SARs, MERs, Ebola, and Covid-19.

Key words: Autonomous robotics, ethical consideration, healthcare robot, humanoid robot, hazardous environment.

1. INTRODUCTION

Advancement in robotic technology results in the integration of various sophisticated technologies such as mechanical engineering, electronics, control systems, and software, which plays an important role in automating the healthcare sector. Robots are expected to work safely in the human environment and interact closely with humans during operation. Robots development for use in a range of applications has become gradually popular over time, particularly to replace tedious tasks or in a potentially unsafe situation. Though, while the field of robotics is growing rapidly, the more specific areas of hospital service robots for the treatment of infectious diseases remain relatively underdeveloped [1], [2]. There is an expectation for health service robots to play an important role in developing support tools to assist health professionals in the treatment of infectious diseases such as Ebola, Sars, Mers and Covid-19, which would increase the quality of life for both healthcare providers and patients.

Communication between robots and humans is very important to integrate humans and robots. Its function is to break down the barriers between machines and humans. The idea is that an individual can control the robot and establish commands for the required actions [3], [4]. Today's machine learning approach is more like the real world. Rapid advancements in robot technology allow algorithms to perform tasks that were previously limited to humans [5]. Providing relevant information to physicians to make informed decisions. Human robot interactions adds value to assistive technology and ensures that the systems can address the current needs associated with the spread of infectious diseases among health care workers. Healthcare service robots are expected to play a crucial role in the development of a supportive tool to aid medical professionals in the treatment of infectious diseases, which would increase the quality of life of both healthcare providers and patients. Service robots are being widely deployed as daily life companions for children with autism and the elderly at schools, hospitals and home environment.

2. LITERATURE REVIEW

The development of semi-autonomous and autonomous robotics fields has grown significantly in a variety of applications. One of the main goals of existing robots is to operate and interact in a dangerous environment that is inconvenient to humans. It is estimated that by 2030, 800 million workers worldwide will be replaced by robots, and this is evident of a robotic revolution happening in healthcare worldwide wherein procedures and tasks have been made more safe and efficient [6]. This literature review covers existing and advanced robotics technologies in healthcare and beyond.

2.1. Technological Advancement in Human Robot Interaction

Human-robot interaction is a study of how humans interact and collaborate effectively and naturally with robots. [7] carried out a research on how nurses view the potential use of robot in healthcare and pediatric unit in particularly and highlighted some advantages and shortcomings as regards care impact; robots are capable of performing repetitive tasks while assist with precision treatment thereby reducing caregivers' workload but in spite of their enormous advantages they are not capable of feeling emotions which makes them not able to provide true human connections with their patients. Therefore, robots need to work side by side with nurses who are capable of providing natural emotional feelings.

Services for human-robot interaction research in the field of robotics has grown in recent years, and many robots have been designed and developed in this field. Such areas include robot applications ranging from diagnostic tools [8], [9] to robotic telerounding for patient care [10], [11] to robot manipulation [12], [13]), navigation functions [14]-[18], educational and entertainment robots [19]-[26], household robots for everyday activities [27]-[29], robot companion and therapy for children who needs special attention [30]-[33] and care for the elderly [34]-[38], which increases patients' autonomy and relieve the enormous burdens that the elderly place on healthcare providers [7]. Care assistance is one of the identified key applications of robotics in healthcare, which include spoken reminder and errand performance via remotely controlled or programmed robot. [39] presents a robot that helps the doctor to perform remote medical examination by auscultation and ultrasound examination shown in Figure 1. The Nifty robot assisted medical workers to treat Coronavirus patient in the United States. The mobile robot is equipped with a stethoscope, the robot assists the doctors to take vitals and communicates with the doctor via a built-in screen shown in Figure 2.

Figure 1. ReMeDi robot

Figure 2. Nifty Robot

2.2. Mobile Robotic Telepresence (MRP)

The MRP comprises of the interface used to navigate the robot and the physical robot. The main objective of the MRP system is to aid in social interaction amongst people, with the feeling of being in another environment. A video is embedded with a mobile platform that allows users to move around in a robot environment [40].

Table 1: An overview of common mobile robotic telepresence (MRP) systems appearing in the literature

Robot	Proposed area of application	Commercial	Adjustable height	Manipulation
PRoP	Research	No	No	2 DOF hand/arm
Giraff	Elderly	Yes	No	No
QB	Office	Yes	Yes	No
mObi	Research	No	No	No
iRobot Ava	Healthcare	Yes	Yes	Yes

Helo and Telo	Unspecified	Yes	No	No
VGo	Office	Yes	No	No
Jazz Connect	Office	Yes	No	No
Mantaro Bot TeleMe	Office	Yes	No	No
Double	Unspecified	Yes	Yes motorized	No
Beam	Office	Yes	No	No
Mantaro Bot Classic	Office	Yes	Yes	No
Texai	Office	No	No	No
PEBBLES	School	No	No	Hand
RP-7	Healthcare	Yes	No	No
MeBot	Research	No	No	3 DOF arms

Source: [40].

Many remote robotic systems have been developed to operate in dangerous or undesirable environments for humans [41]-[45]. An important advantage of such a system is that human operators remain in a safe place away from potentially dangerous environments [1]. Dangerous or harmful accidents affect replaceable robots instead of humans. Examples of such applications are bomb disposal, space exploration, nuclear decommissioning or inspection, and infectious disease environments. The health sector is fast growing with technological advancement and the introduction of robotics as assistive tool would provide good supportive care for patients' allowing medical personnel to spend more quality time on patients' care for quick recovery [46].

2.3. Service robots

Service robots are widely used to replace or assist humans in almost every domain. They could be either autonomous or tele-operated. Tele-operated robots are robots that are operated from a distance by an operator using any of the available means of control, these robots are able to perform certain actions intended for humans [47]. A dual-arm home service robot shown in Figure 3 is designed by [48], which comprises arms, narrow-angle arm camera and wide-angle head camera and a mobile base. A command of a mobile phone with four degrees of freedom allows the robot to remove the coke from the refrigerator and perform other basic actions to provide convenience for senior citizens. [49] developed a prototype service robot to aid elders by the use of multimode input technology to control the robot for its desired action such as mobility, manipulation of small items, speech recognition, basic nursing abilities, motion detection, etc. which makes the elderly more independent. Designed a prototype humanoid robot with a payload of 500 g. The manipulation function is established by simulating the arm motion, which can be controlled remotely with wireless technology to support health personnel in delivery and other related tasks as shown in figure 4. Table 1 gives a brief description of different applications of robots for supportive care.

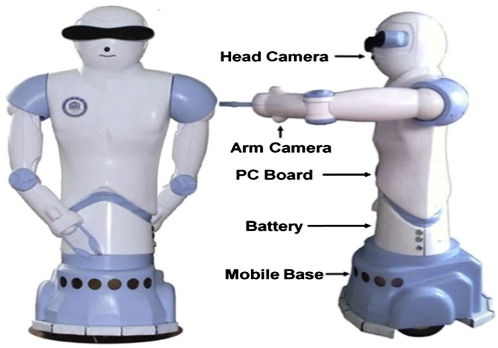

Figure 3: Mobile robot manipulation with cellphone interface [48].

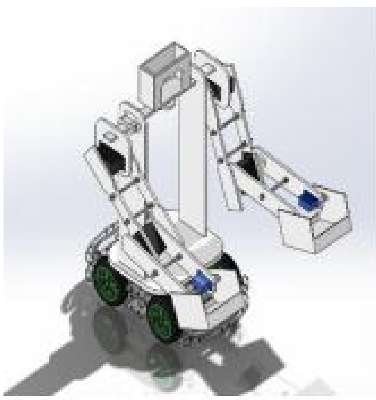

Figure 4: A 3D printed prototype robot [2].

2.4. Autonomous robot

An autonomous robot is a robot that is able to move freely in an environment with obstacles executing several tasks while obtaining information from the environment through sensors. They are generally deployed in dangerous environments that are difficult for humans to tread [50]. E.g. space exploration, waste management, undersea work, assistance for the aged or disabled, aid for children with autism, interventions in hazardous environment, nuclear decommissioning, unmanned bomb disposal, unmanned aerial vehicles and for firefighter robot. To achieve the above tasks, robots must be able to operate intelligently and autonomously while being equipped with perception, location, planning and navigation capabilities, which allows robots to make autonomous decisions based on information gotten from its environment [51]. Path planning algorithms are categorised according to completeness as exact and heuristic. Exact algorithms find optimal solution if one exists while heuristic based algorithms search for a solution with good quality while focusing on solution finding time reduction. In addition, exact algorithms need a high amount of computation while heuristic based algorithms might not be reliable in complicated problems due to their inability to find a good solution in some cases [52].

Table 2: A Review of Robot in Indoor and Outdoor Environment

Author	Robot	Description
[53]	ARMAR III	Built to support personnel in human-centred Environments and to manipulate objects in the environment. The upper torso is humanoid in design.
[54]	Care-O-Bot 3	A mobile robot assistant that supports daily human tasks. It consists of an arm and an end effector to manipulate objects in the environment, and a tray to transport and move objects.
[55]	Cody	A robot assistant assist nurses to help the hygiene of patients, specifically the bed bath. Use the compatible arm and mild force to achieve a cleaning action like those used in bed baths.
[56]	PR2	Mobile humanoid robot design that supports tasks in the human environment. Can work with objects and perform tasks like emptying the dishwasher and setting up a table.
[57]	RIBA	Humanoid robot with high load capacity built to lift and transfer patients.
[58]	RIBA	Designed to transport patients with

		humanoid arms. A touch sensor can be used to detect the position of the patient's contact and make movement adjustments accordingly.
[59]	Robotic Nursing Assistant	The robot is built to help nurses with tasks that are physically demanding, such as lifting and moving patients. The design of the upper body is humanoid.
[60]	Hair-Washing Robot	Assistive robot built to assist nurses wash patient’s hair.
[61]	ASIMO	A human-size robot with the following capabilities: running, walking, carrying objects climbing stairs and pushing carts.
[47]	ROSE	A remote control robot for home care uses. Able to perform tasks such as grip and place objects and cleaning tasks.
[62]	PR2	The findings suggested that patients trust the tele-operator more when they see the tele-operator. He suggested that the research be carried out in other locations to see if his finding is cross cultural
[39]	ReMeDi	Presents a robot for remote medical examination ReMeDi. The system allows for remote auscultation, ultrasound examination and palpation.
[63], [3]	Robco 18	A tele controlled service robot to provide interaction between the elderly and robot such as medication reminder, serving foods and drinks and to sound alarm on emergency. The robot is controlled by any of the four methods: gesture recognition control, joystick control, tele-control and speech command control.
[64], [65]	Care-O-Bot	Care-O-Bot was built to navigate dynamic obstacles and fetch drinks for occupants.
[64], [66]	ASIBOT	ASIBOT was designed able to navigate around the environment and assist the disabled in performing activities such as eating, washing, etc.
[67]	Bobot	Bobot was designed as a supportive tool for medical personnel intended for use in the paediatric ward. The robot is equipped with diagnostic functions, mainly for patients’ temperature measurement as well as a companion robot for patients.
[18]	Muratec Keio Robot	Developed an autonomous mobile robot for hospital application. The robot is equipped with a wagon truck to deliver specimens, luggages and other materials. With obstacle avoidance capability both static and dynamic obstacle using virtual potential fields.
[68]	BETA-G	They developed a prototype of a wheel-based mobile waiter robot for trial runs in an informal dining room outlet. Equipped with adjustable mechanism with three levels of tray to serve tables of different

		height.
[38]	SNOWY	Developed a therapeutic robot robot platform that provides a personalized level of patient interaction. It has the ability to integrate with other interactive devices and provide care for the elderly based on their individual needs.
[36]	The Hobbit project	Develop a care robot, which is capable of fall detection and prevention. Everyday interaction include offering reminders, carrying objects, and entertainment.
[28]	Robot-Era	A service robot designed to assist the elderly at home in their everyday tasks equipped with perception, manipulation and navigation capabilities.

2.5. Communication Interface

Communication interface plays a very important role in integrating robots among people. Their role is to break the barrier between machines and people by direct control or sets of command for executable actions [63], [3]. As regards to speech and touchscreen interaction channels. [69] carried out a study on users preferred choice, according to the study, touchscreen was the more preferred choice of communication probably because the users do not seem comfortable when talking loudly to a robot in the presence of others. However, touchscreen interaction is fast growing over the last couple of years and users are more familiar with it. Table 3 gives an overview of interfacing methods commonly used for tele operation. As shown, the touch screen appears to be the most common interface for human robot interaction.

Table 3: Personal Care Robot and their Control Mode

Author	System name	Interfacing method(s)	Commercial
[70]	Handy 1 robotic hygiene station	Keyboard or joystick	Avail Commercia
[71]	Care-O-Bot	Touch screen	Avail Commercial
[72]	MOVAID	Computer mouse, keyboard other MS3 input devices	Avail Commercial
[73]	MATS Home Care Arm (later became ASIBOT)	Joystick or touch screen	For Research
[74]	JACO	Joystick	Both
[75]	ASIBOT	Touch screen, joystick or voice recognition	For Research
[76]	Personal Mobility and Manipulation Appliance (PerMMA)	Joysticks or touch screens	For Research
[36]	Hobbit Mutual Care Robot	Gesture recognition, speech control or touch screen	For Research
[49]	A service robot	Speech recognition, touch screen	For Research
[77]	A mobile robot	Joystick	For Research

Source: [64].

2.6. Mobile platform

A mobile platform is required to access dangerous areas. For example, in unusual circumstances, such as the release of toxic gases, liquids, or radioactive materials. Entering such an area puts human health at risk. These robots can be remotely controlled to perform hazardous area inspections [78]. An example is shown in Figure 4.

Figure 4. Designed mobile robot with simplify electronic subsystems [78].

The mobile humanoid robot platform can perform various services for humans in the everyday environment [79]. Mobile wheeled robots that can operate safely and precisely in a dynamic environment can have a wide range of applications, ranging from simple delivery tasks to advanced assembly tasks [80], thus improving their control over a wide range has been the subject of many studies. Over the years, mobile platforms have played an important role in robot technology. They are increasingly used in assistance robots, service robots, manufacturing robots, home robots, and home robots that transport items in environments dangerous to humans. [81], [82], [22]. [83] proposed a system integration between the NAO humanoid robot and the mobile platform using the Arduino controller interface, and performed humanoid control navigation with the ability to avoid obstacles. Experiments carried out have demonstrated the suitability of mobile platforms adapted to NAO processing for navigation. To detect obstacles, the robot needs to recognize the surrounding elements. It must identify all objects that are considered obstacles. Some systems use ultrasonic sensors, vision sensors, laser rangefinders, GPS, and sonar rangefinders to solve range detection for localization.

Research activities are facilitated with advanced mobile robots with complex configurations using mobile platforms and basic omni-directional mobile robots. [84] introduced the concept and design of the mobile robot platform. A wheeled mobile robot that replaces the concept of an air cushion unit in a friction-free air cushion table, enables high-precision, long-term simulations using trajectory dynamics [85]. A mobile robot platform, PoultryBot was developed for use in a modern aviary to help farmers collect eggs on the floor every day. PoultryBot has been tested and demonstrated to be able to move around the environment [86]. [87] integrated ultrasonic and infrared sensors into various mobile robot platforms to obtain distance data, the sensed data was analyzed to provide a meaningful interpretation of the sensor response of the human body and metal surfaces. [17] uses a Raspberry Pi and Arduino Uno interface to move to a 2D environment like a line-following robot with mapping, navigation and obstacle avoidance functions, a lower end with a fixed 4-wheel chassis. [88] designed and implemented a prototype mobile robot platform for use in both educational and research activities.

2.7. Wireless Mobile Robot

The growth of wireless technologies along with Internet is faster than any other global infrastructure in history and has made a visible impact in our everyday. The impact is mostly in the direction of entertainment, information transfer, and communication [89]. Currently, wireless mobile robots are used to aid people in executing specific tasks both in healthcare and beyond, especially when the tasks are dangerous for humans. Like in search and rescue operations, evacuations, and infectious disease scenarios. For preventive maintenance and remote inspection of nuclear power plants, wireless mobile robots support the remote maintenance work of reactor cooling systems and pressure pipeline inspection. [90] developed a robot system with an expandable inspection mast mounted on a mobile platform. [91] designed and implemented a mobile robot with an in-vehicle camera that can be remotely controlled using wireless technology. The growth of wireless applications and the demand for systems that can easily connect devices for data transfer over long distances has led to the development of robots based on the Arduino Mega platform that interconnects wireless controllers with mobile robot arms. Wireless communications like the Zigbee protocol limit the coverage of the robot, but wireless robot systems using Arduino microcontrollers have better coverage [92]. [93] designed a microcontroller system that controls the navigation of mobile robots and avoids obstacles. The navigation systems, encoders and ultrasonic sensors used are presented depending on their operation. For monitoring and control applications, a wireless network for data exchange between mobile robot nodes is presented with the aim of finding ways to reduce the energy consumption and computing power of the robot nodes [94].

2.8. Ethical Considerations

Some issues raised in healthcare when robots intend to take over tasks from humans include:

Autonomy: in robot autonomy we talk about whether a robot should have full autonomy or partial autonomy. In full autonomy the robot is able to perform tasks without continuing human guidance in an unstructured environment unlike partial autonomy that requires human intervention intermittently [95], yet researchers today are tending to provide full autonomy for robots. This recent development could take us to a future where robots would completely replace human workers. Now, the question is if a care robot is fully autonomous how far should it go with a patient without human intervention?

Role and Activity: in assigning roles and tasks to robots, what role should be assigned to robots and what role should be assigned to humans in a particular care process, or should robots support or take over from humans? In this context we have to find what can robots do and what tasks to be delegated to robots and what tasks to be delegated to humans in human-robot collaboration.

Decision: the robot does not have emotional intelligence like humans to make intuitive decisions if problems arise or maybe the robot's lack of decision making is not a problem as long as humans are included in the decision making process [95]. Therefore, the question of full autonomy and role arises.

Responsibility: the question here is that if an autonomous robot takes over human tasks, who takes responsibility of the tasks? How can we distribute responsibility when robot takes over some tasks? Can humans be held responsible even when they do not have control over the robot.

Trust: can the robot be trusted as well as humans or to what extent can we trust robots if the robot is tele operated or autonomous, will patients' visibility of the operator give more trust to patients? [62]. Trust in human-robot interaction has been identified as important and establishing trust becomes a priority of human-robot interaction when new technologies are introduced into standard care procedures. Establishing trust in this regard directly affects the willingness of individuals to accept suggestion and follow information produced by robots [96]. Some factors that may affect trust in robots where identified by [96]-[99] and where grouped as relating to the robot, the environment, or the user.

3. CONCLUSION

Robotic technology can be applicable to a wide range of applications in the manufacturing industries, military, hospitals, institutions, homes, and it has recorded success in many areas of applications. Today with the use of algorithm and sensors robots can move autonomously in an unknown and dynamic environment to perform its tasks. Such robots are used to deliver items in hospitals, at home, in the grocery stores and also the military cars employ such technology for autonomous driving. The ageing population, the disabled and children with autism needs care and humanoid robots are being developed to assist them in their day to day activity. Deploying robots to treat infectious disease patience is critical in either replacing or supporting medical personnel. More work need to be done in this area as robots can replace care givers to carry out some tasks hence preventing the spread of disease amongst healthcare workers. Robot can assist in the area of waste management, screening of infectious disease suspects with the aid of non-contact temperature measurement, cleaning and spraying infected environment, as well as monitoring tools for surveillance measures. With these vital approaches, an epidemic can be avoided or stopped.

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