Design and Implementation of an Autonomous Medicine-Serving Robot for Patient Care

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Abstract - *The on-time supply of medications and patient consultations are becoming increasingly problematic in the medical industry. This research aims to overcome these challenges by creating and deploying an autonomous robot to consult online and dispense medications. Fusion 360 software is used to design the robot prototype's proportions and body structure. To enable effective medication distribution, the robot employs a PIR sensor to detect the presence of a patient and a line-following mechanism for autonomous navigation. An ultrasonic sensor is integrated to ensure safe navigation and avoid obstructions. The medication dispensing system includes a servomotor-driven medicine box with LED indicators to display the location of the medication in relation to the patient's bed. The robot is equipped with a camera and a voice recognition system to facilitate communication between the patient and the doctor if necessary. Additionally, a display is provided for patient entertainment and to convey important data.*

***Key Words*: medication, consultation, autonomous, line-following, detect, camera, voice recognition**.

1.INTRODUCTION

Globally, the population growth of patient, along with inadequate in treatments and consultation delay, is leading to a vast financial loss and also decreases the worker productivity. The difficulties of on time medication implementation and advantages of the prolonged consultation times are highlighted in a study conducted by StatPearls, a healthcare education and technology firm [1]. Patients at hospitals needs constant care and attention. The need for creative solutions can be fueled by the expansion in population, the inability for promptly hire consultants, and the development of the airborne illnesses.

Numerous industries are showing and encouraging growth in autonomous robots. Robotics is a main component in the medical industry which helps with patient care issues [2]. Autonomous surgery, cleanliness, rehabilitation, monitoring of patient, and transportation are the key subjects of some investigations. The resources for the monitoring of patient and transportation are presented in this paper. Online consultations are a part of the patient monitoring, and delivering of supplies, drugs, and meals to patients is a part of transportation.

The project can use a line-following technique to navigate independently to a specified place. For the purpose of control, an Arduino Mega board is integrated in all of the sensors and actuators in this project. The method allows for accurate and reliable path-following by locating the bed based on particular floor markings [3]. A passive infrared (PIR) sensor is used to recognize the patient's presence once the robot arrives at their bed. An ultrasonic sensor is used to ensure navigation safety by avoiding the obstructions and enabling operation in congested areas.

Another unique aspect of the medicine box is that it reduces medication administration errors by having a lighting feature which shows the actual location of the medication inside the box based on the patient's bed position. To make sure that the patient receives the right medication, a PIR sensor is used by smart dispenser to detect the patient's presence on the bed and offers a visual approach [4]. With a camera which comes built in and a voice recognition system, it also facilitates direct communication between patients and medical professionals. A Raspberry Pi as the microcontroller is used to integrate the robot's camera and microphone. Patients can consult real time with this configuration, which is also very helpful in circumstances that call for prompt care.

Additionally, the robot has a mobile connectivity so that any members of family or medical professionals can operate it from a distance. The robot's video feed is accessible to users through a specialized smartphone app, allowing the real-time patient condition monitoring. By implementing remote consultations or rapid assessments of the patient's condition without facilitating physical presence, this increases robot's usefulness. Additionally, users can also direct the robot to particular spots within the hospital or care facility by using the mobile app to control its navigation. This flexibility is a guarantee that patients continue to get care and attention even in the absence of hospital workers, which adds another level of convenience and efficiency, particularly in the circumstances requiring quick human involvement.

The robot not only combines the online consultation and the smart drug distribution capabilities, but it also has a display screen that can be used as an entertainment and informational tool, which also helps patients who might feel lonely in private spaces [5]. In addition to providing alternatives in entertainments to improve patients' comfort, the robot's memory will keep important personal information about them. Those receiving long-term therapies might find this feature especially helpful.

1.1 OVERVIEW OF RELATED WORKS AND THEIR APPLICATIONS

Improving the care given to the patients has been achieved through the use of robotics in healthcare, particularly in the areas of medication dispensing, managing chronic conditions, and patient monitoring without human exposure. The creation of the medication dispensing and health monitoring systems is a significant breakthrough. A robot which facilitates for managing chronic medical conditions integrates multiple sensors, such as temperature and biometric sensors, for continuous monitoring and a Raspberry Pi is used for data processing. Moreover, the robot has a SIM800L GSM/GPRS connection module, which facilitates remote data transfer, monitoring, and alerts, guarantees patients receive prompt medical attention. This technique offers a degree of autonomy and decreases the need for frequent hospital visits, making it mainly helpful for home-based treatment for elderly patients or people who are dealing with chronic diseases [6].

In order to improve efficiency and safety in the healthcare, the study "Robotic Patient Monitoring and Medicine Delivery" facilitates the integration of robots and the Internet of Things. Vital medical signs like blood pressure, heart rate, and temperature are automatically monitored by the robot, which sends all the information to physicians via GSM modules. Using RFID tags and infrared sensors in conjunction with line-following navigation, the system locates the patient's rooms and supplies medications from a specified compartment. This strategy shows the expanding significance of loT in healthcare innovation while minimizing the human interaction and exposure, which is helpful especially during pandemics. By implementing remote monitoring and automating repetitive chores, robotics has the potential to save healthcare expenses and ease the burden on institutions, according to the study [7].

The study "Arduino-Based Obstacle Avoidance Robot for Surveillance" details a robot which mainly uses an Arduino Uno microcontroller and ultrasonic sensors to travel on its own in dangerous situations. The robot, that has a wireless camera for live video transmission, can also detect and steer clear of obstructions, providing real-time security and monitoring of places that are off-limits to people. Both military activities and disaster-affected areas benefit from this use. The authors suggest improvements in combining LIDAR and artificial intelligence to improve accuracy and functionality, with an emphasis on creating small, affordable systems that make surveillance and rescue operations easier [8].

The authors of the research "Landmine Detection Using Robotic Vehicle," suggest a robotic system for locating and detection of landmines which are a threat for human life using a GPS module and metal detector. Whenever the robot finds a landmine using the detector, it stops and uses the Blynk app to relay on its GPS coordinates to a remote-control center. This technology is managed by a microcontroller called node MCU, it lowers the risk of human life by allowing the operations remotely without the need of humans implementing independently l in dangerous environments. The design's robustness and affordability are highlighted in the article, which also makes a lot of recommendations for the future enhancements like improved mobility to effectively navigate uneven areas and improved detecting systems for plastic-landmines[9].

By reducing the interactions made by human especially in highly risked areas like hospitals during a pandemic, the "Sanitization Robot" experiment facilitates the value of robots in halting the spread of contagious viruses and diseases. The robot uses a Bluetooth module, ultrasonic sensors, and an Arduino microprocessor to navigate independently on its own. For efficiency, it uses the UV lights and a DC pump to spray disinfectants. This method offers a practical and more economical way to decrease the healthcare people's exposure to infections and to contagious diseases while meeting automatic sanitization during pandemics. In order to optimize the robot's need in public safety and healthcare applications, the study also investigates the robot's functionality and design (10).

To address the important healthcare issues faced by the health care field, the Robotic Assistance and Patient Monitoring in Hospitals Using loT suggests an economical and safe solution which integrates robots and Internet of Things (loT) technology. An autonomous medical robot and a wearable gadget which monitors vital medical signs including blood pressure, temperature, and pulse rate are tracked by the wearable gadget, which sends real-time data to medical professionals. This is enhanced by the autonomous robot, which engages with patients to reduce loneliness while carrying out caregiving duties like bringing food, drinks and medication. This method, which targets to improve patient care quality and decrease the reliance on human caregivers, is especially helpful in hospital settings. Future enhancements include incorporating Al to enable autonomous diagnostics and decision-making [11].

In order to protect healthcare persons from the direct contact with infected patients, the article Medical Assistant Robot ARM for COVID-19 Patients Treatment proposes a robotic system specifically designed for the COVID-19 pandemic. With Bluetooth communication, the system's 6-degree-of-freedom robotic arm may be operated remotely by a Raspberry Pi. This robot arm, that can be controlled by a smartphone up to from 30 meters away, is made to carry out duties like delivering of the food, water, and medication. Especially during pandemics, this system provides a workable alternative by utilizing open-source software and reasonably priced components. However, its usage in bigger settings is hampered by its low range and lack of autonomous navigation. Due to its complete reliance on manual control, the system requires additional development in order to increase its autonomy and operational scope [12].

The study MEDBOT: Line-follower-based on artificial medicine reminder and the delivery robot Automating drug distribution for the elderly and the patients who are cognitively challenged —especially those suffering from Alzheimer's disease—is the main goal of using Arduino Uno in healthcare. A line-follower robot that follows predetermined routes to administer drugs combines with a programmable pillbox. The robot uses an Arduino Uno microcontroller and has LED indicators for any alerts, LCD screens for medication data, and RTC modules for time-based operation. The device can also be used at home or in a hospital because it functions autonomously and it doesn't need human assistance to deliver. It is mainly helpful during pandemics because of its inexpensive cost and small size. However, its adaptability in dynamic contexts is limited by its reliance on manually configured medicine regimes and pre-drawn navigation patterns. While highly effective for its intended use, further improvements could make the system adaptable to broader healthcare scenarios [13].

All Together, these examples demonstrate the various paths that robotics could be used in healthcare to address issues including medication adherence, patient monitoring, and safety of workers. Every system has its advantages and disadvantages, and the integration could result in a complete and adaptable solution. Significant improvements in robotic healthcare systems could result from combining the first study's loT-enabled patient monitoring, the second's safety-focused design, and the third's targeted functionality and affordability.

1.2 PROPOSED SYSTEM

For addressing the important issues of the healthcare industry, especially in the areas of the drug distribution under pandemics and patient consultations remotely, this paper describes the design and development of an autonomous robot. The robot is made to operate independently in accordance with medical settings, including hospitals and homes remotely, offering a practical and very affordable way to enhance the care given to patient while decreasing the effort of the medical staff. Autonomous navigation, accurate medication delivery, patient recognition, and a real-time patient-provider communication are some of its major and key characteristics. Fusion 360 software is used to finish the robot's dimensions and design, it guarantees stability, accessibility, and compatibility. In order to enable smooth communication especially between the patient and medical professionals, the entire structure is designed to facilitate the integration of the sensors, motors, and communication systems.

The robot uses a line-following system which facilitates to navigate on its own. This enables the robot to follow routes which are predetermined, and it guarantees that it can move effectively across the medical environment without even the need for human assistance. The robot comes with an ultrasonic sensor that can identify obstructions in its path and avoid collisions, significantly improving navigation safety. Even in busy or unexpectedly barrier-filled areas, seamless mobility is guaranteed by this solution.

Additionally, the robot is implemented with a passive infrared sensor (PIR) to detect the presence of a patient. The robot automatically stops and positions itself to dispense medication whenever it detects a patient. This ensures that the medication is supplied to the right place, increasing delivery procedure accuracy and efficiency.

A servomotor which opens and closes the medicine box controls the medication dispensing mechanism, guaranteeing accurate administration of the recommended drug. To help the robot to choose the appropriate drug to supply, LED indications inside the box show the medication's position in relation to the patient's actual location. This idea ensures that the patient receives the right dosage and reduces errors in medicine delivery. Instead of using an Arduino Mega for communication, the robot uses a Raspberry Pi, that improves voice recognition and facilitates real-time connection with medical professionals. If necessary, the patient can consult with a doctor remotely to the Raspberry Pi's smooth communication capabilities via a camera and voice recognition technology.

This function guarantees that the patients can still get medical care, advices, medications and support remotely which is very helpful especially in situations where in-person consultations are difficult. The robot also has a display screen that shows the vital medical patient data, including reminders, health updates, and prescription instructions. Furthermore, the display can offer alternatives in entertainments, which, particularly in long-term care settings, could help patients feel less stressed or bored

2. DESIGN AND CIRCUIT INTEGRATION

The robot's integration of circuits and design should be developed to ensure that every part works in perfection and as whole. Every part of the robot including the motors, sensors, Raspberry Pi, camera, servomotor for dispensing medication, and LED indicators, is layered out and implemented in detail and in the design diagram.

The detailed connection circuit diagram shows how each wire connects the Raspberry Pi, servomotor, sensors, and display. This wiring makes sure everything is powered correctly and works efficiently. The PIR sensor, ultrasonic sensor, and servomotor are all hooked up to the Raspberry Pi's GPIO pins, allowing for real-time data processing and control. The voice-recognition system uses the Raspberry Pi's microphone to convert speech into text, making it easy to talk to doctors. The display, connected via HDMI or another suitable interface, ensures that patient info is shown clearly and accurately. This setup ensures seamless integration and functionality, providing a user-friendly interface for efficient medical assistance.

The ultimate aim of the system design is to facilitate and implement an effective, affordable and user-friendly healthcare solution by combining robotics, sensors, and real-time communication technology. Modern healthcare systems mainly depend on the robot's ability to perform complicated activities like voice recognition, active sensor-operation and remote consultations, which are made possible by the integration of the Raspberry Pi for enhanced processing and communication.

A grasp of the robot's architecture is given in the design diagram and the circuit integration details shows how each part is coupled to produce the proposed functionality. These specifics are essential for future enhancements for the system in different healthcare environments.

Concluding, the system improves care given to the patient and helps the healthcare workflows by facilitating and combining the most recent developments in the field of robots, sensors, and communication technology. Because of its propagation, integration and design, the robot can function independently without the help of human, safely, and effectively, making it a useful tool in the ever-changing healthcare industry. In order to visualize and examine the whole framework, we produced the CAD model for the robot's structure. By this method, subsequently, the CAD model streamlined the major building process by acting as the blueprint and guaranteeing the robot's structure. It is optimized for functionality and performance.

The Cad model build in fusion 360 and the final design are fig 1 and 2

Fig 1 Fig 2

Cad model of the robot Final design of the robot

A simple block diagram is provided in Figure 3, illustrating the integration of various components

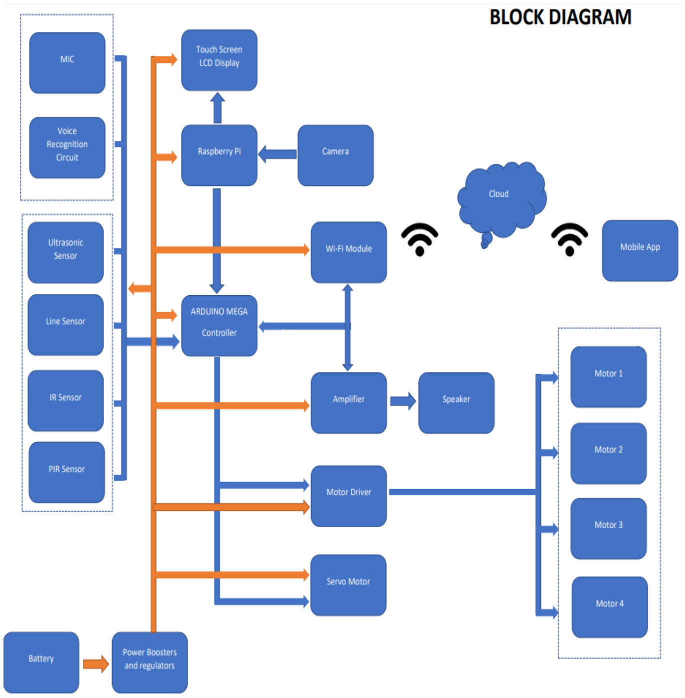

Fig 3 - block diagram

Table -1: The table contains the details of the robot

Attribute	Details
Robot Body Material	Fiberglass, Resin, and Cobalt
Robot Dimensions	Length: 400 mm, Width: 450 mm, Height: 950 mm
Robot Mass	15 kg
Support Wheels	2 caster wheels
Drive Motors	4 DC motors with wheels (for movement)
Motor Power	12V DC motors
Motor Type	Brushed DC motors
Power Supply	12V battery (Lithium-ion)
Sensor Types	PIR Sensor, Ultrasonic Sensor, Camera
Voice Recognition	Raspberry Pi with microphone
Display Type	LCD (7 inches)
Servomotor	1 servomotor for medicine dispensing
LED Indicators	10 small LEDs inside the medicine box
Speed	0.1 - 0.2 m/s (depending on motor and terrain)

The components of the robot are:

Arduino Mega 2560

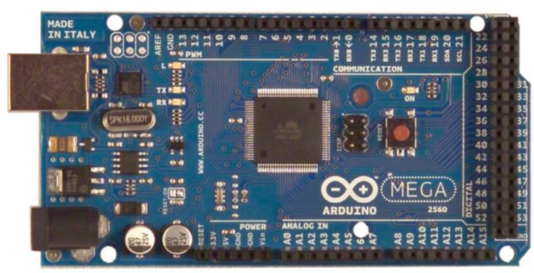

Fig 4 - Arduino Mega 2560

The ATmega2560 serves as the foundation for the Arduino Mega 2560 microcontroller board. It features a 16 MHz crystal oscillator, four UARTs (hardware serial ports), sixteen analog inputs, 54 digital input/output pins (14 of which can be utilized as PWM outputs), a USB connector, a power jack, an ICSP header, and a reset button. It has all the components required to support the microcontroller; to get it going, just plug it in via a USB cable, power it with an AC to DC adapter, or use a battery. The majority of shields made for the Arduino Duemilanove or Diecimila can be used with the Mega.

Raspberry pi 3b+

Fig 5 - Raspberry pi 3b+

A small and reasonably priced single-board computer, the Raspberry Pi 3B+ has a 1.4GHz quad-core ARM Cortex-A53 processor and 1GB of RAM. It is perfect for networking and Internet of Things projects because it has Ethernet, Bluetooth, and Wi-Fi integrated in. The board supports a variety of peripherals via USB, HDMI, and camera connections and features GPIO pins for hardware interaction. It is widely used for learning robotics, embedded systems development, and programming and is well-liked in education, prototyping, and do-it-yourself electronics.

MG996R High Torque Metal Gear Dual Ball Bearing Servo

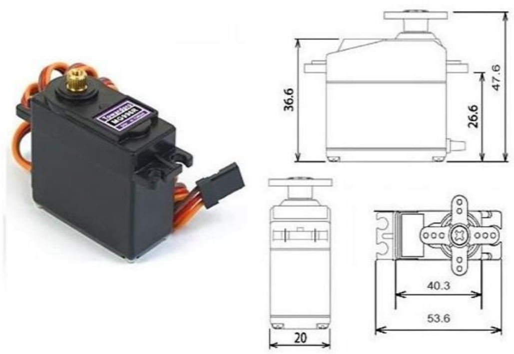

Fig 6 – Servo motor

Metal gearing gives this High-Torque MG996R Digital Servo an exceptionally high 10 kg stalling torque in a small package. In essence, the MG996R is an improved MG995 servo with improved shock-proofing and a revised PCB and IC control system that greatly increases accuracy over the original. Additionally, the motor and gearbox have been improved to enhance centering and dead bandwidth. A 30-cm cable and a 3-pin 'S' type female header connection are included with the unit, which is compatible with the majority of receivers, including Futaba, JR, GWS, Cirrus, Blue Bird, Blue Arrow, Corona, Berg, Spektrum, and Hitec.

PIR Motion Sensor

Fig 7 - PIR Motion Sensor

PIR sensors perceive motion and are nearly usually used to determine whether a person has entered or exited the sensor's field of view. They don't wear out, are portable, affordable, low-power, and simple to operate. They are therefore frequently found in devices and equipment used in homes and workplaces. They are frequently called "IR motion" sensors, "PIR" sensors, "Pyroelectric" sensors, or "Passive Infrared" sensors.

Voice Recognition Module V3.

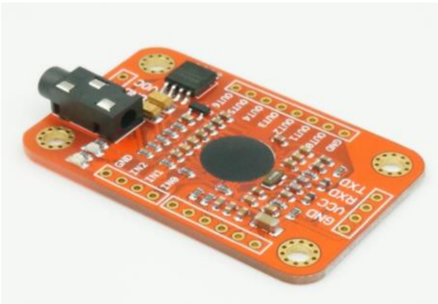

Fig 8 - Voice Recognition Module V3.

A small and user-friendly voice recognition board is the ELECHOUSE Voice Recognition Module. This device is a voice recognition module that depends on the speaker. In total, it can recognize up to 80 voice commands. A maximum of seven voice commands might be used simultaneously. You could teach any sound to be a command. Before allowing the module to recognize any voice commands, users must first train it. There are two ways to control this board: the General Input Pins (part of function) and the Serial Port (full function). The board's general output pins were capable of producing a variety of waves when the corresponding voice command was detected.

Geared DC Motor

Fig 9 - Geared DC Motor

A Geared Motor 500 RPM 12V DC is a versatile motor designed for robotic and automation applications. It combines a DC motor with a gearbox to reduce speed while increasing torque, making it suitable for tasks requiring controlled and powerful motion. With a speed of 500 RPM, it offers a balance between speed and torque, ideal for small to medium-sized robotic platforms. Operating at 12 volts, it is compatible with most robotic power systems and controllers. Its compact design and high efficiency make it a popular choice for projects like wheeled robots, conveyor systems, and DIY automation projects.

IR Sensor Module

Fig 10 - IR Sensor Module

IR LEDs emit invisible infrared light with a wavelength of 700nm–1mm, beyond the visible light range. They have a light-emitting angle of 20–60 degrees and a range from a few centimeters to several feet or even kilometers, depending on the transmitter. Typically, white or transparent, IR LEDs maximize light emission efficiency for applications like remote controls and object detection.

Ultrasonic Waterproof Range Finder

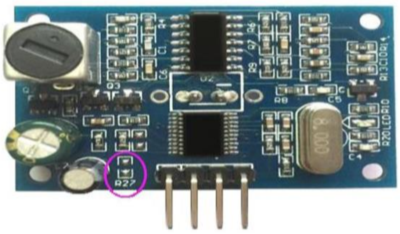

Fig 11 - Ultrasonic Waterproof Range Finder

An integrated ultrasonic sensor and control circuit are included in the JSN-SR0T4-2.0 ultrasonic distance measurement module, which has a 20–600 cm non-contact distance sensing capability with an accuracy of up to 2 mm. Use of the Division's JSN-SR04T-2.0 module and mode one. This product uses the best MCU available, an industrial-grade integrated ultrasonic probe design, a waterproof construction, and stable performance. 1. The module operates steadily, and the measurement distance is precise. Also comparable are foreign SRF05, SRF02, and other ultrasonic rangefinder modules. The device has a solid foundation for success on the market because to its high precision, blind (20 cm), and robust range module.

Power Supply Boost Adjust Module

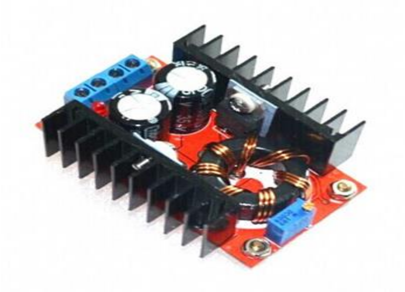

Fig 12 - Power Supply Boost Adjust Module

A 150W Power Supply Boost Adjust Module is designed to step up a lower DC voltage to a higher, adjustable output voltage, delivering up to 150 watts of power. It uses a DC-DC boost converter with high efficiency to minimize power loss and heat generation. The module features an adjustable output voltage range, making it suitable for powering various devices. It also includes protections like current limiting and over-voltage safeguards, ensuring safe and reliable operation in applications such as DIY electronics and robotics.

7 Inch Capacitive Touch Screen LCD

Fig 13 - 7 Inch Capacitive Touch Screen LCD

A 7-inch capacitive touch screen LCD is a type of display module that offers bright, crisp images with a responsive touch interface. Because it supports multiple touches, it can be used for interactive applications in robotics, embedded systems, and do-it-yourself projects. Generally speaking, the screen works with gadgets like Raspberry Pi and Arduino, making integration and control simple using touch gestures.

3. CONCLUSIONS

This work presents the design and development of an autonomous robot system aimed at addressing two major issues in healthcare: prompt drug delivery and remote patient consultations. The proposed system offers a practical and cost-effective way to enhance patient care, reduce the burden on healthcare providers, and improve the efficiency of healthcare service delivery by combining advanced robotics, sensor technologies, and real-time communication capabilities.

The robot could operate effectively in dynamic healthcare environments thanks to its obstacle-avoidance abilities, patient detection system, and autonomous navigation using a line-following mechanism which helps to operate it safely. A servomotor-driven precision medication distribution system with LED indicators facilitates accurate delivery of all the medications by reducing mistakes and ensuring timely treatment. By integrating a Raspberry Pi for voice recognition and real-time communication, medical professionals can advise patients remotely, increasing accessibility and providing them with the support they need without face-to-face interaction. Additionally, the display system of the robot provides entertainment facilities and important patient information, making the healthcare experience more pleasant and engaging.

Overall, the proposed autonomous robot system is an advanced step towards improving the quality and safety of healthcare. It addresses critical issues like efficient drug delivery, patient monitoring, and remote consultations, demonstrating how robotics can transform the healthcare sector. Future research can explore further enhancements, such as better navigation algorithms, enhanced communication capabilities, and integration with electronic health record (EHR) systems to create even more advanced and integrated healthcare solutions.

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