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Design of Smart Medical Assistant Robot for Contactless Preliminary Health Check Up of Patients

Supreet Thale[1], Bhushan N Chopda[2], Shreyas Deo[3], Viraj Nyayadhish[4], P Srivalli[5], Unnati Choudhari[6], Serlin Agnes[7], Nilofar Sameena. M[8]

[1]*Student, Dept. of Mechanical Engg, K.J. Somaiya College of Engineering, Mumbai, India*
[2]*Student, Dept. of Mechatronics Engg, Manipal University, Jaipur, India*
[3,4]*Student, Dept. of Electronics and Telecommunication Engg, MIT Academy of Engineering, Pune, India*
[5]*Student, Dept. of Computer Science and Engg, Sanskrithi School of Engineering, Puttaparthi, India*
[6]*Student, Dept. of Computer Science Engg, SIES Graduate School of Technology, Mumbai, India*
[7,8]*Student, Dept. of Electronics and Communication Engg, BS Abdur Rahman Crescent Institute of Science and Technology, Chennai, India*

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Abstract – *The preliminary health tests of patients in the hospital are carried out by doctors. This requires them to be in contact with the patient which may unknowingly expose them to contagious diseases and it wastes their invaluable time for tests which are primitive in nature. This also increases the waiting time of other patients in the hospital and these lead times can stack up to delay urgent medical treatment of the patients with severe illness. The present guidelines of the World Health Organization amidst the ongoing pandemic of COVID-19 strongly suggest social distancing among humans to curtail the spread of the novel coronavirus. The objective of this project is to minimize the contact and the time of interaction between doctors and patients for preliminary tests which can be conducted autonomously by developing an Autonomous Smart Medical Assistant Robot for contactless preliminary testing of patients. This project uses Autodesk Fusion 360 software for the design and testing of the robot and Arduino IDE for control and programming. The robot can also be used as a companion for patients and to transport other medical supplies to both the doctor and the patients.*

Key Words: Coronavirus, Autonomous Robot, Contactless, Design Concept, RFID Tags

1. INTRODUCTION

The project aims to provide a contactless testing method to the doctors in hospitals to conduct initial health check ups like measuring the body temperature of the patients, their heart rate, pulse rate and oxygen levels. This paper was conceived as a result of the observations made during the ongoing pandemic of COVID-19, wherein the doctors are having to be in contact with the patients in order to test and treat them, thereby increasing the risk of a community spread. There is a strong requirement of contactless technology for the testing of patients to prevent spread of highly contagious disease like the novel coronavirus. The robot contains sensors like Oximeter MAX 30105 to measure the blood oxygen saturation and heart rate of the patients as a preliminary test criteria.

2. LITERATURE REVIEW

A few research papers related to medical robots have been reviewed and the following references show influence on the design of the smart medical assistant robot. Marcin Zukowski et al [1] have developed a humanoid medical assistant and companion robot dedicated to children hospitals. They have focused on the robot being able to express emotions and communicate with the children by recognizing their faces and using pictures and text on the chest display to tell stories and present educational videos. The 'Bobot' autonomously navigates through hospital rooms and performs simple medical tests like measuring patient's body temperature or heart rate and sends live video feed to the doctors and nurses. The robot is run using ODROID XU and XU4 with Ubuntu 14.04 operating system and has a dedicated Raspberry Pi 2 computer to animate the robot's eyes.

Marcin Zukowski et al [2] presented the implementation of patients' temperature measurement system for the medical robotic assistant. They have experimented with MLX90614 infrared thermometer and FLIR Lepton thermal camera and found out that the MLX90614 infrared thermometer cannot be used as the only input source of the system and to get more accurate results, robot would need to come as close as less than 0.3 metres to a patient's face. To overcome this they created a hybrid system having infrared thermometer along with thermal camera to provide ambient temperature and approximate skin temperature that can be used to detect presence of humans in front of the robot.

Kaveh Bakhtiyari, Nils Beckmann and Jürgen Ziegler [3] have proposed a non-invasive contactless Heart Rate Variability (HRV) measurement with Respiratory Sinus Arrhythmia (RSA) correction. They have incorporated Infrared and RGB cameras to measure the heart rate signal, and a 3D Depth sensor has been used to capture the human respiratory signal to correct the calculated HRV with RSA. They have performed correlation analysis by different methods and devices to find an appropriate method for HRV calculations based on the required accuracy and application. Contactless heart rate variability sensors can become an important part of sensors for preliminary health tests. Sachit

Mahajan, Prof. Vidhyapathi C.M [4] have designed a medical assistant robot which helps the patient to carry the necessary medical equipment along with them. They have created a person following robot assistant which provides support to the patients. The robot uses a Pixy image recognition sensor for person detection and ultrasonic sensor for obstacle avoidance.

Azeta Joseph et al [5] have presented an overview of the current and potential applications of humanoid robotics in healthcare settings. Their paper describes various characteristics required in humanoid robots in healthcare such as presence of vision system, sensing behaviour, mobile platform and the ability to perform dexterous manipulation tasks. We explored similar human assistant robots available in various roles as helpers for the patients in hospitals.[6-10]

The scope of the present study is to design a smart medical assistant robot by exploring various contactless less sensor technologies. The robot should be compact for efficient handling and incorporate a quick learning real time environment recognition technology for its locomotion in a crowded hospital.

3. DESIGN AND DEVELOPMENT

A detailed study has been carried out for the design of various components of the robot. The major systems of the robot include the mechanical aspect, electronic sensors and circuitry and the user interface and user experience of the robot with human beings. The robot is designed for the preliminary health check up and also as an assistant for the patients and doctors. To utilize the space present inside the robot structure, it is modified to accommodate a specially designed compartment for material handling and transportation of medical supplies to the doctors and patients.

3.1 Mechanical Design

The design of the robot was inspired from the viewpoint that it being an assistant to the patients of all ages, it should be appealing, approachable and also friendly towards them. To achieve this, a humanoid design concept was found to be the most suitable. The robot features a spherical head with a headphone featured on it to enhance the aesthetic look. Robotic arms are added on either side of its shoulder to complete the humanoid look. They also double as a support structure to hold the material handling tray which can be used to transport medical supplies as well.

A 20x20mm T-slot Aluminium extrusion is used for the internal support structure of the robot because aluminium is lightweight and provides sufficient strength. Keeping the future scope in mind it gives flexibility and modularity as the extrusion is easily replaceable and adjustable to accommodate changes in the components.

For the outer casing of the robot a polypropylene thermoplastic is selected as the robot is designed for use in hospital premises and hence requires the use of medical grade plastics. The casing material used should be dust free, biocompatible, eco-friendly, be durable for long term, should not react with chemicals present in hospitals and also be resistant to corrosion and high temperature so as to withstand the high wear and constant sterilization that the hospital equipments are subjected to.

The robot has a 600mm circular base of wood on which all the components are mounted. A wooden base is selected as it provides strength and also doubles as an insulator between the metal structure and the electronic components to prevent short circuiting. A combination of two driving wheels and two idle polyurethane wheels are selected for the stability and motion of the robot. Three idle casters are added on the perimeter of the base to make the robot steady and to prevent toppling. The batteries are placed on the base of the robot to keep the centre of gravity of the robot as low as possible.

Yutaka Hiroi and Akinori Ito [11] studied the influence of the height of a robot on the comfort of verbal interaction. They clarified the comfortable height for verbal interaction and then studied what degree of vertical change from this height would be acceptable. From which they concluded that the comfortable height of interaction with robots should be lower than human height or human eye level for both the standing and sitting postures. The most suitable height was when the robot's height from the floor surface was around 300mm lower than the human's height from the floor surface to eye level. Besides, raising or lowering the robot by 100mm does not adversely affect the comfortableness of interaction. Although if it is raised by 300mm or lowered 200mm, the dialog becomes uncomfortable. Change in distance from human to the robot does not have any effect on the comfortable height for dialog. The average height of humans in India is 5.25 feet (1600mm) and taking aforementioned findings into consideration, the robot height is set at approx 4 feet (1200mm).

The aesthetics of the robot are designed keeping in mind the need for it being approachable and appealing to all ages. It should be a companion for the patients rather than just a machine. The outer casing design is kept as simple as possible for ease of manufacturing of the casing and also due to sanitary conditions required in the hospital. The design features consists of an automatic sanitizer dispenser machine at the back of the robot which is deliberately designed to make the task of refilling the sanitizer efficient by simply removing the empty bottle and replacing with a new one. This methodology is adapted instead of a concealed sanitizer dispenser to avoid repeated reopening of the robot casing to refill and also to eliminate accidental leakage of fluid inside the robot casing. The robot also has a tray and a concealed compartment incorporated for efficient material handling and transportation of important items such as patient files and medicines to the doctor as well as the patient. The design of the medical assistant robot is shown in figure 1 and 2 respectively.

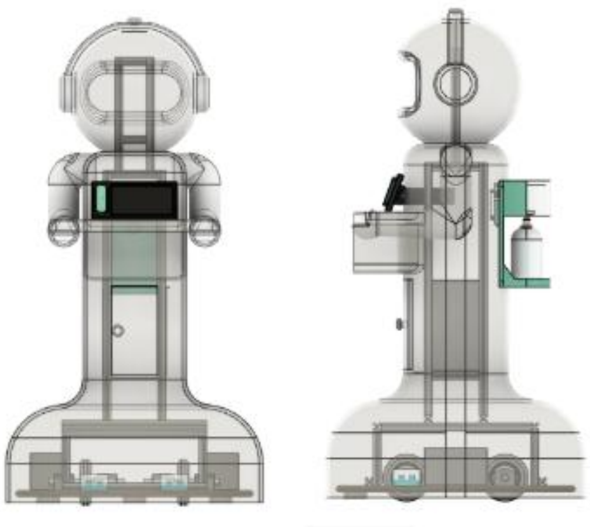

Fig 1. Front and Side View of the Medical Assistant Robot

Fig 2. Rendered Isometric View of Medical Assistant Robot

3.2 Electronics and Hardware

The electronics and hardware of the robot are the most significant working system which governs the functional and non functional service delivery of the mobile robot. The robot is equipped with two 12 V lead acid batteries of 7.2 Wh capacity which is charged via a XHM601 charging module, this ensures over charge and discharge protection and a stable power supply for charging. The batteries are mounted on the circular base to ensure stability of the robot through equal weight distribution. The base has two DC motors connected to the wheels having 60kgcm torque which is used for the locomotion of the robot and are controlled using an H bridge motor driver L293D. The development board used for governing the robot is Arduino Mega R3, based upon Atmega2560. The board is capable of handling the sensors required efficiently and offers a wide range of libraries for programming.

The robot features a RFID MFRC522 module to identify patients and create a temporary unique profile of the patients. SG-90 Servo Motor is aided with a crank and slider mechanism to dispense sanitizer for the patient before and after his preliminary checks to ensure sanitation of the patients. It also houses MAX 30105 which is a Pulse and Oximeter sensor for taking key health statistics from the patient and a ISD1820 Voice Recording Module for the patients to describe their symptoms. For contactless temperature sensing the robot has been accommodated with MLX90614 Infrared Thermometer. To facilitate easy data collection from the patients, the robot features a 10.1 inch TFT module which can display a custom GUI. The connections of the electronic components are shown in figure 3.

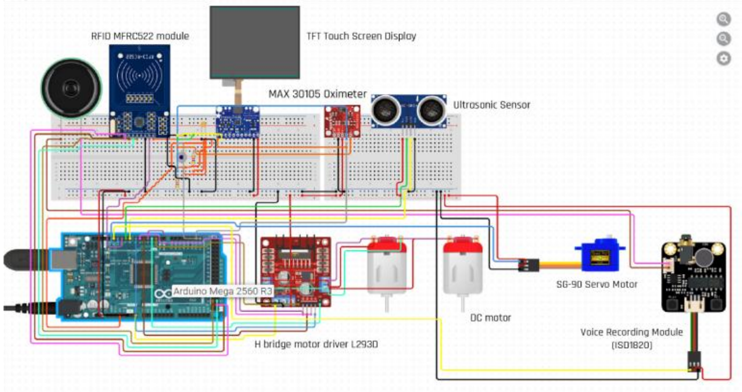

Fig 3. Component connections to Arduino Mega R3 2560

3.3 User Interface and Experience

The user interface (UI) has been designed keeping the robot - human psychology, dialogue comfortness, ergonomics in mind and to ensure approachable and appealing interaction between the two. The interface is dynamic in terms of the feedback received from the patient and provides questionnaires accordingly. Figures 4 (a) and 4 (b) show the user interface of the touch screen display which is used to interact with the patients.

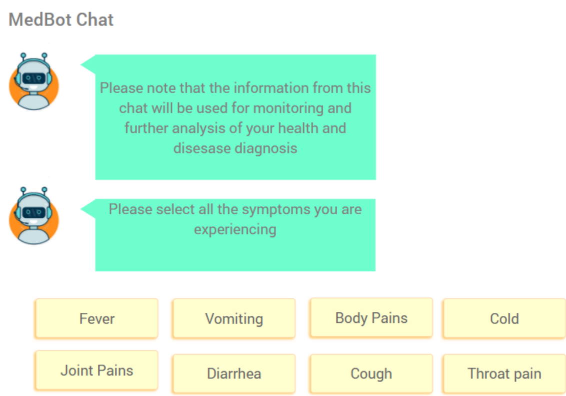

Fig 4 (a). User Interface of touch screen display

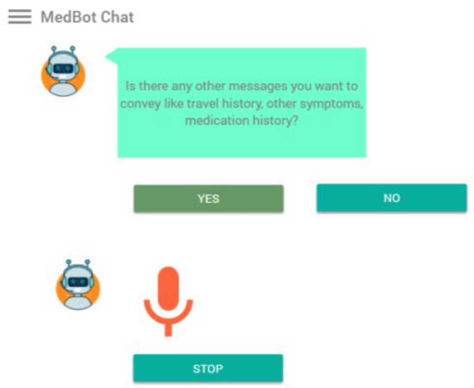

Fig 4 (b). User Interface of touch screen display

3.4 Working

Upon entering the hospital premises, the patient is assigned a temporary RFID tag which is scanned by the robot as a temporary identity and transaction for the patient. The robot identifies and avoids obstacles using the ultrasonic sensor. It instructs the patients to sanitize their hands using the automatic sanitizer dispenser mounted on the back. Only after using the sanitizer, the patient is able to continue the process forward. This is done to prevent unnecessary spread of contagious viruses through the touch screen display present on the robot. The robot then reads the temperature of the patient using an infrared thermometer and asks the patient to place their finger on the Oximeter MAX30105 to collect important data regarding their heart rate, pulse rate and blood oxygen saturation level. Through the touch screen display, the patients are then enquired about their travel history and present symptoms or allergy history. These data are collected using a voice recording module and are directly sent to the doctor. The doctors have live access to the patient and their data. An integrated storage compartment and tray are present on the robot for material handling and transfer of medicines or medical reports to the doctor or the patients. Figure 5 describes the working protocol of the medical assistant robot.

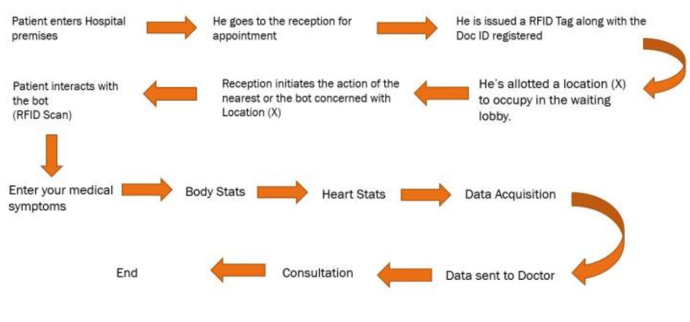

Fig 5. Working protocol of the Medical Assistant Robot

4. CONCLUSION

The design of the smart medical assistant robot has been presented in this project. The internal structure of the robot has been tested for safety with a load of 500N (50kgs) using Ansys and Fusion 360. The outer casing of the robot was chosen to be made of medical grade plastics to maintain the global medical standards of sanitation and being biocompatible. The components are designed and selected with consideration to reduce the weight of the robot and at the same time be safe and efficient. The current scenario requires innovative contactless solutions to prevent the spread of contagious diseases. Our project has the potential to be a viable solution for this. The fabrication and testing of the robot is the next stage in this project. Real time environment recognition technologies like LIDAR and SLAM can be implemented along with Artificial Intelligence and Machine learning to make the robot adaptive to changing environment and being more approachable to the patients. Speech recognition technology can be used to understand the feedback from patients of different backgrounds and help interact with them more efficiently in the future. Accurate heart rate measurement through image processing, facial recognition and retinal scanning techniques can also be implemented for the identification of patients and for advance contactless tests.

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