Implementation of Nursing Assistant Robot

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***Abstract*—Cyber physical systems are need of modern era to cater the need of humanity in a better way. Unpredicted pandemic situation demands the deployment of cyber physical systems in the healthcare industry to prevent the spread of infectious disease in the medical staff while serving the infectious patients. CORONA has exhibited a need for autonomous assistance to carry out nursing tasks. For nursing staff, it is almost impossible to maintain the norms of social distancing as their job involves the personal care of the patients. Monitoring the patient's body temperature and oxygen level, Supply of food and drug at regular intervals are the main duties a nursing staff needs to perform for a corona-infected person. Such tasks can be performed using a cyber physical system, which enables the nursing staff to perform their duties while maintaining the social distancing norms. This paper discusses a cyber physical system that is remotely controlled and capable of gathering important health-related data of patients like body temperature and oxygen level. The system also enables audio and video communication between the nursing staff and a patient without employing over a Internet. A state-of-the-art Raspberry Pi board is used with an ESP32 camera module to set up the wireless audio and video link for communication. The system is implemented and tested in the controlled environment of the laboratory.**

Key Words — Cyber Physical Systems, COVID, Nursing Assistance, Wireless Video, Tank Drive

I. INTRODUCTION

With the spread of the Global COVID crisis, the world has faced a lot of challenges. The challenges were already there but ignored to date. Some of those challenges are managing overcrowded places, maintaining social distancing norms, convincing people to follow the guidelines for the prevention of the spread of the virus, etc. One of the major challenges is to assist the virus-infected patient. The risk of infection to the nursing staff involved in the assistance of the virus-infected person is very high. During the coronavirus pandemic, every country has faced a situation where the healthcare staff was infected with COVID while serving the infected Patient. The spread of infection forced a situation where most of the countries were helpless against the pandemic as their front fighters were unable to take care of patients due to the risk of infection.

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Constant monitoring of the oxygen level and body temperature of the infected patient is an uncompromised need for the proper recovery of the patient. On the other hand, it is also necessary to maintain a safe distance from the patient to prevent the spread of the virus. The situation has motivated the need for a means which enables the healthcare workers to serve the patient without actually contacting them. Various embedded systems and solutions available in the market can be deployed to create an environment to deal with the said situation.

The paper discusses such an embedded system that enables the nursing staff to take care of the infected patient remotely. The system uses wireless audio and video calling devices, which enable communication between the nursing staff and the patient. Moreover, the nursing staff will be able to measure the oxygen level and body temperature of the patient remotely at the same time can also provide the patient with medication, food, and water as and when required without actually contacting the patient.

In the medical world, the use of robots was introduced to help the nursing staff in the last few decades. Since the beginning of the research, the mobile robot was developed to help the elder community, physically challenged personnel, and the nursing community. In ref [1], a prototype of a mobile robot was presented, which communicates with people through audio and video including their physical motions. The main aim behind this design was to remind the people of the particular events and guide them through their environment. As this would be a common memory-related problem with aged people. It also helps the person assisting them to provide routine mediation at a regular time interval.

The use of a robot to help the nursing staff to transfer the patient from one surface to another surface without changing the patient's posture is presented in [2]. This prototype gives relief to the patients while transferring from bed to stretcher. This design was capable to help the nurse to transfer the patient between two surfaces that have equal height. A similar approach with the more stable movement of patients between stretcher and bed is reported in the ref. [3]. The mechanical structure with servo motor working behind this design is discussed in the detail. The authors have experimented and demonstrated a smooth transition of patients from bed to stretcher.

Another robotic mechanism to help bedridden people is reported in ref [4]. This mechanism has proposed independent movement of patients in bed. This design was based on two robotic arms and having a pressure sensor array on the mattress. These pressure sensors were deployed to estimate the position of patients and based on that sensor value; the robotic arm will perform an appropriate task. Experiment results are also presented in this article to show the effectiveness of their proposed design.

In [5], a mobile manipulator robot is reported to guide the human through a direct physical interface with the robot. Authors have evaluated this interface in terms of uplifting the patients in the controlled laboratory environment. These experiments open up the research in the field of upliftment of patients which reduces the injuries of nursing assistants.

In [6], the authors have presented a robot named "RIBA". This prototype was equipped with a human-type arm to lift the patients from the bed and put them on a chair or vice versa. This prototype works under the guidance of a person who is responsible to monitor the surrounding environment and deciding necessary actions while the robot performs physical jobs. Communication between RIBA and the caretaken person is performed through the tactile guidance method in which the caretaker will adjust the movement of the robot's hand as and when required. This prototype was capable to lift the weight up to 180 kg. In this method, the caretaker has to keep one hand raising the head of the patient while the robot will perform lift the patient from the backside. A study on the Reliability and safety of patients while transferring patients using a RIBA – robot is carried out in [7]. In this study, experiments were conducted to check hardware and software safety issues in RIBA at different working stages like lifting patients, stopping while lifting, etc. Their experiments were mainly focused to check the accuracy of the tactile guidance system which was working on the feedback of the tactile sensor. They have found that RIBA is capable to lift /down patients from beds or wheelchairs however patients' mental and physical burdens should be studied before using this robot.

In [8], a prototype of a mobile robot named "RoNA" was reported which is capable to uplift patients. It was capable to uplift the load up to 300 lbs. This approach reduces the chances of back and shoulder injury for any nursing staff. In this prototype, the robot will follow the nurse and help them as per their audio or visual commands. This prototype is based on the humanoid design with an electric actuator which adds more strength to the safe and reliable uplift operation. Results of different tests like load test, patient lifting, range motion, and force feedback test were discussed to support their claim. However, the operating mechanism is complex.

Patient response to the robotic system used for assistance is presented in the ref. [9] The authors have presented the result based on the experiment carried out on 56 patients about their response while gaining assistance through a robot over a physical assistant. Responses were taken on different effects like safety, fear, and willingness to receive robotic assistants in the future. These factors were chosen to compare the response received in the case of human assistants. The study has shown that proper counselling should be done before providing a robotic assistant helps to reduce patient stress.

To provide more comfort and safety to the patient, a chest carrying robot prototype is presented in [10]. These prototypes mimic the style of humans carrying another human. This prototype was developed based on their measurement of different human motions like holding a person from the chest, leaning forward, lifting a person, and putting down. Their prototype has demonstrated a moving subject with a weight of about 60 kg and height of about 170 cm from bed to chair and vice versa. Lifting a subject from the chest requires a less complex mechanism unlike in the case of the RONA and RIBA prototypes. However, the maximum weight lifting capacity is less in this prototype.

Another prototype of the nursing assistant robot with an intelligent interaction mechanism is reported in [11]. This robot was interacting with a person through 10 special gestures. These gestures were given through a camera that is on the person's wrist. Authors have incorporated different chassis movements to respond to these 10 gestures. The purpose of this robot was to assist elderly people in their homes. In this design, a dual manipulator is responsible to perform necessary actions which can help an elder person in his day-to-day life. This robot can be operated remotely with the help IoT device. So, a person from the far end can also give the command to this prototype to perform necessary actions for the help and comfort of an elder person at a home.

Recently, a high payload robotic arm to assist nurses is reported in [12]. Authors have proposed an effective control mechanism to dodge the occurrences of the harmful situation during robot and man interactions. Experiment results are presented to verify the required load capacity and pressure management for the nursing task. The above-mentioned research is carried out and deployed in most developed countries to meet the shortage of nursing staff and avoid injuries to them while lifting patients. In this pandemic, a country like India has also come up with a few prototypes to help nursing staff in terms of measuring body temperature and serving food and medicine to Covid patients.

A robot nurse was introduced in the Government Stanley Medical College Hospital, Chennai [13]. Three different robots are used to deliver food, water, and medicine to covid patients. Each robot is equipped with a two-way camera and can perform one particular task only. This solution demands three different robots which makes it a costly solution. Further, it also requires additional space to park other robots which are not in use at a particular time.

A company called club first from Jaipur makes

autonomous robots that can transfer material and sanitize the hotels and hospitals. This company's robot has been deployed in Sir Sayajirao Gaekwad Hospital in Vadodara jointly by L&T hydrocarbon engineering and GCSR [14]. This robot is capable to transfer items like food, water, and other material from one place to the patient. Another robot from the same company is deployed in the same hospital which measures the body temperature of the person at the entrance of the hospital. The same robot is now deployed in the civil hospital of Rajkot, Gujarat to help nursing staff.

In [15], a robot named "V2 buddy" is reported as a nursing assistant. This robot is capable to measure the only body temperature of the patient through a temperature gun and dispensing sanitizer. Further, it is also capable to deliver food and medicine to the patient. It is equipped with audio-video interfacing through which nurse and patient can communicate with each other. This robot can be controlled by nursing staff through an installed app on their smartphone. This robot is only measuring body temperature and can store 32 patient data at a time.

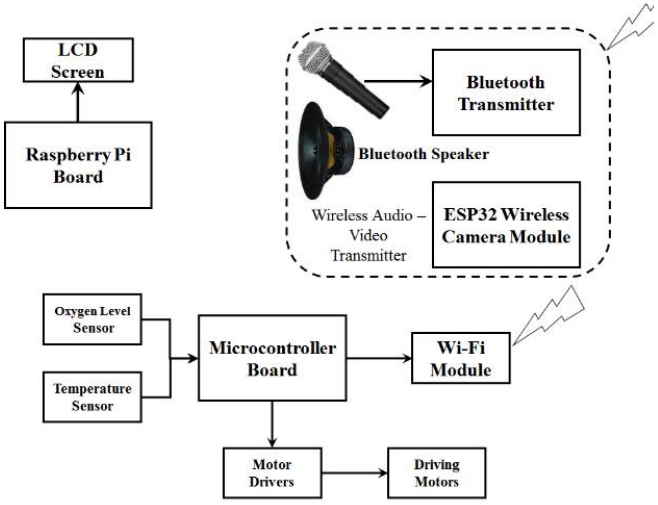
The rest of the paper discusses the details of the proposed system. Section II provides a brief study of the hardware and wireless technologies which can be used to implement the proposed solution followed by the proposed system model in Section III. Section IV discusses the Software Model for the proposed solution whereas Section V is the results of the implemented prototype of the system.

II. PROPOSED SYSTEM BLOCK DIAGRAM

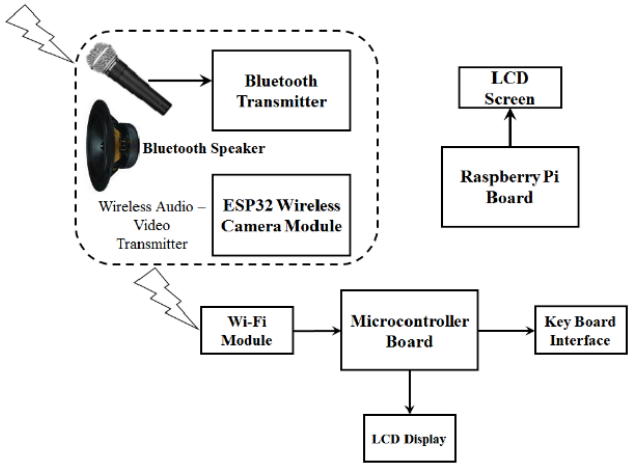
The primary aim of the proposed system is to gather data of the body temperature and oxygen level of the patient admitted to the ward. The second aim is to provide the patient with the food, water, and medication as and when required without actually contacting the patient. During the pandemic time, it is also necessary to talk to the infected patient so that the motivation of the patient can be boosted and the patient never feels lonely. To facilitate the same, audio-video communication with the patient is always required. All the objectives listed above must be performed without personally contacting the patient.

The proposed system is a movable machine that is wirelessly controlled with a keypad. The movable part of the machine remains inside the ward where the infected patient is admitted, while the keypad remains with the nursing staff, which enables the staff to control the machine from the remote end. Fig 1 shows the block diagram of the proposed system. The system comprises two parts: an assembly to be kept on the machine inside the ward and the assembly to be kept with the nursing staff.

Fig **2** shows the machine that carries the assembly to be kept inside the ward. On the top of the machine, wireless audio and video transmitter, LCD screen, and Raspberry Pi board are located. The audio transmission is performed by the Bluetooth transmitter, which accepts the input from a microphone. A similar Bluetooth transmitter is available to the nursing staff outside the ward. The outside assembly part also has a microphone to transmit the audio to the patient. At both assemblies, a Bluetooth-based speaker is placed to receive the audio. For transmission of the video, both the assembly is equipped with an ESP32 camera module, an LCD screen, and a Raspberry Pi module. The ESP32 camera module is a Wi-Fi-based camera module, which acquires the video and transmits the same over Wi-Fi. The reception of the same video can be done on the browser using the Raspberry PI board connected to the same Wi-Fi network. The received video is shown on the LCD screen. This setup is available on both assemblies for video communication as shown in the block diagram. In the entire audio-video communication, a local Wi-Fi network is used which needs not be connected to any Internet.



(a) Assembly on the Machine



(b) Assembly with Nursing Staff

Fig 1. Proposed System Block Diagram

The assembly on the movable machine also carries a temperature sensor and SPO2 sensor to measure the body temperature and oxygen level of the patient respectively. The obtained readings of the sensors are transferred to the assembly

outside the ward using a Wi-Fi module. The assembly outside the ward also has a Wi-Fi module that receives the sensor data and displays the same on the LCD connected to the microcontroller board. Monitoring the display, the nursing staff may decide on the medication for the patient. The Wi-Fi module also enables the signals from the nursing staff to the movable machine to operate remotely. The nursing staff may move the machine as per the choice using the keypad and also trigger the commands to acquire the body temperature and SPO2 measurements.

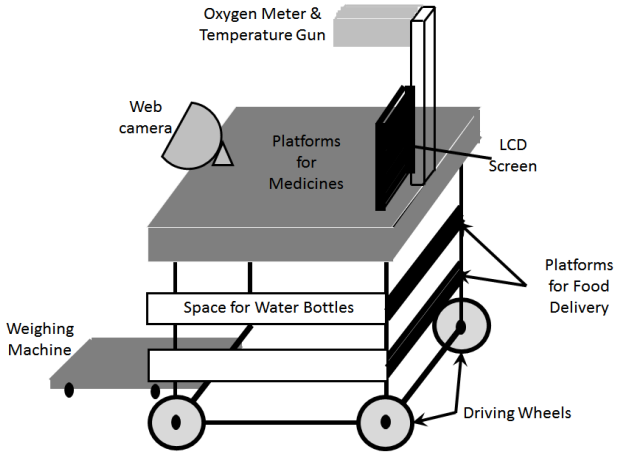


Fig 2. Proposed Movable Machine

The proposed machine shown in

Fig **2** will be driven by two BLDC motors in-tank wheel drive. The machine has a provision to keep the food and water at two different levels as shown in figure 2. On the top of the machine, the medication can be accommodated to be supplied to the patient as and when required. The camera mounted on the machine will enable the nursing staff to navigate it to the proper position from the remote end and the same camera will be useful to see the patient while performing the wireless video communication.

III. FLOW OF SOFTWARE

This Section describes the Software model for the implementation, it discusses the approach used for writing the embedded firmware for the controllers to implement the functionality required for the device. The software model is prepared for two processes.

Fig **3** shows the model that is prepared for the movable machine. The machine uses the Wi-Fi module to accept the input command from the remote control and identifies the command to execute.

The command may be used to navigate the machine if a forward or reverse direction or for turning off the machine. The command may also ask a machine to take the body temperature and SPO2 measurements from the patient and send the same to the remote controller module. The model shown in

Fig **4** is designed for the remote controller part. Where a key is pressed and the command received is transmitted with the use of a Wi-Fi module. The remote

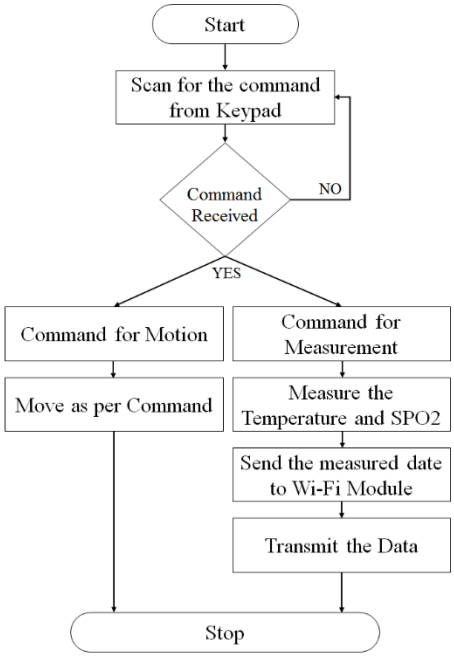


Fig 3. Flowchart for Software Model 1

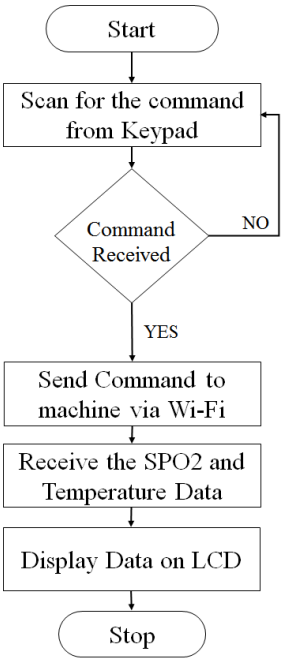


Fig 4. Flowchart for Software Model 2

controller is equipped with the LCD module to display the temperature and SPO2 data received from the patient end. The audio and video communication are always on and no specific flow of control for the same is required.

IV. RESULTS

This section presents the implementation of the covid auxiliary robot and obtained results. Figure 5 shows the prototype of the machine which will be going to the patients. This machine helps the nursing staff to measure the temperature and SPO2 level by asking patients to put their fingers on the sensor. The given instructions can be heard on the speaker and the patient can reply using the mic which is shown in figure 5. The water bottles and food tray space can be utilized to supply food and water to the patients. Figure 6 shows the motor driver interfacing circuit which drives the entire machine

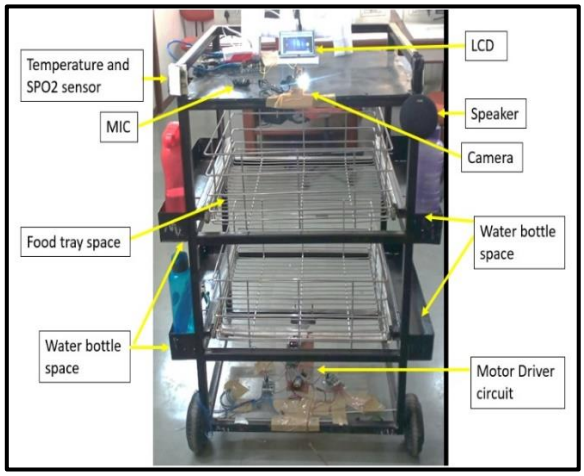


Fig 5 Covid Auxiliary robot

A patient can communicate with the nursing staff using a mic and LCD. The entire machine movement is controlled by the nursing staff who is standing outside of the room through the

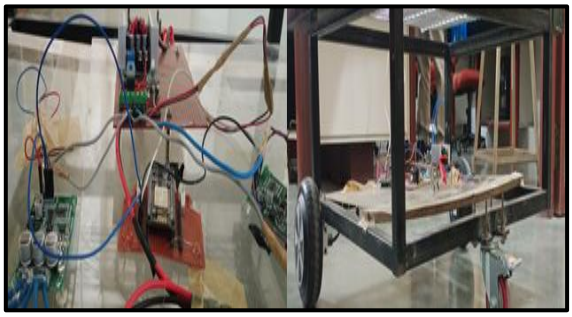


Fig 6 Motor driver circuit interfacing

remote which is shown in figure 7. The remote helps the nursing staff to control the machine's movement through push buttons. The red push button helps the staff to stop the machine's movement in case of any obstacle around.

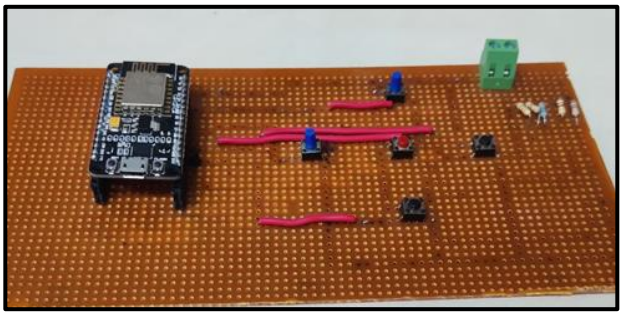


Fig 7 Remote circuit with nursing assistant staff

Figure 8 shows the obtained output of temperature and SPO2 sensor. The output will available with assembly available with the nursing staff.

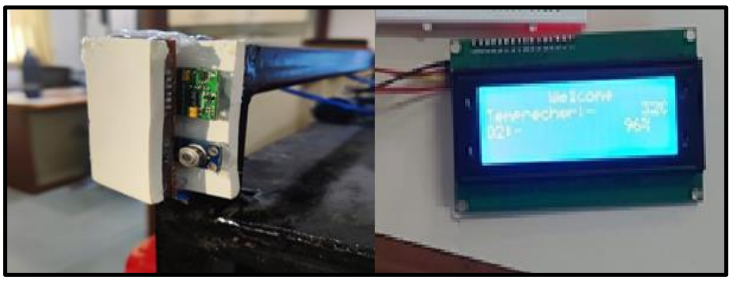


Fig 8 Temperature and SPO2 sensor output

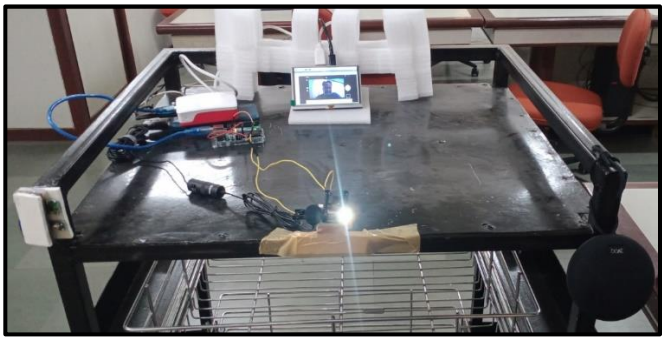


Fig 9 Audio video link setup on the machine

The wireless communication link setup on the machine is shown in figure 9. A camera captures the face of the patient. The instruction given by nursing staff can be heard through speak and the patient can communication with the mic that is available on the platform. The nursing staff has a similar setup with the remote to communicate with the patient. The machine is will collect the medical samples of the patients one after the other. In case, if the readings are to be stored for multiple patients, then the same can be incorporated at the server end by updating the program. The proposed hardware is capable of transmitting the medical sample data of every patient as and when required.

V. CONCLUSION

The nursing assistant robot is successfully implemented. The implemented machine can navigate using a tank wheel with the remotely controlled command received through the Wi-Fi module. Wireless audio communication using a Bluetooth-based transmitter and speaker is performed. The wireless video communication is implemented using the ESP32 Camera and Raspberry Pi module. Temperature and SPO2 sensors are interfaced and successfully utilized for the measurement of the body temperature and oxygen level of an individual. The implemented system can easily be deployed to serve the infected patients without actually contacting them and helps the nursing staff to perform their duties without any risk of infections.

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