# A Remote-Operated Humanoid Robot Based Patient Monitoring System

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***Abstract*— This study presents the design and implementation of a remote-operated humanoid robot-based patient monitoring system. The humanoid robot is been remotely operated by a healthcare personnel situated at the Nurse/Doctor station, and comprises Arduino Nano, HC-12 transceiver and FPV camera modules to provide a full duplex communication between patients and the healthcare personnel without coming in contact with each other. Furthermore, a Far-UVC 222nm lamp is embedded on the robot for self-decontamination after being in contact with the patients. Hence, provides an effective way of evaluating and monitoring patient's medical condition without risking the life of any healthcare personnel. The experimental results obtained showed the system was able to measure the patient's vitals as well as administer medications where necessary.**

***Indexed Terms*— Arduino Nano, HC-12 Transceiver, Humanoid Robot, Far-UVC 222nm Lamp and FPV camera.**

## I. INTRODUCTION

The effects of Coronavirus Disease 2019 (COVID-19) and other communicable diseases such as diphtheria have brought several threats and restrictions to our societies, affecting nearly all continents including Africa. The healthcare personnel are at the forefront fighting these diseases. Thus, makes them more exposed to contracting the virus. As per earlier reports from COVID-19 epicenter in Wuhan (China), 40 out of the first 138 recorded cases are healthcare personnel [1]. Therefore, it has become essentially important to utilize the services of technologies that will protect these personnel at all times so as to minimize casualties associated with such diseases. This can be achieved through the utilization of a remote based robotic system.

A remote based robotic system is a technological solution designed to allow healthcare professionals to remotely monitor and interact with patients using a humanoid robot. This system combines the capabilities of a humanoid robot, such as mobility and dexterity, with remote operation and monitoring capabilities [2]. Some of the key features and benefits of such a system are; vital sign monitoring, telecommunication, reduced risk of contagion, medication administration, remote physical examination, emergency response, as well as data logging and analysis [3].

Several studies have been in existence to aid the healthcare personnel in carrying out the aforementioned operations [4]. However, communicable diseases spread not only from person to person through close contact with respiratory droplet transfer, but also through contaminated surfaces. In addition, the disease can persist on inanimate surfaces including metal, glass, or plastic for days [5]. To address this issue, ultraviolet light devices such as Pulsed Xenon Ultraviolet light systems (PX-UV) can be employed to effectively reduce contamination on the high-touch surfaces [6].

This study presents the design and implementation of a remote-operated humanoid robot-based patient monitoring system. The system would be remotely controlled by a human operator at the base station to provide medical services to the infected patients. Hence, reducing contact between the patient and healthcare provider. Furthermore, a Far-UVC 222nm lamp is embedded on the robot for self-decontamination after being in contact with the patients.

## II. RELATED WORKS

This section presents the review of related works that have been carried out in the area of robotics. The relevance of this review is to provide an insight to different types of technologies used to help the healthcare personnel in combatting these diseases. In this regard, a robotic device was developed to perform the storage, sealing and handling of test plates [7]. The system is utilized to diagnose the SARS virus, which is categorized later as a new member of the coronavirus family. The developed system successfully diagnoses the patients; however, the robot is not equipped with an audio-visual system that will allow the healthcare personal to monitor as well as interact with the patient remotely.

A smart robot was developed to conduct lab test, interpret results, and other remote supports at the healthcare centers [8]. The basic remote function can be performed like telemedicine, taking blood pressure and dispensing pills. However, there is need to integrate the robot with a decontamination system in order to sterilize it. Hence, prevents the robot from spreading the disease. Similarly, a Tele-Robotic Intelligent Nursing Assistant (TRINA) was also utilized to deliver nursing jobs which provides basic communications and interactions with the patients [9]. However, due to the lack of self-decontamination system on the robot, the virus can be transmitted to other persons via the robot after been in contact with an infected patient.

A semi-automatic oropharyngeal swab robot was developed to take swabs test from patients [10]. The authors utilized a remote camera embedded on the swab robot to aid the healthcare personnel perform the sampling with a clear vision without coming in contact with the patient. The experimental results showed a sampling success rate of 95%. In addition, an auto-guided vehicle equipped with infrared and ultrasonic sensors was also developed [11]. The infrared sensors placed at the bottom of the robot are capable of identifying the path, while the ultrasonic sensor in front can detect the obstacle dynamically. However, due to the fact that the developed vehicle is not remotely controlled and has no any virtual platform, its mobility and functionality are limited.

In view of these limitations identified from the review of related works, it is evident that the existing technologies failed to self-decontaminate after coming in contact with an infected patient. To prevent the spread of these diseases, there is need to develop a decontamination system and integrate it with the robot. This will significantly reduce the rate at which the virus is been spread.

## III. MATERIALS AND METHOD

This section presents the materials and method utilized for the development of the remote-operated humanoid robot based patient monitoring system. The overall methodology of the developed system is divided into two phases namely; the hardware development phase and the software development phase. The hardware development involved the implementation of the system circuitry modules, whereas the software phase involved developing a computer program required for the control modules.

### *A. Hardware Development*

The hardware development phase comprises two basic units namely; remote-control unit and humanoid robot unit.

The remote-control unit is situated at the Base station where the attending healthcare personnel are residing. The main function of this unit is to remotely control the directional movement of the robot as well as provide the necessary medical attention needed. While the humanoid robot unit is tasked with the delivering of medications and supply of essentials to the patients; and it operates in accordance to the signal received from the base station.

Having known the desired output specifications, suitable components specifications were chosen that will provide the prescribed task. The overall methodology for the hardware development phase can be summarized in the block diagram presented in Fig 1. An explanation of the block diagram is presented herewith.

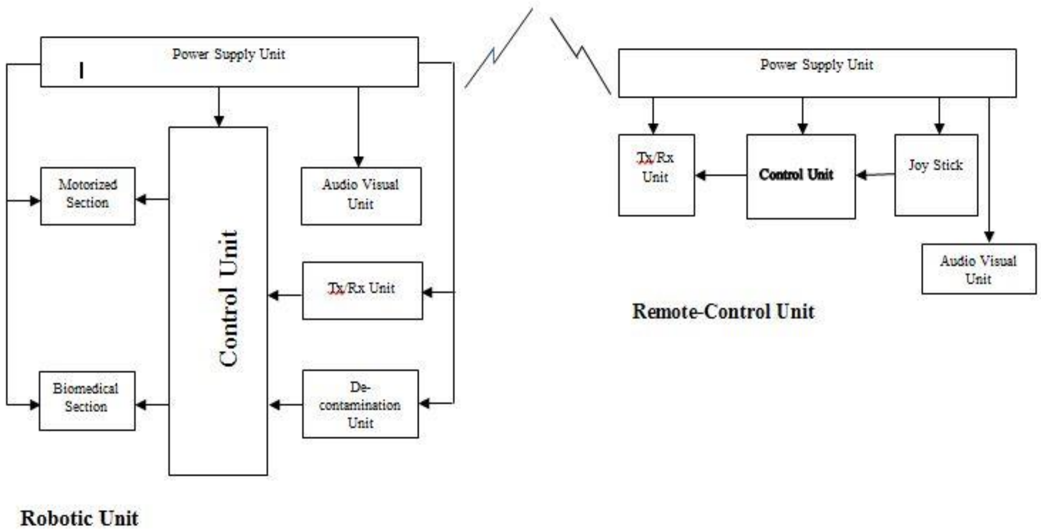


Fig. 1: Block Diagram of the Developed System

*I. Control Unit*

The developed system comprises two Arduino Nano, one situated at the remote-control unit and the other at the robotic unit. These boards are based on ATmega328P microcontroller employed to serve as the central control units of the entire system; and has a preinstalled boot loader and a SRAM of 8kb. In addition, it has a serial pin that is utilized to send and receive TTL serial signals. This makes the Arduino Nano board suitable for the developed system.

The mode of operation is in such a way that when a particular pin at the remote unit is activated, the transmitter module is activated through a serial communication pin. The transmitter then sends a wireless signal to the receiver module situated at the robotic unit. The Arduino Nano at that unit then controls the actions taken by the robot in accordance to the command received from the remote-control unit.

*II. Transceiver (Tx/Rx) Unit*

A HC-12 transceiver module was employed to provide a wireless communication link between the remote-control unit and the robotic unit. This transceiver is capable of transmitting a signal at the rate of 473MHz up to an open range of 1km. Thus, makes it suitable for deployment in the healthcare facilities.

*III. Motorized Unit*

The motorized unit controls the speed and directional movement of the DC motors and hence, that of the robotic. This unit is implemented using a dual H-Bridge circuits being controlled by the Arduino Nano board. The pins from the board to which these switches are connected to, drives the motors to move in either forward or backward direction through PWM.

*IV. Audio-Visual Unit*

Live streaming without any delays and barriers is a core part of this study. A variety of methods and systems were experimented and evaluated upon multiple parameters considering cost, range, latency and blockades. However, this study employed an analog FPV 5.8GHz dual camera modules to provide a full duplex communication between the patient and the healthcare personnel without coming in contact with each other. This is due to its low latency as well as long range transmission without been dependant on Wi-Fi.

*V. Biomedical Unit*

The biomedical unit enables the healthcare personnel to evaluate the patient's blood pressure, pulse rate, as well as blood oxygen level. Furthermore, provides all the necessary medications needed after the evaluation is carried out.

*VI. De-contamination Unit*

A Far-UV 222nm is employed to sterilize the robot after being contaminated by coming in contact with the patients. This Far-UV 222nm is safer and more efficient that existing 250 to 280nm UVC systems due its rapid disinfection as well as reduced UV damage to skin and eyes. The decontamination unit sterilizes the robot after being contaminated by coming in contact with the patients.

*B. Software Development*

For the system to be fully functional, a program is installed into the program memory of the microcontroller. This program was written and compiled using Arduino IDE to be compatible with ATmega328P microcontroller. Fig. 2 presents the flow chart of the developed program.

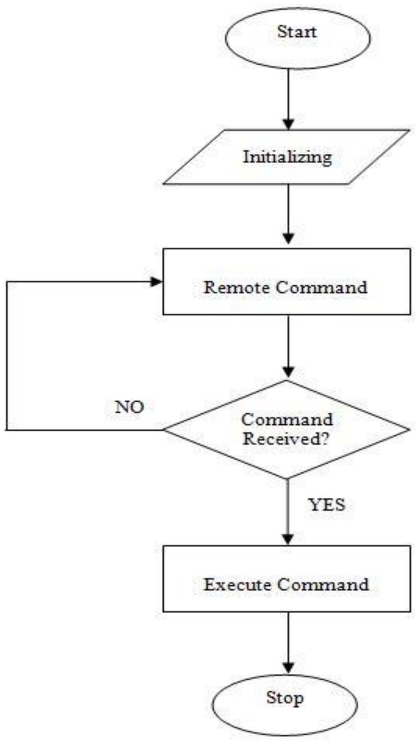


Fig. 2: Flow Chart of the Developed Program

Fig. 2 shows the step-by-step procedure followed to develop the software program that will enable the system to function. When the system is powered on, the Tx/Rx unit starts initializing. The receiver at the robotic unit then waits for incoming command from the base station before it starts operating. Furthermore, when this command is been received the control unit at the vehicle side executes the command in accordance to signal received from the remote-control unit.

*C. Body Frame*

The material selection for the body frame includes iron sheet, aluminum bar and plastic filaments for the production of the head and other parts of the robot. Fig. 3 present the sketch of the body frame of the robot.

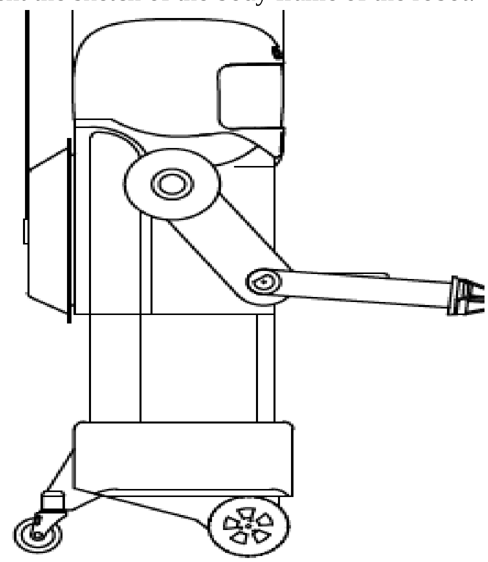

Fig. 3: Side View of the Robot

The construction of the complete circuit was then neatly assembled in a specially constructed body frame presented in Fig. 3 so as to provide protection for the entire system. Fig. 4 presents the 3D representation of the developed system.

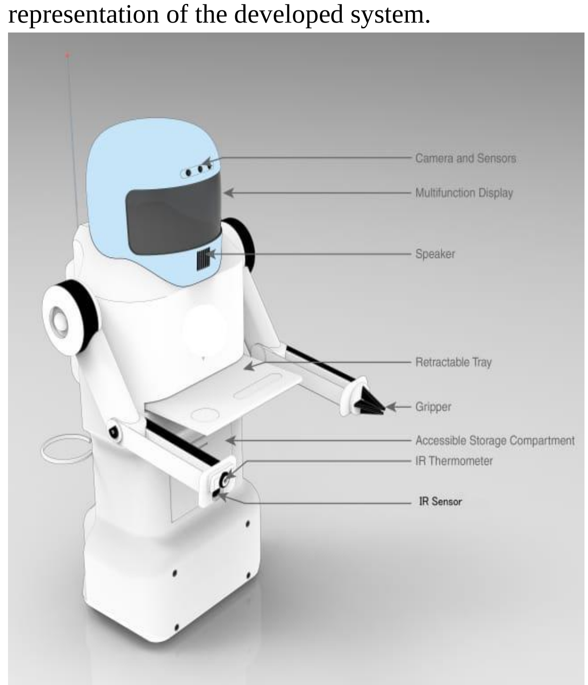


Fig. 4: 3D Representation of the Robot

## IV. RESULTS AND DISCUSSION

This section presents the results obtained after the successful realization of the developed system. The system comprises three (3) major features namely; live streaming, medical evaluation, and self-sterilization. Therefore, various tests were carried out and evaluated based on multiple parameters in order to determine the functionality of the system.

For the live streaming, the FPV camera module used was tested and evaluated based on latency, Television Lines (TVL) quality, and Range. The results obtained for this unit are presented in Table I.

Table I. Audio-Visual Test

| Evaluation Parameters | Results |
|---|---|
| Latency | 33ms |
| Quality | 1200 TVL |
| Range | 2km |

Table I shows that the FPV camera used for the audio-visual unit has an average latency of 33 milliseconds (ms), a fair quality of 1200 TVL and a transmission range of up to 2 kilometers (km). Furthermore, another test was conducted to determine the functionality of the system in carrying out medical evaluations. Fig. 5 presents a simulation result obtained in terms of pulse rate and oxygen level measured.

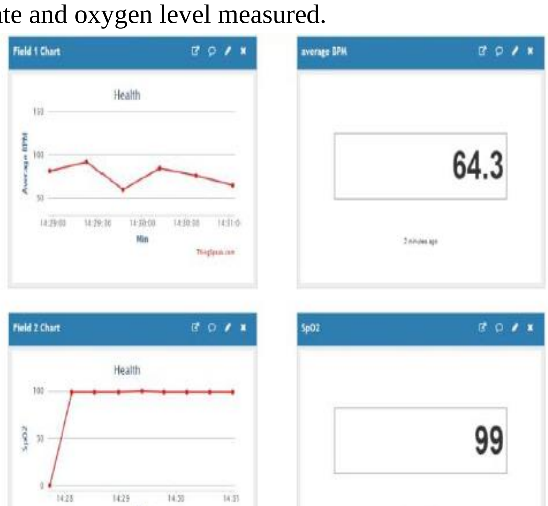


Fig. 5: Measured Pulse Rate and Oxygen Level

Finally, decontamination test was carried out and the experimental result shows that the far UV-C 222nm technology employed for the sterilization of the robot kills 99.9% of viruses and bacteria.

Based on the experimental results obtained, it can be observed that the developed system provides an efficient and reliable means of evaluating as well as monitoring patient's medical condition without risking the life of any healthcare personnel.

## V. CONCLUSION AND FUTURE RESEARCH

In this study, a robotic medical utility and remote patient monitoring system is presented. The robot was embedded with a HC-12 transceiver and FPV camera modules to provide a full duplex communication between the patient and the healthcare personnel without coming in contact with each other. In addition, a far-UVC 222nm lamp was utilized for self-sterilization after operation and thus, minimized the risk of contracting diseases. Functional tests were conducted in the lab as well as in the field. The results obtained showed that all components and other features have an acceptable level of functionality. Therefore, this study presents an outstanding demonstrator of design, manufacturing and control capabilities that can be utilized to develop more sophisticated robots for different application in the future

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