Hexafunctional Autonomous Robotic Cart (HARC) for Covid Wards minimizing human contact risk

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Abstract. Medical robotics has shown a significant uprising in the era of COVID 19 global pandemic. With the medical and paramedical staff being in the frontline of this deadly virus it is really important disseminate simpler technologies integrated together to protect them and provide nascent solutions to the problem of contact risk in hospitals. In this paper we have proposed and designed a Hexafunctional Autonomous Robotic Cart (HARC) for covid and isolation wards. The design with its simplicity, durability and cost effectiveness offer a great aid to the healthcare system in not only maintaining social distancing and minimising contact risk but also diagnosing the health of patient and establishing active communication with the concerned doctor.

1. Introduction
The Pandemic has wrecked the world to some unprecedented consequences. Current WHO statistics while writing this paper shows more than 26 Million active cases with 871,166 deaths due to COVID-19 around the world. While medical staff is acting as vanguard in the pandemic, it is the outmost priority to offer a plausible safeguard to them [6]. Healthcare Robotics would be playing an important role in management and mitigation of the contact risk and contamination. Yang et al proposed and designed a tele-operated robot for isolation ward to mitigate the contact risk from patients to medical staff [2]. Zhanjing Zeng mentions the adoption of artificial intelligence and robotics will continue even after the COVID situation becomes less serious [3].

A number of individual robotic solutions have been proposed to address the current situation in hospitals for sanitization, delivery, monitoring and healthcare analyses [7]. A major drawback of some of the designs are their high cost, complexity and inability to multitask. We have designed HARC a hexafunctional robot, which is cost effective robot with relatively simpler mode of operation.

2. Methodology and Function
HARC works on autonomous and semi autonomous configuration. The simplicity of Node MCU interface add to its operational simplicity with lightweight but rigid PVC structure that can handle a
good amount of weight at a considerable speed. With Hexafunctional utility HARC can operate as the following.

2.1. Essential MobilityCart
Evans et al demonstrated an autonomous mobile robot courier for hospitals [4]. The HARC has 30\*50 cm\(^2\) tray for carrying a weight up to 30 kg without losing its speed and breakdown. It can carry essentials including medicines, food & edibles and other essential items. The wheels of robots are designed so that they have traction with the floor all the time. For delivering the supplies robot is designed to have a detachable table like shape so that items can be placed on that table top tray. Before delivering the items outside the room robot firstly self-sanitize all the items it was carrying and then securely delivers disinfected items. Długosz et al designed an autonomous robot for small deliveries in schools, offices and hospitals [5].

2.2. Mopper

2.3. To avoid the contact risk to janitor and cleaning staff the HARC is installed with a mopper. Floor cleaning robots based on inertial measuring unit (IMU), encoders and LIDAR have been proposed with context to hospital management [9]. HARC is installed with a rectangular mopper in the bottom. The obstacle detector (HC-SR04 ultrasonic sensor) along with an inbuilt algorithm makes the mopping system autonomous to cover the entire carpet area of the room.

2.4. LiquidSanitization
An adjustable spray nozzle and pump fitted in the HARC helps in surface sterilization and self sanitization of the HARC’s body. With a 1l capacity to hold a liquid sanitizer.

2.5. UVC Disinfection Chamber for dedicatediitem
There are some items which cannot be disinfected directly by spraying liquid disinfectant on them like cell phones, electronic devices, masks or for more disinfecting of items such as medicals equipment, thermometers etc. a UV sanitization chamber is created inside the HARC so that all this item can be disinfected by the UV light without damaging the lights. For UV sanitization chamber a room is created with walls which does not let any UV light pass through them and reflects it so that UV light cannot affect human body.

2.6. Audio-VideoCommunication
Telemedicine have illustrated an exponential growth in the era of combating COVID-19 minimizing contact risk [2][10]. For supervising the patient or doing a checkup of patient the robot is installed with two-way video communication device. With the help of this device the doctors can easily interact with the patients and can check the status of patient’s health without coming in actual contact with patient. By this technology a doctor can supervise a greater number of patients letting a greater number of patients which will control the imbalance of medical health care. With the help of this technology patient through this video communication Technology robot can be remotely controlled from anywhere in this world without physical presence.
2.7. **Real time healthcare monitoring system**

A GOQii smart vital wristband [11] worn by patients is connected to the communication device equipped inside HARC. Its helps us in keeping a track of essential parameters like temperature, oxygen saturation (SpO2), heart rate and blood pressure. An advantage added along with this feature is the type and dose of medicines to be given to patients by keeping a check on these four essential parameters. The communication device generates a real time and periodic (weekly & daily) plot of the parameters which would determine the affect of medicines on patient’s health.

3. **Robotic Architecture**

3.1. **Structural Analyses**

The robot has the structural same design as of a room service cart so that it could carry certain amount of weight from one place to another. The roll cage of robot is in form of a cuboid made out of PVC pipe for weight reduction and increased strength. The roll cage of robot is designed and simulated in ANSYS. The capacity of robot is up to 25 Kg for which the designed roll cage is analyzed under 400N of load taking FOS as 1.5. The max deformation of roll cage is approx 04mm which is acceptable as it is low speed robot.

![ANSYS Simulation of HARC roll cage](image)

3.2. **Electronic Components**

3.2.1. **NODE-MCU.** It is an open-source based firmware and development board with the ESP-12E module containing ESP8266 chip having TensilicaXtensa 32-bit LX106 RISC microprocessor. [12] This microprocessor supports RTOS and operates at 80MHz to 160 MHz adjustable clock frequency. It controls the nozzle spray and motordriver.
3.2.2. **H bridge motor driver:** The geared motor with a voltage of 12 V and current up to 4 amps is required for rated torque. An H-bridge is a configuration of 4 activated doors with small signals in pairs of two. Current will flow in the one direction or another depending of the switched "doors". Two PNP transistors are connected on the top of the 5x7cm PCB with equal distances from each other. Two BD139 NPN transistors are placed at the bottom of the board. Two BC547 transistors are connected near the BD140 to make connection easier. They are connected through two resistors of 100 ohms each. All the connectors are placed and connected with two 1k ohm resistors to the two BC547 transistors bases.

Wiring begins with thin wires. First GND is connected to the emitters of the transistors BD139. After, Vdd is connected to the emitters of the BD140 transistor.

3.2.3. **High Torque geared DC motor:** It is a motor with gearbox of metallic gears. The operating voltage of motor is 12V having 20Kg-cm of torque running at 150 rpm. The output shaft of motor is connected to 6cm diameter wheels having 2 cm of width made out of high strength plastic.

3.2.4. **Spray pump with relay:** It is a self priming pump operates on 12v voltage supply. In this pump water enters through inlet port passes through diaphragm in which due to vibration of rotating shaft water get pressurized and exits through a nozzle having small orifice due to which water atomises/mistifies and comes in from of spray. This pump is operated through a relay connected in series with pump making it controllable through our microcontroller nodeMCU.

3.2.5. **Battery pack:** A battery pack made up of 3.7V Li-ion cells scavenged from old laptop batteries connected in 3s5p pattern forming a battery pack of 11.1v and 11000mAh. Due to use of Li-ion cells this battery has higher power to weight ratio as compared to normal lead acid batteries.
3.2.6. Miscellaneous
- UVBulb
- Communication device(Phone/Tablet)
- Mopper
- Ultrasonicsensor(HC-SR04)

Top load on the HARC

The base structure of HARC
3.3. Operation

The main processing unit of robot is Node micro controller unit which controls all the processes of robot. All the driving components of robots like motor driver, pump relay are connected to NODE MCU along with a battery pack. The NODE MCU basically takes instructions from an outer server connected via WiFi like mobile phones or a computer server connected via wifi router. When a task is to be performed on robot the instruction goes from server to NODE MCU in which this gets converted to a digital signal which goes to motor driver or relay which perform energizing or de-energizing according to this digital signals performing the required task.

The HARC is connected to the main server through cloud via our communication device. It can be controlled from anywhere through internet. When HARC is loaded with essential items it would reach the patient in covid ward through our pre-defined algorithm. While returning back the spray disinfectant sanitizes itself and the items it returns back. The server and pre defined algorithm can be harvested to be applied to a swarm of robotic carts as an extended application.

When HARC is used for mopping/surface disinfection the upper part is removed and the action is carried out. The HC-SR04 ultrasonic sensor detects the obstacle and turns accordingly to cover the entire carpet area. For cleaning action the pump dispenses liquid soap/disinfectant contained the sanitization chamber through nozzle and mopper cleans the floor. Apart from liquid disinfection HARC also has a UV chamber to disinfect dedicated items.

Schematics of network of HARC swarms
An important feature of HARC is a continuous analyses of essential parameters like temperature, heart rate, oxygen saturation and blood pressure. The information is sent and stored to the main server of the hospital. The graphical information is obtained by plotting a curve on the same which would help the doctors to analyze the health, affect of medicine and also provide datasets for research. The communication device installed in the HARC provides an interface between doctors and patients without physical presence.

3.4. Conclusion

The simple design and structural durability of HARC makes it a favourable choice to be used in Covid wards and home-isolated patients. An x-factor included with the design is first its cost effectiveness, a typical fully functional design could be fabricated in less than $100. Second is the feature to keep a graphical check on the patient’s vital parameters which would help the medical staff for better analyses of patient’s health and fasten the process of recovery. It would help in maintaining social distancing and would decrease the contact risk. Looking it with a perspective effectively it can function as a nurse, a doctor and a janitor. Though the project is in the stage of prototype but it positively addresses the solution and material capability of the design.
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