

## IOT based Automatic Drug Delivery Robot in Hospitals

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**ABSTRACT** This paper presents the implementation of automatic drug delivery robotic system using the Internet of Things (IoT) to be used in hospitals for internal logistics. This system helps to reduce the manual work. A smart health caring system which is developed comprise of IoT and sensor technology. The proposed system can check patient's health by monitoring the patient's heartbeat, blood pressure, body temperature, fall detection and level of the saline in the bottle. The heartbeat, temperature and fall detection sensors are interfaced with the Arduino. The system developed also helps in conserving the energy by controlling the electricity in a hospital from distant position. Further, a line following robot can distribute required drugs and foods to the patients and also aid to sanitize devices especially during pandemic.

**INDEX TERMS** Internet of Things, Automation, Saline, Arduino, Sensors, and Drug delivery.

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### I. INTRODUCTION

In the whole world, health care is one of the main concerns and requires special attention for the patients. Presently, with the growth of innovative electronic devices, easier recognition of irregularities inside the body is very much required [1]. Internet of Things (IoT) devices are widely employed in the health sector to access the data of patients. To shorten the working time in delivery of foods and drugs to patients and to reduce hospital personnel workloads, the automation system originated to care the maximum number of patients [2]. In hospitals, automated robots gained high demand especially during the COVID-19 pandemic to reduce the direct contact between staff and patients that also helps in avoiding the spread of diseases [3]. With the belief that the robots will substitute the hospital personnel in redundant tasks, increase the efficiency of work with greater accuracy. The robots are included to support patients who need treatment. Smart hospitals have been developed in health organizations to monitor health with suitable treatment of patients [4]. In health cares the major cause of excessive energy use is from lighting, and electronic devices and how often it is left 'on' when not needed. But there are simple changes that can be avoided by automating lights and fans which can save energy and the cost of hospital maintenance can be reduced. Thus, smart hospital save lives, energy, money and making innovation that is much needed.

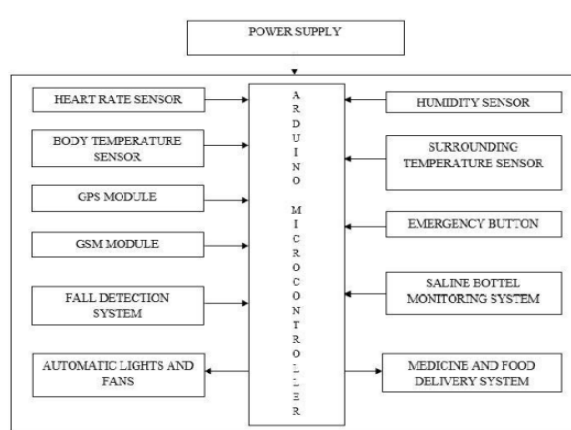
A system was developed to monitor the basic health parameters like heart rate, body temperature, and humidity of hospital rooms. In this system, hospital personnel can view and track the patient health when patient tests are performed outside the hospital [5]. This system is helpful in treating the disease like novel coronavirus. A smart saline management system to monitor and control saline infusion rate was developed in [6]. This system was capable of notifying the status of saline bottle until remaining 5% of the saline. It was capable of monitoring and managing the saline therapy by reducing the bed-side visits of the patients. Patient's Health Data Assortment (PHDA) device is installed in all the hospitals where the patients can fill up their details, and difficulties they face [7, 8]. At the same time it is directed to doctor through the mobile application (app). Saline is used to improve patient's health and evade dehydration. The patient gets special care during this phase. The saline level monitoring system is developed to safeguard patient's life from this problem [9]. A predefined acute level is fed into the system and compared with initial value. When the level reaches the threshold value an alert message will be sent to the respective nurse or doctors for replacement of bottle. An intelligent medicine box was developed that gives alerts to patients for their modification at precise time [10]. It is connected to internet to make timely updates about drugs to patient's smartphone via notification in android app. The model automatically gives alarm to the patient to take the drug at the precise time.

Telemedicine is used to treat patients after diagnose in a remote area that uses health apps [11]. For doctors and patients, telemedicine is more helpful. In this, patients and doctors can have the medical history thereby doctors can review the treatment process. IoT resolves different healthcare challenges such as decrease in healthcare expenses, increase in patient safety and health care services accessibility [12]. It improves the efficiency of the health. The regularity and quality supply of the drugs and medicines has to be monitored on the regular basis. IoT technology is used to monitor the drugs and medicine in the store [13]. Recently IoT has raised the ability for vital data transfer. A novel IoT based paradigm for medical equipment should be developed to manage them efficiently [14-16]. Various sensors are used to monitor the health status of the patients and data obtained from these sensors are sent to Arduino [17]. The sensors are smaller in size, faster, and more affordable. A pile delivery line follower robot is designed in [18]. This robot uses radio frequency identification cards to identify the patient's room number and uses a voice play back kit to speak to patients regarding the medicine. which is an added advantage in this model. The research activities on humanoid robots in healthcare that can communicate with humans effectively to improve healthcare deficiency are described in [19]. Normally people leave the wards without switching off the lights and fans that leads to unnecessary consumption of energy [20, 21]. A smart portable intensive care unit using IoT for real-time monitoring of patient and delivery of medicines from the remote location was developed in [22-26]. An IOT connected sensor based health monitoring system using different methods were studied for a patient health care system [27-30].

From the above existing papers, it can be observed that till now no attempt has been made to integrate drug delivery robot with patient health monitoring, saline bottle monitoring and automatic on and off of the electrical appliances. Thus, in this paper an integrated automatic food, drug delivery system with patient monitoring using sensors is proposed to ensure the smooth operation of medical units with personnel intervention.

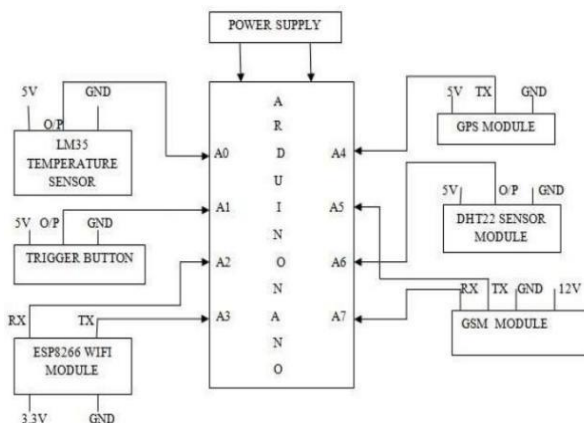
## II. METHODOLOGY

### A. PROPOSED HEALTH MONITORING SYSTEM



**FIGURE 1. (a) Block diagram of proposed health monitoring system**

FIGURE 1(a) and FIGURE 1(b) shows the block diagram and circuit diagram of health monitoring system, respectively. It consists of heart rate sensor, temperature sensor, humidity sensor, fall detection sensor, Global System for Mobile Communications (GSM) module, Global Positioning System (GPS) module, Arduino nano, and emergency button. The sensors are interfaced with Arduino nano for automation and health monitoring purposes. The system will collect information about the patient's health condition. The system to be developed can be used to measure the oxygen saturation level, heart rate, temperature of the human body and display the results on a web-based platform. When a finger is placed on the heart beat sensor, heart rate of a person is obtained and are sensed by using a high intensity light emitting diode and light dependent sensor. The sensor works on the principle of light modulation by blood flow through finger at each pulse. Body temperature sensor like LM35 constantly measures the patient's body temperature, which becomes an important parameter to check the patient's health. The temperature sensor DHT22 is used to measure the surrounding temperature in patient's room. GSM module is a chip used for communication between a mobile device and the health monitoring system. GPS module is used to detect the location of the remote patient and is sent to Arduino nano in terms of longitude and latitude.



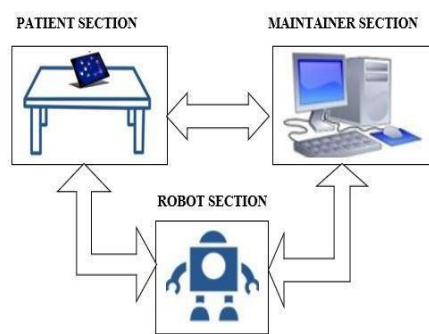
**FIGURE 1. (b) Circuit diagram of proposed health monitoring system**

The emergency button is placed near the bed of a patient in the hospital and used whenever the patient feels that he needs any emergency medical support.

## B.MEDICINE AND FOOD DELIVERY ROBOT

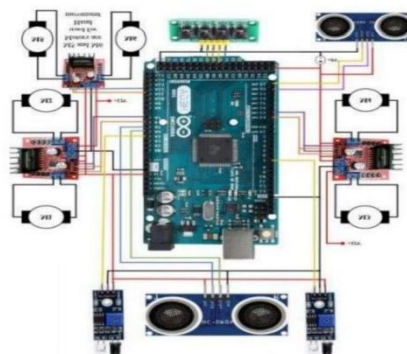
To prevent doctors and medical staff from getting infected with coronavirus, the robots are used to serve food and medicines to COVID-19 patients or people infected with the disease. It eases the task of hospital staff. FIGURE 2(a) and FIGURE 2(b) shows the block diagram and circuit diagram of the patient, maintainer and robot section, respectively.

### 1. PATIENT SECTION



**FIGURE 2. (a) Block diagram of the patient, maintainer and robot section**

The patient's smart phone will be installed with the application, which will be utilized to order food and medicine. There will be two sections in the order list. If the patient needs medicine, then he/she can enter the medicine section.

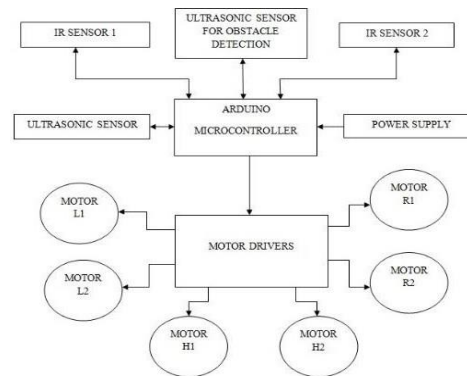


**FIGURE 2. (b) Circuit diagram of the patient, maintainer and robot section**

If the patient needs to order food, then he/she can enter food section in the application. Patient has to order the select items from the app which are presently available and the suitable cost of the item is displayed. The prices are calculated based on the order placed. The most vital part of this section is application and maintainer. The menu is synchronized with maintainer system through application.

## 2. ROBOT SECTION

The orders or services requested from the patient will be placed on the robot and deployed to the patient's room. The number of the room is noted, the robot will go to the respective room and it stops. The patient has to take the items and automatically robot will return to the counter for next delivery. The robot works on the principle of line following and it uses four motors for its movement. Line follower robotic system is shown in FIGURE 3(a). It has two IR sensors in the anterior (bottom center) which is used for line follower.



**FIGURE 3. (a) Block diagram of line follower robotic system**

The proposed robot design consists of the following components such as Arduino Mega, 8-bit microcontroller with 54 digital I/O pins, 16 analog pins and four Universal Asynchronous receiver or transmitter. The controller receives inputs from IR sensor, ultrasonic sensor, analyze it and produces output to the connected motor drivers for its arm movement. HC-SR04 ultrasonic sensor has Vcc, ground, echo and trigger pin interfaces helps in measuring an accurate distance at which an obstacle present from 2 cm to 400 cm. The ultrasonic sensor keeps on scanning the object continuously in front of the robot and sends the signal to microcontroller when an object is detected. Here, three L293d IC H-bridge motor driver circuit and six stepper motors are used in the system. A 12V battery is needed to run the motors. Each H-bridge drives two motors, two H-bridges are used for robot movement and one for robotic arm movement. A 30 rpm and weight of 7Kg torque stepper motor is used in this system. Four stepper motors are used to carry the robot body and two stepper motors are used to lift the robotic arm.

## 3. MAINTAINER SECTION

Maintainer section consists of spreadsheet integration and app development to display the orders placed by the customer. The interaction among the maintainer and patient happens through the app developed which displays the ordered items requested by the patient. Then the ordered items will be placed on the tray of the robot and will be delivered to respective patient's room.

### C. SALINE BOTTLE MONITORING AND FALL DETECTION SYSTEM

The lack of awareness of the hospital staff in monitoring saline bottle may lead to air embolism which further leads to heart attack. The moment when saline finishes, blood rushes back to the saline bottle due to difference in blood pressure and pressure in the empty bottle. In the proposed system saline bottle monitoring has been incorporated. When the saline level goes below a certain level, the alarm sound will be produced and the alert messages will be sent to the nurses. Hence the system eliminates continuous vision monitoring of the saline bottle and patient by staff. FIGURE 3(b) shows the circuit diagram of fall detection system which uses ADXL 345 to measure the static acceleration of gravity in tilt-sensing applications and dynamic acceleration due to motion.

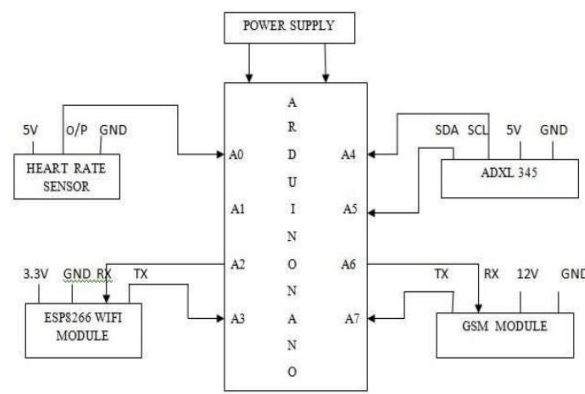


FIGURE 3. (b) Circuit diagram of fall detection system

### D. AUTOMATIC FAN AND LIGHT CONTROLLER

An automatic fan and lighting control system using Arduino is developed for the efficient use of energy in hospitals. The system developed will control fan and lighting in particular area of hospital based on the presence of human

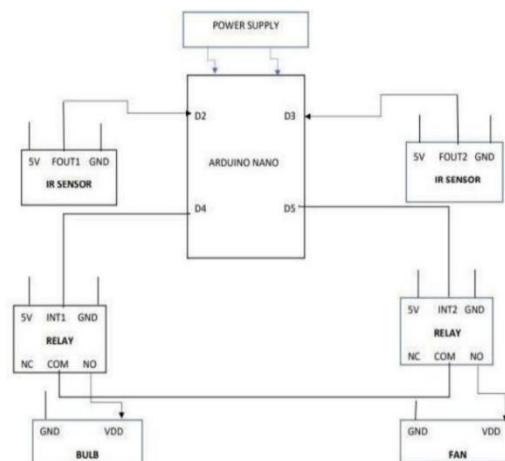
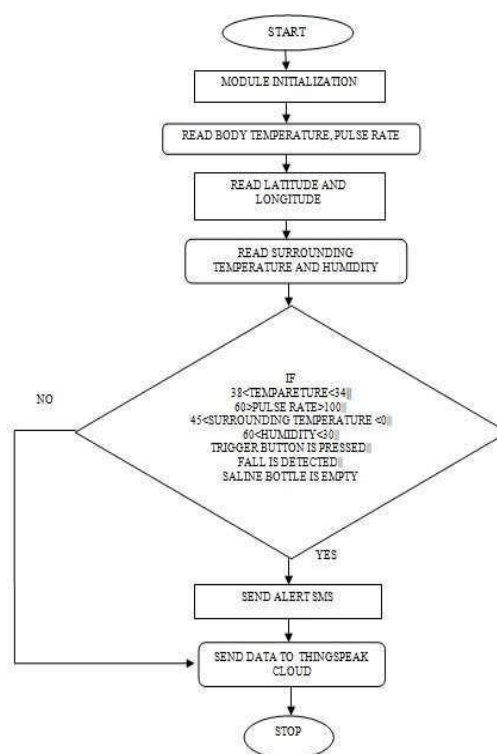


FIGURE 3. (c) Circuit diagram of automatic fan and light control

using relay control. Basically, controlling the devices of a room according to the needs are achieved using Arduino.

Devices such as fan and lights will get turned on as soon as somebody enters the room and if the room is empty then it will get turned off. In this system, two infrared (IR) sensors are used, one is for entry and another is for exit, and voltage regulator to step down the voltage to 5V, so that all sensors and Arduino will work under this voltage. Circuit diagram of automatic fan and light control is shown in FIGURE 3(c). The liquid crystal display will display the count of people entering and exit the ward. Two relays are used, one is for light control and another is for fan control. When the people enter the ward, relay will get turn on until the count shows zero, when no one is there in the ward relay will turn off. All these sensors, relays and display are integrated with Arduino nano. The automatic fan and light control will start only when some individual enters the hospital wards, according to the flowchart when number of individuals is greater than zero indicates someone should be there in the room then relay will get turned on and correspondingly light and fan are turned on automatically.



**FIGURE 4. Flow chart of proposed system**

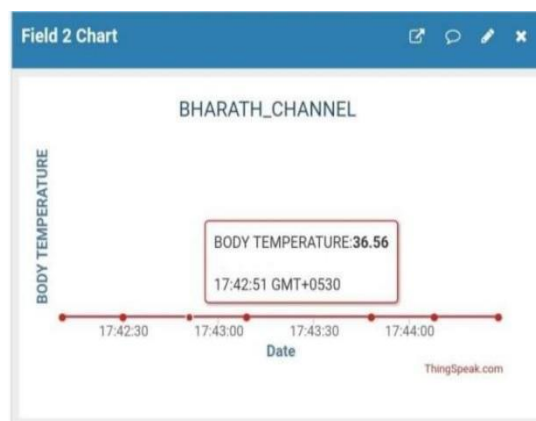
The relay remains turned on until someone should be there in room. The exit IR sensor detects the number of people left the room, then the count will decrease, once it becomes zero both relays will get turned off.

The algorithm of drug delivery system is depicted in the form of flowchart as shown in FIGURE 4. The module is initialized, Arduino reads the heart rate, body temperature, latitude

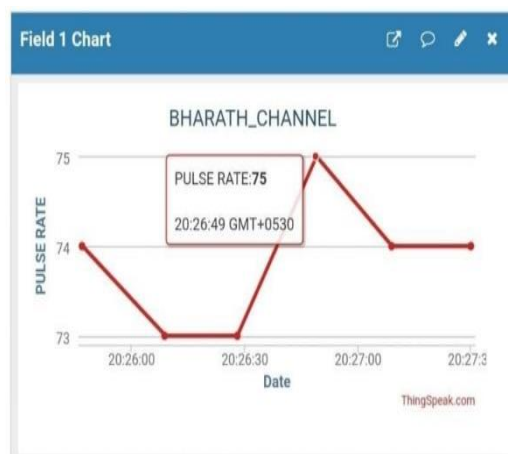
and longitude, surrounding temperature and humidity. After reading all the sensor data, the values are uploaded to the Thingspeak cloud. When the readings of heart rate, temperature and humidity goes below the threshold value an alert message is sent to the hospital staff.

### III. RESULTS

The Arduino IDE, MIT app inventor and ThingSpeak cloud software are required to build the proposed system. The Arduino IDE is useful to upload code to the microcontroller using USB type-B cable and to observe the output in the terminal. A web application-based IDE such as MIT app inventor is used to build the applications that uses a block-based programming method. The blocks can be dragged and dropped in the MIT app inventor in order to create various applications. An open source software, ThingSpeak cloud and an IoT analytics platform helps to visualize, analyze the real time data streams in the cloud. In this system, a low cost, low power sensor IoT technology is employed.



**FIGURE 5. Patients body temperature measured on Thingspeak cloud**



**FIGURE 6. Patient's pulse rate measured on ThingSpeak cloud**

FIGURE 5 and FIGURE 6, shows uploading of body temperature and heart rate of the patient to the ThingSpeak cloud, respectively. Similarly FIGURE 7 and FIGURE 8, shows uploading of surrounding temperature and humidity to the ThingSpeak cloud, respectively. These sensor values are used by the specialists from anyplace in the world to know the health condition of

the patient in real time.



**FIGURE 7. Surrounding temperature measured on ThingSpeak cloud**



**FIGURE 8. Humidity measured on Thing Speak cloud**

Patient 1: BODY TEMPERATURE ALERT!!  
 HEART RATE:80  
 BODY TEMPERATURE:39°C  
 LOCATION:  
<http://maps.google.com/maps?&z=15&mrt=yp&t=k&q=13.479726791+77.421669006>

a)

Patient 1 : PATIENT FALL DETECTED.  
 LOCATION:  
<http://maps.google.com/maps?&z=15&mrt=yp&t=k&q=13.479750633239746+77.421791076660156>

b)

Patient 1: HEART RATE ALERT!!  
 HEART RATE:110  
 BODY TEMPERATURE:34°C  
 LOCATION:  
<http://maps.google.com/maps?&z=15&mrt=yp&t=k&q=13.479726791+77.421669006>

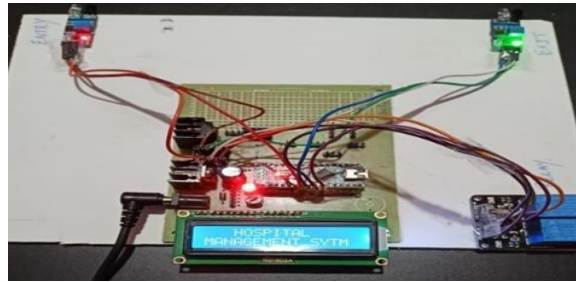
c)

Patient 1: PANIC BUTTON PRESSED EMERGENCY!!  
 HEART RATE: 80  
 TEMPERATURE:37.10°C  
 LOCATION:  
<http://maps.google.com/maps?&z=15&mrt=yp&t=k&q=13.325592041+77.124130249>

d)

**FIGURE 9. a) Alert message of patient’s body temperature, b) heart rate, c) panic button is pressed, d) patient falls**

As soon as the body temperature of patient exceed the normal value, an alert message is sent to the doctor. The normal body temperature is between 35°C to 38°C.

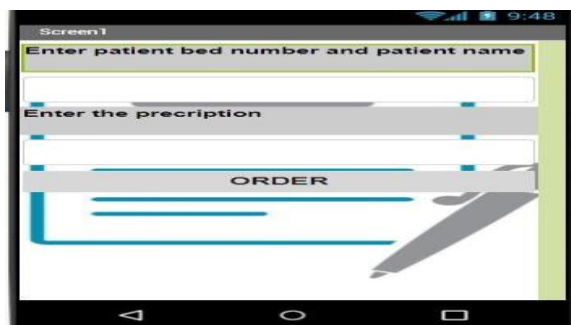


**FIGURE 10. Hardware setup of health monitoring system**

FIGURE 9(a) shows the body temperature of the patient as 39°C. Hence, an alert message will be sent to doctor. FIGURE 9(b) shows the alert message sent to the doctor as soon as the pulse rate exceed the normal values. The pulse rate of normal person is between 60 beats per minute to 100 beats per minute. FIGURE 9(c) shows the pulse rate of patient is 110 bpm. Hence, the alert message is sent to doctor. The emergency alert message sent as soon as the patient presses the panic button that is placed near the patient bed is shown in FIGURE 9(d). The patient can use panic button whenever the patient need an emergency help.



**FIGURE 11. Hardware of automatic fan and Light control system**



**FIGURE 12. Android app for medicine and food delivery**

FIGURE 10 shows the hardware implementation of health monitoring system. The system consists of pulse sensor, humidity sensor, body temperature and DHT22 surrounding temperature sensor. The monitoring system also contains GPS unit, GSM module and Arduino nano microcontroller. The entire setup will be located near the bed of the patient and can be used by the patient whenever needed. FIGURE 11 depicts the setup of fan and light control system. The fan and light inside the ward is made on based on the number of persons present inside the room. If number of persons inside the room are greater than or equal to one then the electrical appliances will be in on condition else the lights and fans will be in off condition.

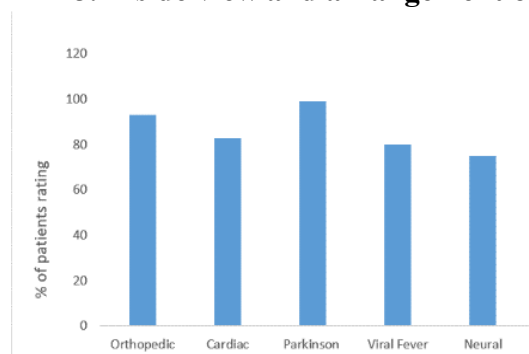
This helps to avert the excess of electricity usage. Further, the count of the number of persons in the room will be displayed on the LCD display.

The android application platform is built and located close to the patient bed and the doctors can only access it. After diagnosis of the patient, the doctors can enter the prescription in the application developed. The information includes the patient name, bed number and type of medicines to be taken by the patient. Then doctor needs to click the order button. As soon as the order button is clicked, all the information will be sent to the medical store personnel who in turn can send the robot to the required bed number for the supply of medicines and is shown in FIGURE 12.

FIGURE 13 shows the information entered in the tabular form which will be received at the medical store when the doctor orders the prescription. The name of the patient and bed number is shown in first column, the second column stores the medicines prescribed by the doctor. The status of delivery of medicines which will be updated by the medical store personnel once the supply is completed and is shown in the third column.

	A	B	C	D
1	Patient bed number and patient name	Precription	Status	
2	4   Sham	Azithromycin -10 Vitamin C -20	Delivered	
3	3   Siraj	Paracetamol-10 Amoxicillin-5	Delivered	
4	10  Kuldeep	Cipladin-1 Betadin-1		
5	6  Navdeep	Paracetamol-5 Betadin-1		

**FIGURE 13. Inside view and arrangement of modules**



**FIGURE 14. Comparison of patients rating**

FIGURE 14 shows the feedback from five different diseases affected patients regarding the functionality of the robot in taking care of patient allotted by giving them drugs in right interval and recording the patient’s body parameters.



**Figure 15. Medicine and food delivery robot**

FIGURE 15 shows the robot which is used to carry medicine and food from the medical store to the patient. It is the line follower robot. When the switch number 1 is pressed the robot delivers medicine to the first patient, when the switch number 2 is pressed the robot delivers medicine to the second patient and so on. Once the delivery of medicine is completed the robot will return back to the medical store. Hence with the help of this robot, the human interaction is reduced which is very essential in the time of pandemic. The Arduino receive the input from the two IR sensors at the bottom of the robot and compares the input from them, take decisions as per TABLE 1.

Case 1: If the black path present at the left position, then the robot has to turn to right in order to make the black path to present at the middle so H-bridge 1 is off and H-bridge 2 is on to make right turn.

Case 2: If the black path present at the right position, then the robot has to turn to left in order to make the black path to present at the middle so H-bridge 1 is on and H-bridge 2 is off to make right turn.

Case 3: If two sensors are off (no reflection of light) which means the black path remains in the middle so the robot has to continue its straight path so both the H-bridge is on.

Case 4: If the black path present at both the sensor, then it is stop point so both H-bridges will remain off.

**TABLE 1**

**Movements of line follower robot based on sensor data**

Sl.No.	SR	SL	Black path Present	Robot Turn	H-Bridge 1	H-Bridge 2
1	ON	OFF	LEFT	RIGHT	OFF	ON
2	OFF	ON	RIGHT	LEFT	ON	OFF
3	OFF	OFF	ABSENT	STRAIGHT	ON	ON
4	ON	ON	LEFT AND RIGHT	STOP	OFF	OFF

The proposed robot focuses on complete working with patient care. This robot helps to increase the patients' security by reducing time, cost and risk of errors in terms of hiring staff nurses for

redundant enduring workloads. Besides, this system aids in improving the efficiency by reducing the stuff related to the traditional formats and also provides better tracking of medicines. In this perspective, an automatic drug delivery robot can achieve the above-mentioned tasks with great feasibility and versatility. Some of the challenges identified in the present work are as follows.

1. The deployment of drug delivery robots is cumbersome and has complicated issue.
2. Robots may fail to identify the loading which lead to incorrect drug delivery to patients. This will result in health impediments.
3. The system may prone to malfunctioning and manual breakdowns. This will cause workflow disruptions with more human interference.
4. As the software needs regular updates and rectification, which may cause time delays without notifications.

Practical implementation of the system is demonstrated with sensor readings uploaded to cloud, alert messages, android app interface, hardware prototypes etc. The use of a robotic mechanism for contactless medicine delivery can help reduce hospital staff workload and risk of infection, which is highly relevant during pandemics. The cost of the overall proposed system is approximately around 11 thousand rupees which is cheaper than the existing systems. The supporting staff need a training for one week. It can be easily integrated with the existing systems with less effort.

#### **IV. CONCLUSION**

In this paper, the importance and benefit that the smart hospital will provide to the patients is found. As health is one of the vital parameter the implementation of IoT in healthcare makes a big impact on the patient's life that even though the patients are away from doctors, this will help the patient to reduce the fear of emergency or danger. Hence the developed system helps in continuous monitoring of the patient health in a real time and the disease can be diagnosed by the doctors from any distance. The drugs and food delivery robot will reduce the human resources which is necessary during the time of pandemic. The automatic control of electrical appliances will help to prevent the redundant consumption of electricity. Hence the smart hospital helps to automate the hospital and save the valuable human life in critical condition.

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