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Medbot- Design and Development of Medical Robot for Healthcare Digitalization

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***Abstract*—The main goal of this paper is to make a multifunctional robot with a database management system named "MEDBOT." That will reduce the problem of spreading any viral or infectious disease by maintaining social distancing. A robot designed and implemented will replace the ordinary system in the medical sector in a digital way with fewer life risks. Being a multifunctional robot, it can perform as a receptionist, entertainer, nurse, cleaner, and deliveryman. As a nurse, it will check a patient's Temperature, Heart Rate, Oxygen Saturation, and Heart condition in a contactless way.**

Furthermore, these vitals are easily stored in its database system. These vitals are broadcast on the device's display and server, where the doctor can quickly monitor them in real-time. This robot is equipped with a mobile application-based remote-control system to control it remotely. Moreover, a disinfecting system and UV-C light are used for sterilizing purposes. The previously invented medical robot can perform one or two tasks, but a revolutionary change will come into the medical sector by making this robot. At last, it can be said that the 'Medbot' can reduce infectious disease, save time moreover digitalize the medical industry by doing these works. Finally, to build a digital Bangladesh, it will work with the medical sector as a warrior.

***Index Terms*—Medical Robot, Multifunctional Robot, Virtual Assistance, Database Management, Medbot GUI.**

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I. Introduction

A robot can reduce human effort and make life easier by performing various tasks more efficiently. A medical robot is such a kind that is used only for medical purposes. The safety of life is the primary demand of all human beings. However, due to infrastructural obstacles, every year, many people die without treatment. Moreover, many people die from lack of treatment caused by improper medical services and insufficient number of doctors. For instance, Bangladesh is a highly populated country; around 180 million people live in this country. However, there is an average of 6.37 doctors per 10,000 and 4.8 nurses per 10,000, which can easily be estimated from the updated World Health Organization (WHO) Global Health Observatory datasheet [1]. The same scenario is seen in India as well, where the ratio between doctors to population is 1:1000 [2].

The importance of healthcare services in contemporary culture is enhancing people's quality of life and social security has long been acknowledged. Doctors and nurses of the hospital give adequate medical care to the patients. However, in pandemic conditions such as covid-19, they cannot provide proper care to patients being feared of getting infected while handling the patients. As a consequence, almost 5000 people are dying every day around the world. Moreover, the second wave of covid-19, a triple mutation variant have devastatingly attacked India. As a result, 1500+ people died every day [3].

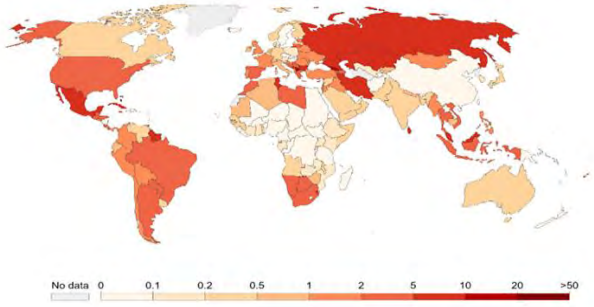

Fig. 1. Daily new recorded covid-19 death per million citizens worldwide [4].

To date, WHO has recorded 221.64 million documented COVID-19 cases and 4.4 million deaths worldwide, according to their weekly epidemiological summary released on August 31, 2021 [5]. Patients with chronic cardiovascular disease or respiratory problems have a higher risk of dying from coronavirus than others who do not have such comorbid illnesses. Figure 1 depicts the number of newly recorded deaths caused by coronavirus regularly across the world. So far, at this moment, the most affected countries are the USA, India, Brazil, Russia, the UK, France, Turkey, and Argentina [3].

The first case of Covid-19 was found in Wuhan city of China, on December 31, 2019, and now it's rapidly spreading all over the world [6]. But China fought against the coronavirus and successfully suppressed it using its technology and techniques.

Nevertheless, people are getting affected invisibly by this deadly virus in contact with suspected cases. For instance, droplets or tiny particles bring the virus from their nose or mouth into the air as an infected entity cough, sneezes, or talks. It can be inhaled into someone's lung closer to six feet. So, maintaining social distance is not only a solution to suppress; it also needs technology that can help in this situation. Otherwise, the world might lose many health workers and human lives [7].

Lots of medical robots are used in the medical sector around the world. Among these robots, some are of barrel-shaped, bear-shaped, and humanoid [8-10]. These robots can be classified by their features like 'HOSPI,' 'TUG,' 'Lo Robot L1', 'Relay,' 'Nuro' etc. medical servicing robot which is able to serve indoor hospital works such as serving foods and drugs to the patients, carring hospital materials [11-14]. 'Roomba i7', 'UVD' 'Peanut,' 'Swingobot,' etc. are cleaning or disinfecting robots that can clean and wipe the hospital room and washroom, disinfecting from various viruses by using UV light and disinfecting liquid [15-18].

Some nursing and caring robot are also used in hospitals around the world 'Robear,' 'Moxi,' 'Dinsow,' 'Dinsow mini-2', 'HOSPI-R' etc. These robots work as a substitute of nurses. They can take care of patients and assist doctors in the hospital [8, 19-22]. 'ROBO-R,' 'Dinsow-4', and 'Pepper' are well-known receptionist robots. These robots can quickly interrogate people as good receptionists. Moreover, it can also guide patients and visitors [23-25].

All these described robots can also be generalized by their operating system. Some are based on ROS (Robot Operating System), some on AI (Artificial Intelligence), and others on microcontrollers. After analysis, it is clear that all these existing medical robots, used in various hospitals, are not multitasked robots. Still, their prices are much higher according to robot features. Moreover, there were other limitations like moving speed, battery capacity, and weight; but there couldn't find any robot that could disinfect itself, which is crucial in this covid-19 situation.

II. Mechanical Design

The robot's mechanical or architectural design is the most visible step in planning. Therefore, fusion 360 (AUTODESK) software was used to create the structural design.

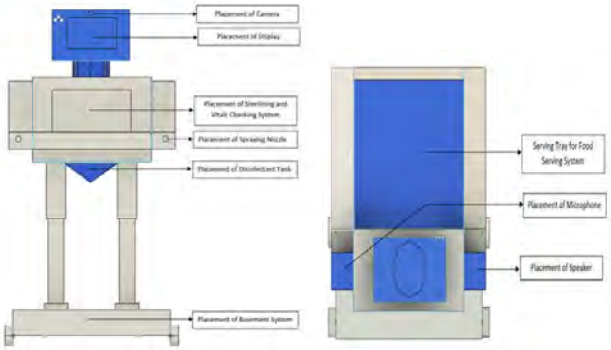

Fig. 2. Different robot views indicate where the different components have been placed.

The medbot height is 4 feet and 5 inches, and different components are placed in other body parts of the robot. Simultaneously wiring and piping are also completed. The placement of various equipment like display, disinfectant tank, spraying nozzle, pump motor, controlling circuits (Uno-based), raspberry pi circuitry, etc., are shown in Figure 2.

A. *Medbot Block Diagram and Working Process*

This endeavour is divided into two phases. One is the robot-controlling part, and another is the medical functioning part. In this medbot, two microcontrollers have been used; one is raspberry pi, another is Arduino nano. Arduino microcontroller is used for controlling, Disinfecting, and Servicing purposes; Raspberry pi is used for vital checking systems, Database management systems, Nursing systems, and Entertaining purposes. The robot controlling part contains robot movement and sterilization controlling functions. A Bluetooth module is used in the controlling factor to monitor the direction of the robot and disinfection purposes through a mobile app. In the sterilization part, there are two switches; one is used for disinfecting the room, and another for sterilizing itself. UV-C (for disinfection purposes) can destroy more than 70 percent of bacteria and viruses relative to the conventional approach [26].

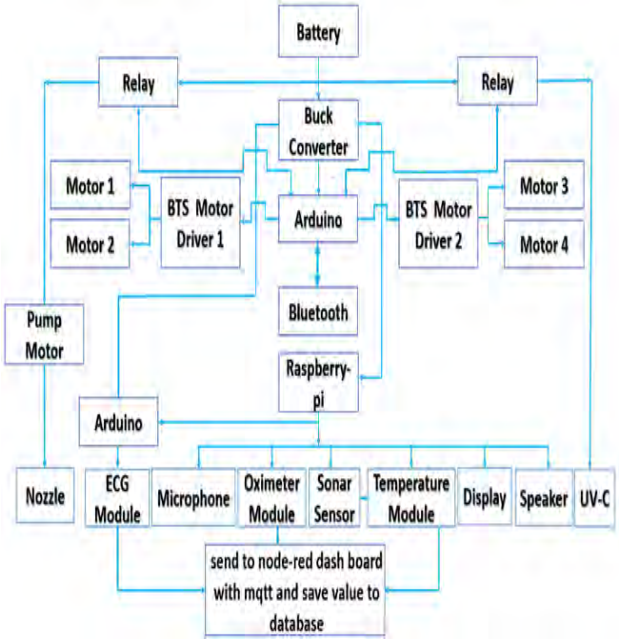

Fig. 3. Block diagram of Medbot hardware connections.

A medical function is divided into vital measurements, patient database management system, and receptionist. As a semi-automated multitasking robot, Medbot has a built-in python-based chatbot capable of interacting with people as a receptionist. Here Raspberry-pi works as a central processing unit. Raspberry-pi is interconnected with MAX30100 (to measure oxygen saturation and Heart rate), LM35 (to measure temperature), and AD8232 (to monitor heart function or ECG. These things will measure the vitals of patients. When the temperature sensor, MAX30100 & AD8232, runs, the robot will measure the value of the patient's vitals, shows the result in the dashboard, and save it in the MySQL database. A SQL query is created in MySQL named **MEDBOT**. With the help of SQL query, those data are transferred to the Medbot UI through the MQTT protocol.

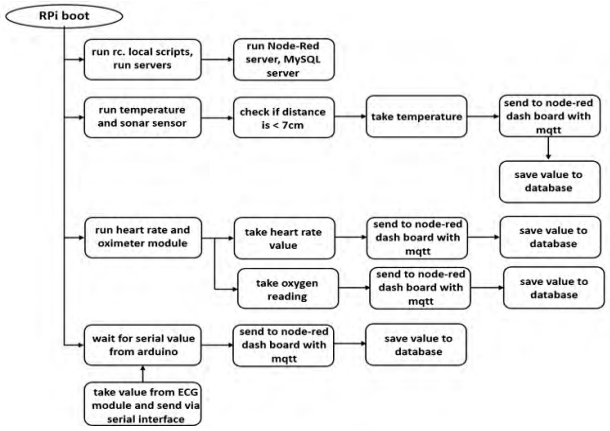

Fig. 4. Flow chart of software working process.

B. *Database System*

Here, phpMyAdmin is used to build the database, and with the help of the phpMyAdmin database, it can be accessed easily. According to patient vitals checking, a chart or report is created automatically and saved in a notepad file from where the doctor will be able to know the health condition of a particular patient.

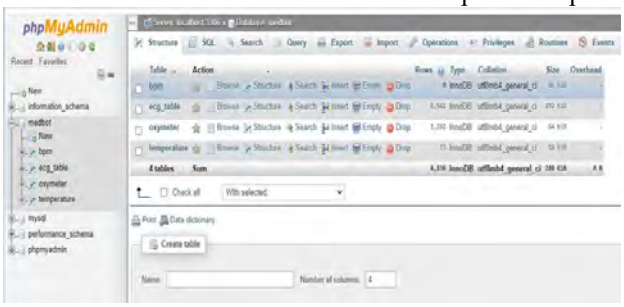

Fig. 5. Table for each vital in phpMyAdmin.

C. *Chatbot System or Virtual Assistant*

For making the chatbot, python language is used; additionally, different packages are imported, for example, speech-recognition, pyttsx3, pywhatkit, Wikipedia, etc. The chatbot uses speech recognition to understand the voice command through the Microphone. Pyttsx3 is used to convert text into speech, and pywhatkit is used for searching movies, songs, or other things from YouTube.

III. Hardware Implementation

A. *Basement and Robot Controlling Part*

The basement of the robot will carry almost all the mechanical loads; it is made of an iron sheet (16 inches by 13 inches) and iron bars (7 inches). Now, the arduino controlling part will be discussed. The main motive of medbot is to maintain a distance between a patient and a medical worker. To do this, wireless controlling arduino is connected with the HC-05 bluetooth module. This bluetooth module works as a full duplex communication medium between medbot and controlling app. The serial input data is taken from the user command (RC controller app) through the bluetooth module then the arduino processes that data. A picture of the basement part is illustrated in Figure 6.

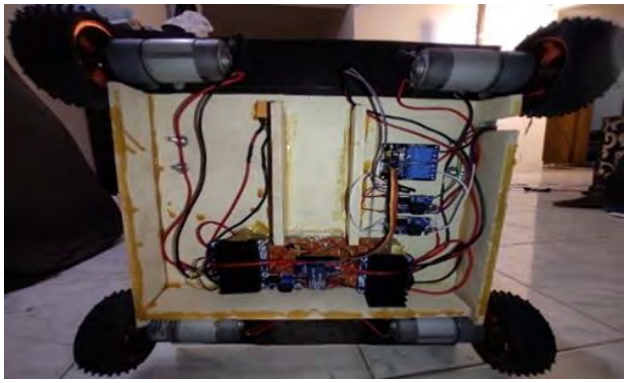

Fig. 6. Basement implementation of the robot.

B. *Implementation of Sterilizing System*

A mini pump is used to supply the disinfectant to the nozzle from the disinfectant tank through a pipe. Due to pipe wiring, there need to be several pores. Additionally, a mini pump is placed on the robot's upper legs, and a disinfectant tank is appropriately paced below the chest, which is moveable.

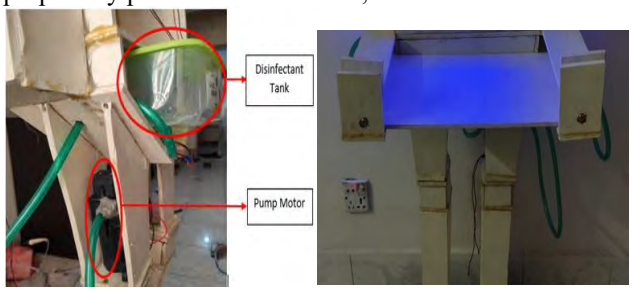

Fig. 7. Integration of mini pump, disinfectant storage tank spraying nozzle.

C. *Sensors Integration*

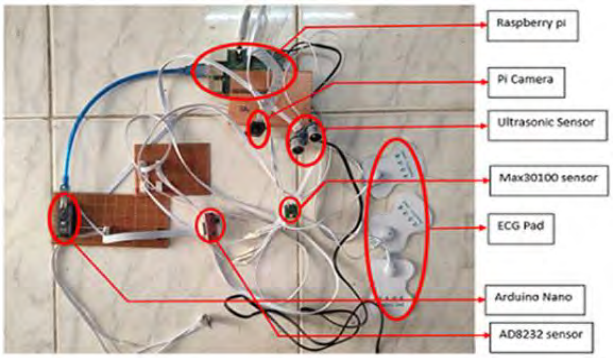

Fig. 8. Connection of different sensors to the Pi pins.

In this segment, the raspberry pi microcontroller and all sensor demonstrations will be discussed. All the vital measuring sensors, pi camera, and pi displays are integrated with raspberry pi, another microcontroller used in this system. The pi camera is used to know the robot's location, and the pi display represents the patient's vitals. Also, a microphone is connected to raspberry pi via built-in Bluetooth connectivity, and the Microphone is attached to raspberry pi via USB. Figure 8 represents the connection of raspberry pi. And Figures 9 (a) (b) illustrate the integration of raspberry pi and sensors in the robot body.


Fig. 9. Implementation of the sensors.

IV. Results and Analysis

The efficiency of a system depends on its outcome. Besides, the result section of every research indicates its significance. In this part every outcome of medbot will be discussed step by step. Medbot is a hardware and software-based multitasking robot. To analyze the accuracy of the robot, the percentage error formula is used which was established by sir Ronald Fisher, the father of statistics.

A. Human Medbot Interaction Analysis

Fig. 10. Human medbot interaction and appointed a doctor for a patient.

A person is providing data for a doctor's appointment and booking a cabin. Therefore, the medbot asks some questions before being given a token or cabin no. As per the requirements, the person provides the patient's name, age, and address, and chooses the problem of the patient, etc. In Figure 10 here, medbot shows the patient details and allocates the patient to a doctor with a convenient time.

Fig. 11. Medbot plays a movie to entertain the patient.

Figure 11 depicts the entertaining function of medbot. Through this function, a person can watch a movie, listen to songs, and even search on the internet. These are the final output for the chatbot function. For both reasons, the conversation between the human and robot is converted from voice speech to text format. It's a case-sensitive feature in medbot. Sometimes it does not recognize the human voice speech. Therefore, a recursive method was used to reduce this problem. When the medbot cannot match the voice speech with the given instruction, it will say, "please say it again," and retake the voice speech. Due to the surrounding noise, this problem was faced, but almost 70% time, it recognizes human speech.

B. Vitals Measuring

Now in Figure 12, a person measures their temperature by medbot using a non-contact temperature module; the person's temperature is showing 97.5 degrees Fahrenheit.


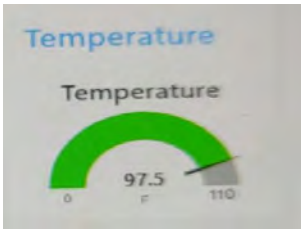

Fig. 12. Measuring temperature via medbot.

Further, that person measured his temperature using a traditional thermometer; the body temperature of the person was 97.8 degrees Fahrenheit.

The percentage error of temperature measured in-human body

$$= \left|\frac{Accepted\ Value - Experimental\ Value}{Accepted\ Value}\right| * 100\% \quad \ldots\ldots\ldots\ldots\ldots\ldots (6.1)$$

$$= \frac{97.8-97.5}{97.8} * 100\%$$

$$= 0.3\%$$

In similar way that experimented on other people for temperature accuracy testing, the results are shown in TABLE I.

TABLE I
Temperature Measurement Accuracy Test

Experimented person details	Accepted Value (Which is Measured by Thermometer) in Fahrenheit	Experimental Value (Which is Measured by Medbot) in Fahrenheit	Percentage Error in percentage (%)
Person-1(Age between 7-10 years)	99.2	99	0.2
Person-2(Age between 7-10 years)	98	98	0
Person-3(Age between 20-25 years)	98	98.2	0.2
Person-4(Age between 25-30 years)	98.6	98.5	0.1
Person-5(Age between 30-40 years)	98.4	98.3	0.1
Person-6(Age between 50-60 years)	98.3	98.3	0

After this accuracy test, it is clear that the error in calculating the temperature of any person is less than 0.5%, so it's a good indication for medbot.

C. *Heart Rate and Oxygen Saturation*

In Figure 13, a person is measuring his pulse rate and oxygen saturation in blood by medbot using the Max30100 module; the heart rate of the person is 96.2%. The oxygen saturation of the person is 77 bpm.

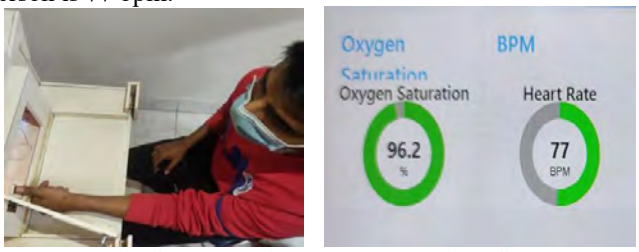

Fig. 13. Measuring heart rate and oxygen saturation via medbot.

Next, that person measures his heart rate and oxygen saturation in blood using a pulse oximeter and finds that the person's heart rate is 77bpm and oxygen saturation is 99%. The percentage error for measuring the heart rate of a person is

$$= \left|\frac{Accepted\ Value - Experimental\ Value}{Accepted\ Value}\right| * 100\% \quad \text{----------(1)}$$

$$= \frac{77-77}{77} * 100\%$$

$$= 0\%$$

The percentage error for measuring the oxygen saturation of a person is

$$= \left|\frac{Accepted\ Value - Experimental\ Value}{Accepted\ Value}\right| * 100\%$$

$$= \frac{99-96.2}{99} * 100\%$$

$$= 2.8\%$$

To test the accuracy level for the heartbeat, experimented on other people, as shown in TABLE II.

TABLE II
HEART RATE ACCURACY TEST

Experimented person details	Accepted Value (Which is Measured by pulse oximeter) in bpm	Experimental Value (Which is Measured by MedBot) in bpm	Percentage Error in percentage (%)
Person-1(Age between 7-10 years)	93	89	4
Person-2(Age between 7-10 years)	78	81	3
Person-3(Age between 20-25 years)	99	100	1
Person-4(Age between 25-30 years)	82	82	0
Person-5(Age between 30-40 years)	86	88	2
Person-6(Age between 50-60 years)	74	74	0

Similarly, it's experimented on other people for oxygen saturation accuracy testing, with results shown in TABLE III.

TABLE III
OXYGEN SATURATION ACCURACY TEST

Experimented person details	Accepted Value (Which is Measured by Thermometer) in percentage (%)	Experimental Value (Which is Measured by MedBot) in percentage (%)	Percentage Error in percentage (%)
Person-1(Age between 7-10 years)	99	97.8	1.2
Person-2(Age between 7-10 years)	94	94	0
Person-3(Age between 20-25 years)	96	96.2	0.2
Person-4(Age between 25-30 years)	92	92	0
Person-5(Age between 30-40 years)	99	98.9	0.1
Person-6(Age between 50-60 years)	96	95	1

Oxygen saturation and heartbeat depend on a patient's physical condition and feelings; if any person is afraid of anything or anxious about any situation, the heartbeat can be higher. Similarly, if any person measures his oxygen saturation or heartbeat after scampering of exercise, it might be higher; however, it is tried to avoid this situation and then experimented on these persons. Therefore, the authors get a higher accuracy level for both vitals checking, less than 5%, which is represented in TABLE 2 & 3.

D. *Cardiac System Monitoring*

For measuring cardiac signals Limb lead (Single Lead) technique is used. The most accurate waveshape propagation is shown in Figure 14, which is the Lead I system. This electrical propagation direction is almost parallel to the heart's electrical propagation; as a result, it gives a proper visual shape of cardiac signals such as P wave, QPS complex, and T-wave. Here, three electrodes are used positive, negative, and ground or reference. One is placed on the left side of the chest and another on the right side of the chest. The third/common reference electrode is located on the right side of the belly. Due to baseline interference and mechanical movement of the body, some noise has been added to the desired output, reducing the signal's intellectual property.

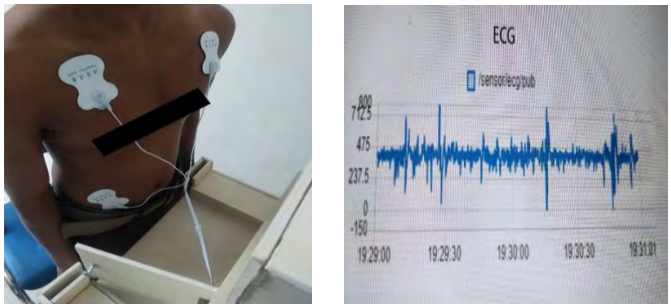

Fig. 14. A Person Monitoring his Cardiac situation via medBot.

E. Sterilizing System Analysis

To disinfect the robot itself and to sterilize the hospital, a UV-C light system and the sterilizing system were implemented, which can sanitize the whole thing. UV-C light kills viruses and germs at 257nm wavelength. Figure 15 depicts the UV-C light sterilizing system.


Fig. 15. Sterilizing the equipment via UV-C light.

F. Food and Medicine Serving System Analysis

A built-in tray is prepared in the robot's hand to serve food and medicine to the patient. It can able to carry a load of up to 2kgs and capable of moving smoothly. Figure 16 represents the food and medicine serving system accomplished by the medbot.


Fig. 16. Serving food and medicine to the patient.

G. Data Storage System Analysis

When medbot measures the vitals of any person, it is automatically stored in its database (in an excel sheet), which can be easily collected or analyzed by the admin or doctor further. Figure 18 represents the database of patient vitals checking.

TABLE IV
PATIENT'S VITAL CHECKING DATABASE

Patient's No.	Temperature	Heart Rate (bpm)	Oxygen Saturation (%)	Time
1	98	93	99	22:10
2	97.9	86	96	22:21
3	98.2	88	95.4	23:10
4	97.6	80	99	23:11
5	99	89	97.8	13:06
6	98	81	94	13:10
7	98.2	100	96.2	13:12
8	98.5	82	92	13:16
9	98.3	88	98.9	13:18
10	98.3	74	95	13:20
11	97.9	77	94	13:24

V. Cost Analysis

Cost analysis is one of the essential parts of the field of project management. Therefore, this cost analysis was planned to determine the expense versus the gains in the project plan.

TABLE V
Cost Analysis of Medbot robot

Component	**Quantity**	**Final Cost (BDT)**
Arduino Nano	2	420
Ultrasonic sensor	1	60
BTS Motor Driver (7960)	2	1000
Raspberry-Pi 4	1	4400
Pi Camera	1	1500
Display	1	3800
Buck Converter	2	60
Bluetooth Module	1	230
Battery	1	4000
Max-30100	1	150
Temperature sensor	1	1500
UV-C Light		500
Gear Motor	4	2000
Memory	1	450
Wheel	4	1000
Speaker	1	230
Microphone	1	720
PVC Board	1	1700
Relay Module	2	90
Nozzle	2	40
Pipe	3m	75
HDMI Cable	1	230
Connecting wire	5m	100
Pump motor	1	360
Total		24,615

From the final cost analysis, it can be seen that to build this robot, a total of 24,615 TK in BDT will be required, which is not so expensive compared to other existing robots. On the

contrary, the price based on the functions of of medbot is also less than that of other bots.

VI. Conclusion

The author's primary objective with this research is to develop a low-cost multifunctional medical robot that is accurate. Through hardware implementation, the goal was accomplished by maintaining the prospect. Based on the survey findings, the authors tried to implement a user-friendly medical robot that can simultaneously do multiple tasks like nursing, serving, and sterilizing. It can also work as a receptionist robot that can interact with people through the chatbot. Using the robot, every person related to medical work will be benefited and minimize the possibility of being affected by infectious diseases. A new contagious disease, monkeypox, which is now another outbreak after corona, can also be treated by this medbot. From the survey, it can be concluded that most people were pleased with the idea of making a multifunctional medical robot. It will digitalize the medical sector and play a significant role in creating Digital Bangladesh.

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