Development of a Wireless Surveillance Robot for Controlling from Long Distance

Shahajada Mahmudul Hasan, Syed Mamun R Rasid, Avijit Mallik, Md. Rokunuzzaman

***Abstract*— A robot has been developed which can be used for multipurpose application related to surveillance and security systems. From ground testing of this robot it has been found that it can be controlled from unlimited distance as the system is based on World Wide Web (www). This robot also has a teleoperation system based on radio frequency (RF) for signal processing. It has been found that this robot shows about 78% efficiency when a constant 512 kbps Wi-Fi internet connection is applied. Visual Basic software has been used to operate the robot. Four cameras are attached with the robot for acquisition of images from the surroundings. Vmcap software is used to show all these camera images at a time. The images from the four cameras and the control panel will be transmitted and displayed in the user's monitor. Virtual network computing (VNC) software has been employed for the purpose. By watching the situational images sent by the remote robot it is the user who can control the motion as well as can get the idea of the environment. A GPS (Global Positioning system) device is mounted over the robot to get the satellite image of the mobile robot trajectory of motion and a total track map. This paper describes the methods and scopes of the above-mentioned robot**

***Index Terms*— Surveillance robot, wireless communications, tele operated robot, long distance control, image transmission.**

I. INTRODUCTION

Wireless system has been under rapid development in recent years. Communication without wiring makes a control system very compact and robust. The key feature of this technology is that it reads a signal (Transmitting/Encoding Circuit) and processes it into a wave (low frequency) form which is then sent into a specified signal receiver (Receiver/Decoding) which then decrypt the signal into the previously transmitted signal resulting in a successful wireless data communication [1]. In robotics, this technology is of heavy demand. By applying a wireless signal communication, a robotic system can be made more efficient and compact. Wireless Robotic systems are also less prone to error. They can be applied successfully in the industry, where a very little mistake can make a huge problem. By using robot labor cost of the industries can be reduced considerably. At present many countries use robot in the battle field for assisting their soldiers. Robots can also be used for lifting mine in the war field and can also be used as a perfect soldier. Mobile robots have the capability to move around in their environment and are not fixed to one physical location. An example of a mobile robot that is used commonly today is the Automated Guided Vehicle (AGV). An AGV is a mobile robot that follows markers or wires in the floor or uses vision or lasers [2]. Mobile robots are also found in industry, defense and security environments. They also appear as consumer products, for entertainment or to perform certain tasks like vacuum cleaning. Mobile robots are the focus of a great deal of current research and almost every major university has one or more laboratories that conduct researches on mobile robot. General-purpose autonomous robots can perform a variety of functions independently [3]. These types of robots typically can navigate independently in known spaces, handle their own recharging needs, interface with electronic doors and elevators and perform other basic tasks. General-purpose robots can link with networks, software's and modules that increase their effectiveness. Those gets able to recognize people or objects, talk, provide companionship, monitor environmental quality, respond to alarms, pick up supplies and perform other useful tasks.

Tele-operated robots, or tele-robots are devices which can be remotely operated from a good distance range by a human/programmed operator rather than following a predetermined sequence of movements. Tele-robots are used when it is difficult for human to be present on site performing a specified job as being dangerous, long distanced or inaccessible. Wireless sensors allow otherwise impossible sensor applications, such as monitoring dangerous, hazardous, unwired or remote areas and locations. This technology provides nearly unlimited installation flexibility for sensors and increased network robustness [4]. Furthermore, wireless technology reduces maintenance complexity and costs. When a real-time video camera is mounted on this type of robot can send images instantly to the operation section through internet; which is largely dependent on the internet speed. Internet speed must be high enough to transfer data efficiently. Tele-operated robot plays an important role now-a-day. One of the application of the tele operated robot is that it can be used for space mission like lunar mission, mars mission etc. Tele operated robot is used in the hazardous environment like nuclear radiation area, mining fields where radioactive element exists. At present tele-robot is used in military battle field such as drone which can be controlled from far [5, 6].

Today's internet-based technology provides a convenient way for us to develop an integrated network environment for the diversified applications of different robotic systems. To be successful in real-world applications, internet-based (IoT) robots require a high degree of autonomy and artificial

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Dr. Shahajada Mahmudul Hasan, Department of Mechanical Engineering, Rajshahi University of Engineering and Technology, Rajshahi-6204, Bangladesh

Syed Mamun R Rasid, Department of Mechanical Engineering, Rajshahi University of Engineering and Technology, Rajshahi-6204, Bangladesh

Avijit Mallik, Department of Mechanical Engineering, Rajshahi University of Engineering and Technology, Rajshahi-6204, Bangladesh

Dr. Md. Rokunuzzaman, Department of Mechanical Engineering, Rajshahi University of Engineering and Technology, Rajshahi-6204, Bangladesh

intelligence to deal with the restricted bandwidth and arbitrary transmission delay of the internet [7]. The system derived here has a standard network protocol and an interactive Human-Machine Interface (HMI). Using any web browser, a remote operator can control the mobile robot from a long distance with visual feedback and a simulated environment map via the real-time GPS. The employment of an intuitive user interface enables internet users to control the mobile robot and implement useful tasks remotely. Although at its first stage, the developed system has the potential to be extended to many real-world applications such as tele-manufacturing, tele-training and tele-service etc. [8, 9].
The current available methods are mainly developed around wireless protocols which involve costly equipment's and can transmit only through a limited distance or by using complex software. However, in this project, very renowned and simple 'Visual Basic' software has been used. Furthermore, no sophisticated instruments are used and the whole project is constructed with the materials from local market which are relatively cheap.

II. INTRODUCTION

The trends of robotics research are changed very rapidly in the last decades due to significant changes in information technology. The evolution of new applications of robots and robotic devices are always influenced by the current need of the society. It was around 1960 when industrial robots were first introduced in the production process, and until the 1990s industrial robots dominated robotics research [10]. From this time the development in robotics sector has been increased very rapidly. Cyprian M. Wronka et al., 2006 developed a concept of Internet remote control interface for a multipurpose robotic arm. In their work authors proposed a tele operated model for controlling a robotic arm [11]. Akiyuki Minamide et al., 2007 proposed a distant control robot model where game robots are controlled from long distance through internet. They practically implemented the concept and arranged robot gaming competition between the children of a Japanese school and of a Singapore school [12]. C. Pacchierotti et al., 2015; B. Fang et al., 2015 and S. Chatel et al., 2016 made different researches on teleoperation system for robotics and found great success on respective fields and also describing an available public implementation of an Internet robot controller [13-15]. A. Hiyama et al., 2017 implemented a robotic system for telecommunication by using remote wireless system [16]. L. J. Williams took a patent on a method and system for determining position and/or pose of an object and showed that signal can be transmitted with quite low distortion by applying RF on a moving robotic system [17]. O. Javed et al., 2003; O. Javed and M. Shah, 2008; A. A. Altahir et al., 2018 and G. Verma et al., 2018 published detailed and well experimented researches on applying and controlling surveillance-based robots which are capable of capturing and sending real-time image to a operator MCU with lowest delay time along with high performance output. [18-21]

III. METHODOLOGY

The main method applied in this project was not just to develop a wireless real-time signal transmitting and receiving but also to make a very robust control system which can be helpful to mankind in time of danger or accidents. Part-by-part sequential methodology is discussed below:

- Human Robot interaction: User can interact with robot through web server as shown in Fig. 1. For example, user can designate the destination point of robot and also receive the robot position information through network. For interaction with robot, user can use several kinds of terminals like PC, PDA or mobile phone. Here, web server provides services of human robot interaction.

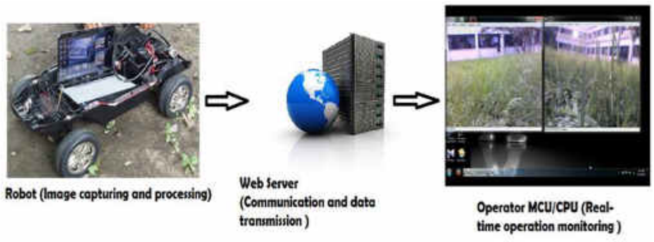

Figure 1. Network-based human-robot interaction

Here, two kinds of network-based human-robot interaction (HRI) services have been introduced, i.e., HRI through web-browser and mobile phone. Fig. below shows overview of network-based human-robot interaction service system.

- Wireless Data Communication: Wireless data communications are an essential component of flexible computing. The various available technologies differ in local availability, coverage range and performance and in some circumstances, users must be able to employ multiple connection types and switch between them. Wi-Fi is a wireless local area network (LAN) that enables portable computing devices to connect easily to the Internet. Cellular data service offers coverage within a range of 10-15 miles from the nearest cell site.
- Parallel Port Data Transfer: There are different types of port used to transfer data between the internal and external devices using different types of cables through peripheral interfaces. The parallel port is a simple and inexpensive tool for building computer-controlled devices and projects. Although being a bit old in manner the simplicity and ease of programming makes the parallel port popular in the electronics hobbyist world.
- Radio Frequency Module (RF) and microcontroller: Radio-frequency sensor is a wireless non-contact system that uses radio-frequency electromagnetic fields to transfer data from a tag attached to an object, for the purposes of automatic identification and tracking.

Figure 2 shows the methodology of the work in brief.

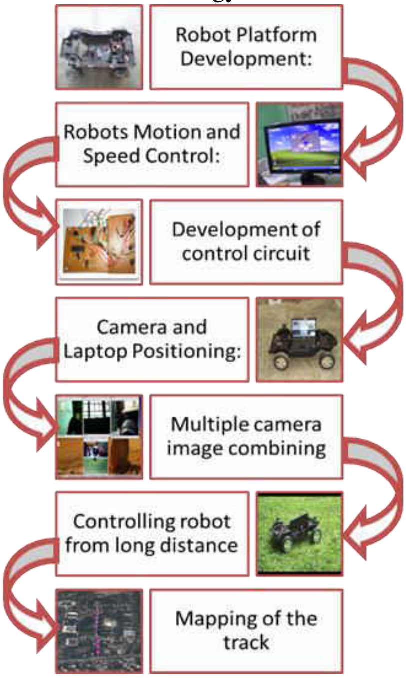

Figure 2: Methodology in brief

IV. DESIGN AND FABRICATION OF SURVEILLANCE ROBOT

For the development of the robot, the first task was to develop a base for the mobile robot. The wheel, steering system and chassis of a rechargeable car (RC) was chosen as the robot base, the controlling circuit is developed as removing the existing car circuit. The car can then be controlled by the computer taking inputs from the keyboard. For controlling the car with a desktop computer having a parallel port, a control circuit has been developed. For communication of data parallel port is used. IC (Integrated Circuit)) TX-2B and RX-2B has been used in the transmitter and receiver circuits respectively. The transmitter circuit with antenna should be kept within the radio frequency range of the robot's motion to be connected with it.

Figure 3. Robot base (including power supply)

The existing steering system is now controlled by the computer keyboard and a robot computer interface circuit is developed. A control panel has been developed by using software 'Visual Basic' and by the four arrows the direction of motion of the robot is controlled. By the four-direction button as indicated in the window below, the direction of motion of the vehicle is maintained. The data transfer will be done through parallel port of the computer. The authors are currently replacing the parallel port data transfer to serial port. If so, the limitations of the existence of the desktop computer within the radio frequency range will overcome and then the robot mounted laptop can be used for the controlling of the robot when the robot will carry the both transmitter and receiver circuit resulting no radio frequency range limitations.

For controlling the car with a desktop computer having a parallel port, a control circuit has been developed. For communication of data parallel port is used. Microcontroller ZYT1AH TR-2B and radio frequency sensor (manually made) has been used in both the transmitter and receiver circuits. The transmitter circuit with antenna should be kept within the radio frequency range of the robot's motion to be connected with it. Fig. 4 depicts a captured image of the developed sensing circuit.

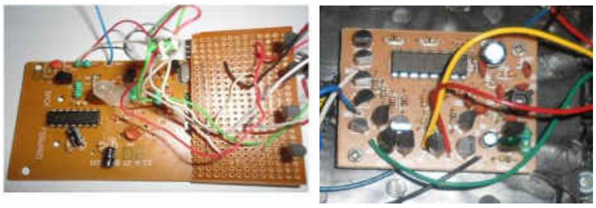

Figure 4. Transmitter and receiver circuit of manually made RF sensor module.

Four webcams are placed front, back, left and right of the robot to get the video images from the surroundings of the robot. Those webcams are placed front, back, left and right of the robot to get the video images from the surroundings of the robot. The four different windows show the different views in the computer screen which is attached with the robot. The acquisition of images is done through Vmcap software. By using the VNC (Virtual Network Computing) software we got the image by communicating between the two computers and transferring the 4 windows on the screen of the robot mounted computer to the distant one.

Figure 5. Fabricated surveillance robot on real-time operation.

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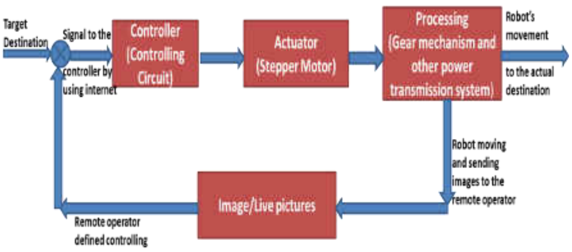
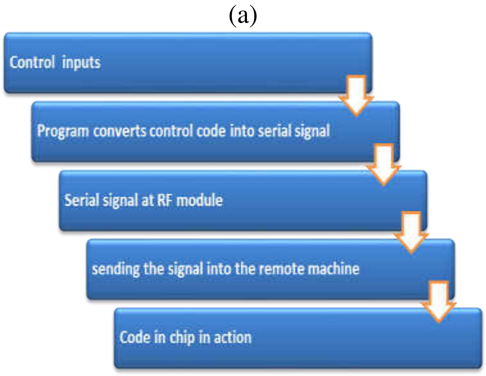
V. Control of the Designed/Fabricated System

Control system of a robotic configuration is the most important part. If there is a very small mistake in control system then the whole configuration can be collapsed in no time. In this designed system when the robot is programmed to reach a certain position and make a surveillance then firstly the program sends signal to the main controlling circuit and then the GPS finds the latitude and longitude of the system via internet mapping and again processes a new signal to the controlling circuit to move the robot to the fixed position which includes the dynamics of the whole system. On completion of the designated task the control circuit automatically sends signal to the webcam section for capturing images of the certain area and then the pictures are send to the monitoring CPU by internet which is located in a fixed position, this work is totally done by radio frequency section and the real-time operation is done. Without any new command from the operator the robot does a quick survey of the area and sends pictures of the area time to time.



(a)



(b)

Figure 6. Control chart of the whole system (a) driving control, (b) signal flow diagram

VI. Performance Evaluation

A. *Image Transmission*

The four different windows show the different views in the computer screen which is attached with the robot. The acquisition of images is done through Vmcap software. Fig. 6 is a representation of real time imaging output on the serial monitor. This image is transmitted to the distant monitor.

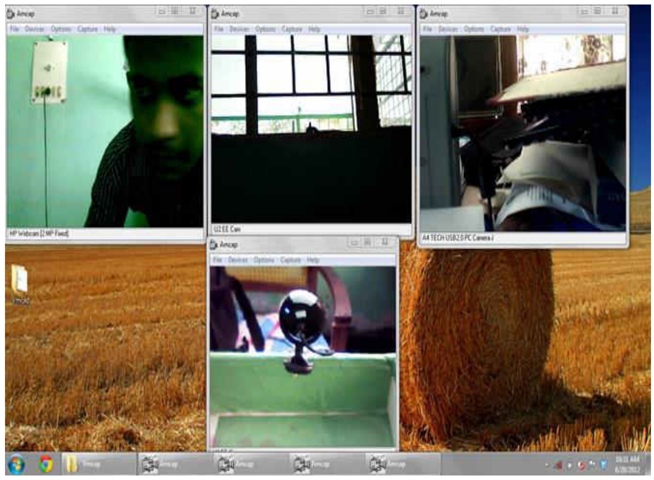


Figure 7. Real-time imaging output from surveillance robot.

B. *Comparison of the captured images*

From this work it is found that the image can be captured from 30 feet distance with A4tech camera. The accuracy of the system is high when the image is transferred with low frame rate but the quality of the images is poor and accuracy decreases with increase in frame rate when internet speed is constant. When internet speed is high image transferring rate is high and accuracy of the system is high, which can be observed from Figure 8. Though some limitation of the system in terms of quick response is not achieved as desired it has given indeed a satisfactory result.

Figure 8. Image quality comparison between mobile robot (left) and operator MCU (right).

C. *Frame/ Image transmission at different internet speed*

Experimenting with the made robotic configuration firstly data transmission rate was checked with different internet speed with a variety of wireless modems available in local markets of Bangladesh. Table 1 and 2 shows the data taken from this experiment. Figure 9 and 10 are respective plots of Frame rate per sec vs Internet speed on Locations 1 and 2. It is observed that the frame rate after transferring the image is quite smooth and also increases.

Location-1: Selim Hall, RUET, Rajshahi, Bangladesh
Date: 25-02-2018 Time: 10:20 AM -12:40PM

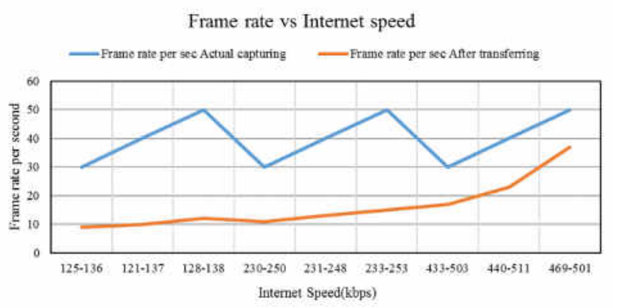


Figure 9. Frame rate per sec. vs Internet speed plot for location 1.

Location-2: Boiler lab, RUET, Rajshahi, Bangladesh
Date: 27-02-2018 Time: 10:30 AM-12:45PM

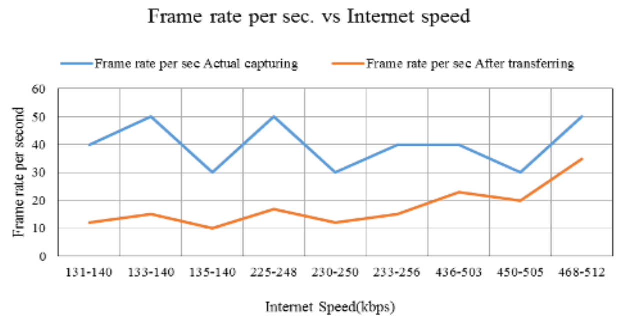


Figure 10. Frame rate per sec. vs Internet speed plot for location 2.

D. Image Transmission Accuracy with different internet speed:

Internet speed is varied by using different internet modems and at a constant internet speed transmission accuracy is measured. From Table 1, it is seen that the transmission accuracy increases with the increase of the internet speed. Fig. 11 is a plot of internet speed vs transmission accuracy.

Table 1: Image transmission accuracy with different internet speed

Internet Speed (kbps)	Transmission Accuracy
131	30
135	33
138	34
230	35
248	37.5
450	57
468	66.67
509	70

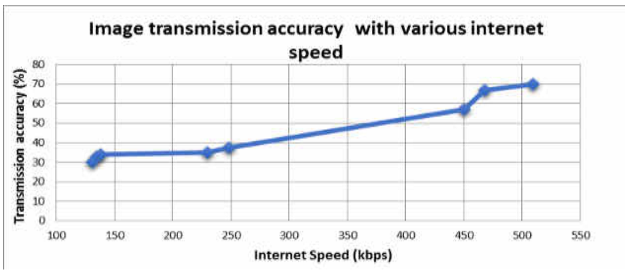


Figure 11. Image transmission vs Internet speed plot.

E. *Variation of image transfer rate with distance.*

From this work it is found that the image can be captured from 30 feet distance with A4tech camera. The accuracy of the system is high when the image is transferred with low frame rate but the quality of the images is poor and accuracy decreases with increase in frame rate when internet speed is constant. When internet speed is high image transferring rate is high and accuracy of the system is high.

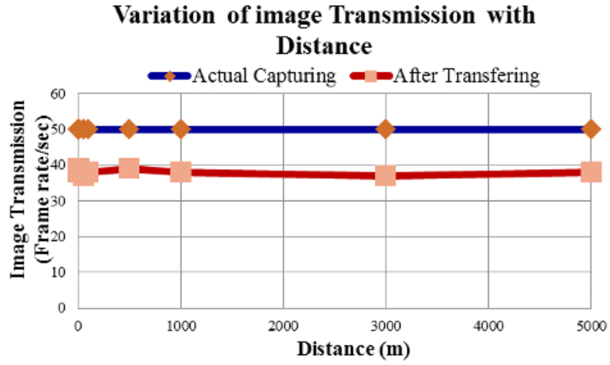


Figure. 12. Distance vs Frame rate per sec.

Data of image transmission is taken by varying the distance and taking the internet speed as almost constant. Various data shows that the image transmission is independent of the distance between the user and the robot. Fig. 12 is the graphical representation of Distance vs Frame rate per sec.

F. Variation of Transmission Accuracy and Transmission Delay with the Processor Speed

Transmission time is computed by a capturer software and it is apparent from the Figure 13 and Figure 14 below that transmission accuracy increases with processor speed while transmission delay decreases with the increase in processor speed.

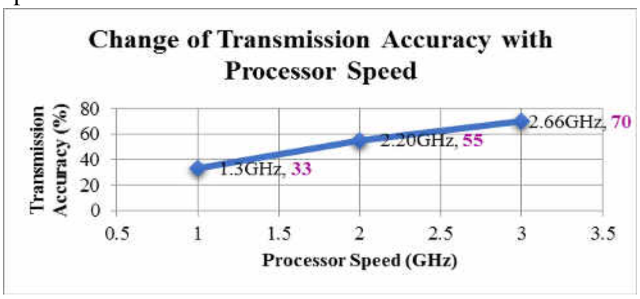


Figure 13. Processor speed vs Transmission accuracy plot.

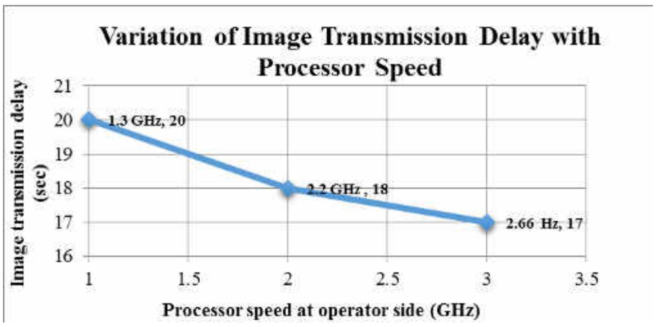


Figure 14. Variation of Image transmission delay at operator side plot.

G. Evaluation of the track Map

For a user of the robot it is possible to control from a good distance in condition of internet connection. In the monitor of the user's computer the real time picture of the surroundings of the robot is seen. We used Map Source and Google Earth software to take the track map of the robot. Figure 15 shows the track map that we have got running the robot from Central Library of RUET to Boiler Lab (around 300 m).

Figure 15. Track map obtained from the robot's movement (from RUET main gate to Central Library)

VII. Results and Discussion

It is apparent from the above result that the accuracy of the system is satisfactory. The minimum accuracy of the system is 24% and the maximum accuracy of the system is 74%. The accuracy of the system is measured in terms of image transmission capabilities. The comparison between actual frame rate that is captured from the surrounding and the frame rate after transmission to the operator determines the accuracy of the system. Distant controlled robot has a huge scope in distant engineering education and distant treatment of patients. Mainly this developed robot can be used in: Surveillance based application, long distance observation of any equipment, device or machinery, control of any process/system from far, observation of office, home, classroom environment, road traffic and security system monitoring, remote image capturing and processing, hazardous environment situational image and control, track mapping for any desired location as well as satellite mapping for further decision making etc.

VIII. Further Development

The research is going on to modify some of the features of the existing robot. The authors are working to change the parallel port data transmission system over the robot with serial port. By this way the requirement of the desktop computer will be eliminated. Due to the unavailability of the DGPS at the instant, authors put the hand GPS over the robot and took the map data by transforming it by data cable. Further updated system will use DGPS system where base station which will be connected with rover GPS mounted over robot may be the computer which is controlling the robot. By this way there will be only two computers used in the model, one over the robot and the other is the controlling computer. Works are also going to use image processing for using the track map to make the robot an intelligent one.

Conclusion

The authors tried to develop a long distance-controlled robot which has a wide applicable range as well as a wide control range. Authors successfully completed to develop the preliminary model and successfully controlled it from long distance with an efficiency of 74% with constant 512 mbps wireless internet.

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Dr. Shahajada Mahmudul Hasan is an associate professor in the department of mechanical engineering, Rajshahi University of Engineering and Technology, Bangladesh. He completed his bachelor degree in the field of Mechanical Engineering from Bangladesh University of Engineering and technology then completed his masters major on Robotics. He has got his P.hD from Saitama University, Japan in the area of Magnetic suspension. His research interest is Electromagnetic analysis, Magnetic suspension, Robotics etc.

Syed Mamun R Rasid is an assistant professor in the department of mechanical engineering, Rajshahi University of Engineering and Technology, Bangladesh. He completed his bachelor degree in the field of Mechanical Engineering from RUET, Rajshahi and completed his M.Sc. in the field of mechatronics from Saitama University, Japan. His research interest includes Robotics, Mechatronics etc.

Avijit Mallik is a Bachelor student in the department of Mechanical Engineering at RUET, Rajshahi. His research interest is in the area of Mechatronics.

Dr. Md. Rokunuzzaman is a professor in the department of mechanical engineering, Rajshahi University of Engineering and Technology, Bangladesh. His research interest in in the field of Robotics and image processing.