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Research Article

Navigation Control of a Multi-Functional Eye Robot

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Abstract: The advancement in robotic field is enhanced rigorously in the past few decades. Robots are being used in different fields of science as well as warfare. The research shows that in the near future, robots would be able to serve in fighting wars. Different countries and their armies have already deployed several military robots. However, there exist some drawbacks of robots like their inefficiency and inability to work under abnormal conditions. Ascent of artificial intelligence may resolve this issue in the coming future. The main focus of this paper is to provide a low cost and long range most efficient mechanical as well as software design of an Eye Robot. Using a blend of robotics and image processing with an addition of artificial intelligence path navigation techniques, this project is designed and implemented by controlling the robot (including robotic arm and camera) through a 2.4 GHz RF module manually. Autonomous function of the robot includes navigation based on the path assigned to the robot. The path is drawn on a VB based application and then transferred to the robot wirelessly or through serial port. A Wi-Fi based Optical Character Recognition (OCR) implemented video streamingcan also be observed at remote devices like laptops.

Keywords: Eye robot, artificial intelligence, UGV, optical character recognition, auto and manual navigation

1. INTRODUCTION

The speedy and extraordinary advancement in the field of robotics is exceptional from the last few decades which causing the scientists overthink to design such reliable and power efficient robots. In areas, where humans can’t approach, robots can reach. Military robots provide the facility of bomb diffuser or weapon carriage. An unmanned ground aerial vehicle can give a "birds-eye-view" of territories of military troops. MIDARS [1] is a four-wheeled car type robot, which has few cameras, radar and a firearm. It is used for preprogrammed or random patrols across a military base and other government installations. If it detects any kind of movement in unauthorized areas, it generates alarms. The remote instructor can then command the robot that it can ignore the interrupt, or handle the intruder itself. In emergency conditions, it can also provide camera manipulations and views.

Canadarm or SSRMS, a Space Shuttle Remote Manipulator System [2] is an example of robotic arm which has multi degree of freedom. The special function of this robot is to perform inspections of space shuttle using a specially deployed boom with sensors and cameras attached at the end effector, retrieval maneuvers from the cargo bay of space shuttle and satellite deployment. The hardware of Canadarm proves the significance of robotics in Space missions as shown in Fig. 1.

Fig. 1. Canadarm space terminal [2].

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The Curiosity rover is depicted in Fig. 2 [3], sent on planet Mars has a robotic arm mounted on it. Such robots are specifically designed for space exploring missions, inspection of the land of different planets and for the coverage of space complexities.

Fig. 2. Curiosity rover on planet Mars [3].

In the near future, evolution of Military and Space robots will ensure the facilities like the applications of medical robots. These robots would be able to help in carrying the deceased and wounded soldiers off the battlefield and also will be able to use as prosthetics for troops who are injured and have their limbs amputated.

Multifunctional Eye Robot is basically a type of advanced unmanned ground vehicle (UGV). In a broader sense, it can be any piece of mechanized equipment which can be classified as follows:

Modes of locomotion
Types of control systems
Intended operating areas range

The idea of this project is to develop and design such a UGV explained above. The scope of this project is not restricted in only domain, as it can be deployed in various environments like reconnaissance, search and rescue, border patrol and surveillance, active combat situations, stealth combat operations and many more. The equipment used in it is safe to handle, less costly, reliable and efficient. The cost of fabricating a UGV is approximately $90-100. This is much cheaper than commercial models which are mostly above $300 for the whole working system. This project, however, is only a proof of concept product that is able to complete as many objectives as those commercially available UGVs can and therefore if we consider the price of UGV, it is reasonably acceptable.

The rest of the paper is divided as follows: Section 2 describes the unmanned ground vehicles (UGV), Section 3 covers the design features of the multifunctional eye robot, Section 4 describes the hardware deployed, Section 5 shows the schematic diagram and prototype of the robot, Section 6-7 illustrate the automatic/manual control of the robot and Section 8 concludes the paper.

2. UNMANNED GROUND VEHICLE (UGV)

UGVs like the under discussion robot, find their applications in modern robotics, power plant inspection, space missions and military. The first ever UGV introduced in the world was the USSR developed Tele-tank, which was a machine gun-armed tank type robot. It was controlled by radio from another tank, which was used against Finland in a war. The British developed their tanks in 1941, which were the radio controlled version of their Infantry Tanks known as “Black Prince” robot. So far, several studies for designing UGVs in modern robotics have been reported [4]. Smuda et al. [5] provide vast information about the use of Stereo Vision used in UGVs for the effective working at the time of night. The work is first to show that the stereo vision could also be practical in UGVs because of its non-emissive, non-scanning and non-mechanical properties. Matthies et al. [6] show the significance of Distributive Architecture for Mobile Navigation (DAMN) UGVs. DAMN provides the feasible solution of a robot to follow path and avoid obstacles by sending votes to a command arbitration module. Asynchronous actions are performed by the system and it is responsible for sending its output to the arbiter at particular speed for that specific action. Herbert et al. [7] shows the Velocity transformation techniques used in MUGVs (Military Unmanned Ground Vehicles) and control of direction and driving velocity. The work shows quite resemblance of these UGVs with the project but the new thing is to ensure auto navigation of the robot by development of App. It's like machines (computer or laptops) controls machines (robots).

Some of the major advantages of UGVs that have made them so popular and significant part of each country's defense strategy today are;

Safety
High access
No loss of life
High speed

The applications of UGVs emerge in any core of military and civil areas are shown in Fig. 3. Currently, Army and Navy are the largest users of unmanned ground vehicles, while Air Forces are making drones that can be controlled or may work more efficiently, it operated in autonomous mode. The threat of encountering chemical and biological weapons in World War III conflicts continues which makes the use of advanced UGVs more significant.

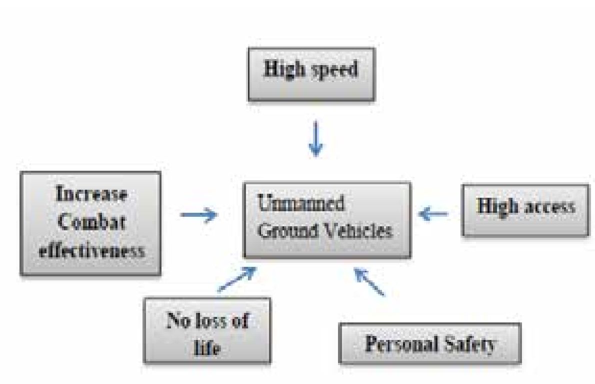

Fig. 3. Diverse and vast advantages of UGVs.

3. DESIGN FEATURES OF THE ROBOT

This paper presents a low cost valuable hardware module for the navigation of a robot in both Autonomous and Manual ways and long range efficient control with video streaming as well as surveillance. It also provides the basic idea of OCR using Multithreading The principal design features of the hardware module are summarized as follows:

It is cheaper and flexible design as compared to the other military robots.

The system can be ungraded under the need and support of advanced robotics techniques. OCR techniques can be improved and made more efficient. Although the response time of robot is already fast but with the availability of strong internet, it can be further improved.

It is flexible and dynamic design.

Battery provides almost 30 to 45 minutes backup. Robot is operated on very low power for its all operations.

All types of alarms or any other interrupts generated by robot can be incorporated and monitored from any location.

In the design of robot, following techniques have been deployed.

3.1. Spy Camera

A camera of common Android based cell phone is used for the video streaming and spying purpose. Its function resembles as Close Circuitry Television (CCTV) networks. Internet-based CCTV flourished in the society due to the expansion of the Internet [8]. The communication channel in the CCTV structure is either wire or wireless network. The crime prevention is now regularly monitored and controlled by the use of CCTV. An application 'CloudCam' is installed in the mobile phone which uses the camera of phone and generates an IP address. Similarly, an application is designed in VB (visual basic) in Microsoft Visual Studio. The IP generated by CloudCam is given to the VB app, and it starts streaming through Wi-Fi and any web browser. This is how, we can monitor the movement of robot or we can use it as spy camera. The basic components for the spying CCTV are the inspection camera of cell phone, image control server for images and video monitoring which is generated by CloudCam, access control server for identification and remote devices like cell phones or laptops.

3.2. SONAR Sensor

Ultrasonic or SONAR sensors are widely used to avoid obstacles. When something, intentionally or unintentionally comes in the path of SONAR oriented robot, what decision it should take? Depending upon the type of hurdle, the programmer must tell the robot that either it should stop moving forward or it should turn left or right. Over the past decade, Autonomous Robot navigation in assistance with Sonar has been the system of research. Initially, Sonar sensor was heralded as a basic and less costly solution of mobile navigation problems, because it enhances the response time and directly gives the range information at user friendly level. However, besides these pros, most scientists would rate the performance of Sonar dissatisfactory [9]. But as far as hurdles detection or distance prediction is concerned, it gives the optimal solution.

3.3. Basic Components

Apart from basic structure, a Robotic Arm is also mounted on the robot which performs drop and carriage functions. Following components are used in the design and implementation of robot:

- Arduino Mega 2560 microcontroller.
- Basic driving tank type structure.
- A Robotic Arm with three degrees of freedom.
- 2.4 GHz 8 channel RF Module (XP8103).
- Orange 9 Channel Receiver.
- Two DC 14V gear motors for driving purpose.
- Relay based H-Bridge circuit for direction control.
- Two DC 14V gear motors for Robotic Arm movement.
- A Jaw with Servo motor mounted on it for catch and drop.
- Sonar sensor.
- L293D QUADRUPLE HALF-H DRIVERS IC for Arm motors.
- 16x2 LCD display.
- 4 cell 14.8V, 4000mAh, 35-70C discharge Li-Po battery.
- 5V battery bank.
- LEDs, connectors, buttons and other miscellaneous hardware.

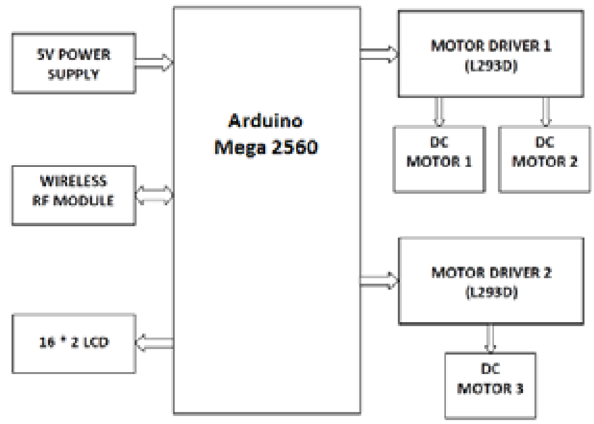

Fig. 4. Block diagram of robotic control unit.

Interfaces of Robotic Arm Unit and microcontroller are shown in Fig. 4. Arduino Mega 2560 works on 5V, while the RF module works on 10.8V, which have a 2.4 GHz frequency range. Physically, for the driving purposes, two DC gear motor are used. These motor work on 14-12V. For direction control, we'll be needing a DC motor driver, which is being designed using relays and Opto-couplers. And to drive the Robotic Arm in multiple directions, we'll be needing a DC motor driver IC called as L293D. The IC drives two motors at a time. The IC has an internal protection suit, just in case to avoid the back EMF generated by the motors when they change their directions. Free Wheeling Diodes are also integrated in the circuit which also gives the protection against back EMF. We have used 16x2 LCD which can be used to check the output of different modules that are interfaced with the microcontroller. Thus, for the better optical vision of the project, checking command lines, and monitoring the output of different modules, LCD plays a vital role.

4. HARDWARE DESCRIPTION

4.1. Arduino Mega 2560 Microcontroller

Arduino Mega 2560 board (Fig. 5) has been featured as the main microprocessor board in this project. It is an open source electrically configured environment, which is based on user friendly and easy-to-use hardware and software. It is basically used for different sensors by controlling lights, motors assembly and other actuators. It has the following specifications:

- ☐ 5V Operating Voltage
- ☐ 8kB Static RAM
- ☐ 256kB Flash Memory
- ☐ A/DC and D/AC Functions
- ☐ 70 I/O Pins
- ☐ 40 Digital Pins
- ☐ 14 Pins with PWM as Output
- ☐ 16 Analog Pins

Fig. 5. Arduino mega 2560.

4.2. Robotic Arm Assembly

The base of the robotic arm assembly (Fig. 6) is made of aluminum metal while the other part of the arm is made of acrylic material. The robotic arm has a two-fingered gripper hand at the end. The robotic arm has 3 degrees of freedom in it. Two degrees of freedom (at the shoulder part and at the elbow one) have simple brushless DC motors for their operation, while, the gripper hand is controlled through a servo motor [10].

Fig. 6. Robotic arm assembly.

4.3. RF Module and Orange Receiver

A 2.4 GHz, XP8103 radio frequency module (Fig. 7) is used to control the movements of robot and the robotic arm assembly. The module used has a vast operating range of about 2-.5 kilometers and is being used to control 9 channels at maximum. Its operating voltage are 10.8 V. The module acts as information transmitter for communication of signals. A multi-voltage charging adaptor is with this module as an accessory.

Fig. 7. 2.4 GHz RF module.

An Orange receiver (Fig. 8) is used for communicating the channels of RF module with Arduino microprocessor board. The receiver used can control at a maximum of 9 channels. Orange Rx is manufactured using the PCBs which have same impedance with signal stability facility and long range scenario which is advanced as compared to previous products.

Fig. 8. Nine channel orange receiver.

4.4. Battery

A Li-Po (Lithium Polymer) (Fig. 9) is a pouch format battery with rechargeable capacity of lithium ions. These batteries come in a soft package which no matter lacks in rigidity but makes them lighter. The main battery source used in this project is the 14.8 V rechargeable Li-Po (Lithium Polymer) battery. It has 4 cells in it that give a cumulative voltage of 14.8 V. This battery has about 4000 mAH current producing capability.

Fig. 9. Li-Po battery 14.8V.

4.5. H-Bridge Driver circuit and L293D Driver IC

Basic H-Bridge circuit (Fig. 10) is shown in the following figure which is designed by using relays, transistors and opto-isolators. The bridge is used for the two ways driving purpose of motors.

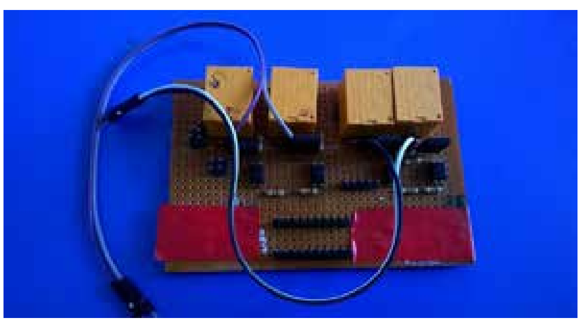

Fig. 10. H-Bridge circuit using relays.

The L293D is a quadrature half H-bridge driver IC (Fig. 11). It is designed to provide bidirectional current of 1A and the voltage ranges from 5V to 36V [14].

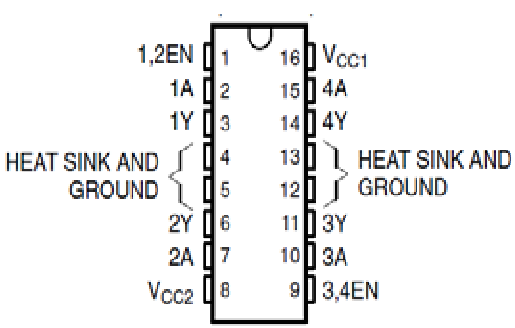

Fig. 11. Driver IC L293D.

5. PROTOTYPE AND DESIGNED CIRCUITRY

The Proteussimulation or the schematic diagram of the project is shown in Fig. 12. The assembling is in such a way that the main control unit or the brain of project is Arduino Mega 2560, which manages all the signals.

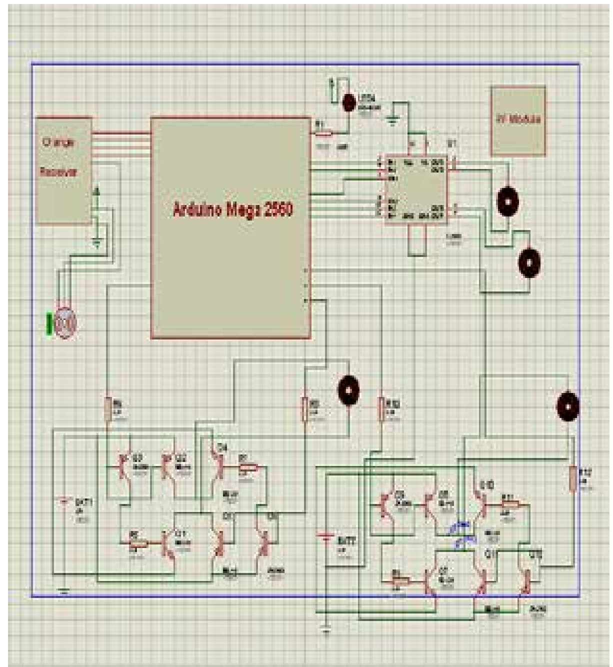

Fig. 12. Drive control circuit for robot**.**

The status of the hardware can be visualized with the help of different LCD mounted on the structure. LCD gives the indication of different types of communication and certain action or response by the microcontroller. A complete assembled robot looks like as in Fig. 13.

Fig. 13. Multifunctional eye robot.

6. AUTONOMOUS FUNCTION OF ROBOT

An application with GUI (Fig. 14) is developed in Visual Basic (VB) which performs the following two major functions.

- First it shows the video streaming through the IP address entered into it, if the IP is correct. Moreover, it shows the machine-encoded text from the streaming by performing its OCR.
- Secondly it has a portion at which the end user can draw a path. The robot follows that exact path in real time which is being drawn on this app.

Fig. 14. Application GUI.
(Optical Character Recognition and Robotic Path)

6.1. OCR Technique

OCR (Optical Character Recognition) is a useful technique, in which, images of typewritten or the printed text is converted into machine encoded text by means of mechanical or electrical approaches. It finds its applications in different fields of data entry like from printed paper data records, passport documents, computerized receipts, business cards, mail, printouts of static-data invoices, bank statements or any suitable documentation. OCR is a vast field of research to recognize patterns, AI (Artificial Intelligence) and computer visions. Different kinds of software are used for the implementation of OCR technique. The libraries of OCR can be found directly on internet like TESSERACT or one can build one's own algorithm.

This technology can be used for the navigation of robot. Robot decisions like either it should move FORWARD or BACK, LEFT or RIGHT, STOP can be manipulated through OCR. To implement this technique physically, we place a signboard in the environment as a landmark to decide the next destination of the robot. This signboard tells the robot to take decisions such as it can perform key functions like, the detection of signboard or its identification.

In power plants or in space fields, where optimization or inspection is required, Autonomous navigation of mobile robots in wide areas requires such different signboards with unique patterns. Colored signboards are also used when there is a clear field of view [11]. As far as military applications are concerned, this robot has pretty much resemblance with RHex – Devours Rough Terrain (Fig. 15 [12]) which has a sealed body, making it fully operational in swampy conditions. This type of robots find their uses in the vast field of military as they are able to be controlled remotely from a control unit. Physical appearance may differ but can be modified according to the conditions. Cameras provide better front and rear views from the robot.

Fig. 15. RHex – Devours rough terrain.

6.2. Path Drawing on the Application

Some autonomous robots, in which human inventions are not necessary, are demanded in various applications like military environment navigation, etc. The robots must be intelligent enough to reach their designed destination. It is a key process to design a proper path for the robot so that it could avoid obstacles and reach its end

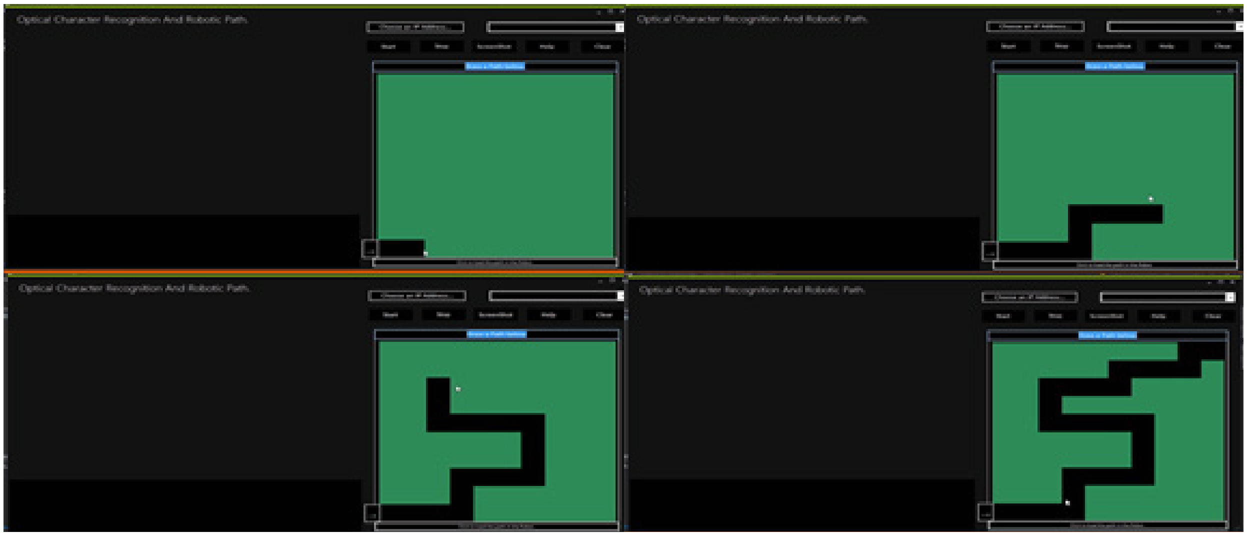

Fig. 16. Drawing a path on OCR app.

point significantly. Thus planning the path carefully is essential in mobile robots as their basic purpose is to find the best shortest and collision-free path up to target point and that must be in accordance of some standards like distance, time and energy. Distance and time are mainly the points under consideration [13]. So keeping that in view, the application is designed in such a way that it has a specific portion at which user can draw any combination of black boxes leading to a correct path and how does the robot follow that path accordingly is shown in Fig. 16.

Application also contains a decoding algorithm which decodes the drawn path and gives the distances along both X and Y axis in numerical values (Fig. 17). These values are then sent to robot and microcontroller then take decisions on the basis of these values that how long the robot should move or it should turn left, right or stop. The path can either be sent wirelessly like through Zigbee Module, Bluetooth or through Serial Port. After the path is sent, the robot starts navigation autonomously, detects hurdles through Sonar sensor and avoid them, take turns according to the decoded path values and streams the video output (Fig. 17).

7. MANUAL FUNCTION OF ROBOT

The robot can also be controlled manually. For that purpose, a 2.4 GHz 8 channel RF module along with a 9 channel Orange receiver is used. The receiver is attached to Arduino board. As long

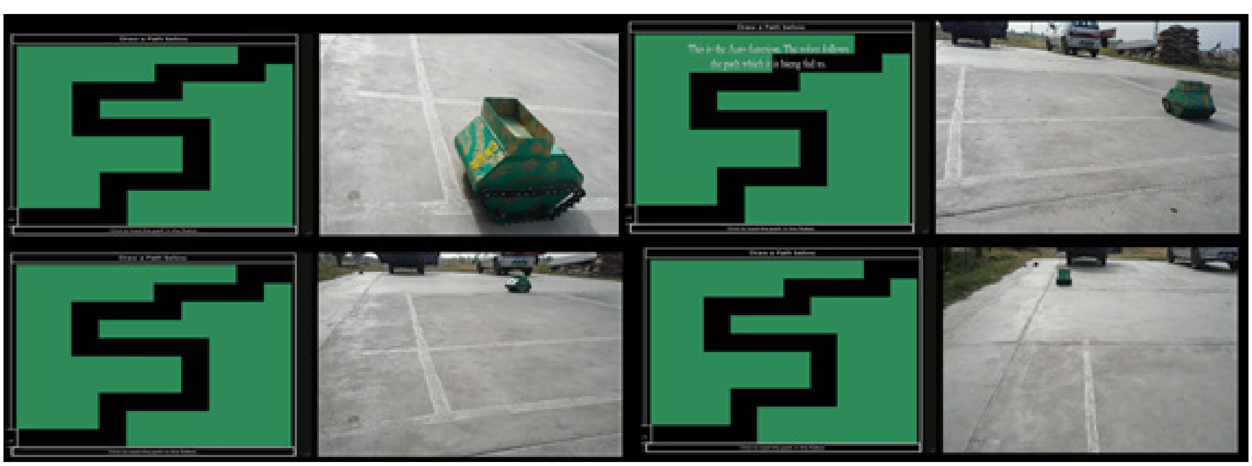

Fig. 17. The robot following a selective pattern of assigned path.

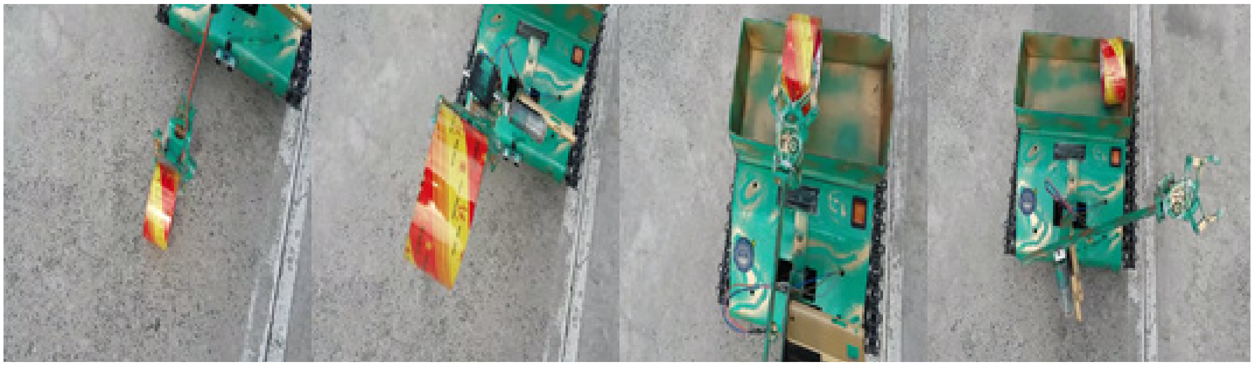

Fig. 18. Movement of robotic arm during Pick and Drop of an object.

Fig. 19. How Cloud Cam works and the output is displayed at the left laptop.

as a signal being sensed on any pin, the robot keeps on moving accordingly. Similarly, all three degrees of freedom of robotic arm (Fig. 18) and camera are controlled via this RF module. The robotic arm moves according to the signals sent by wireless module as explained in Fig. 19.

8. CONCLUSIONS

This paper explains a methodology for the navigation and locomotion of a robot through a path, drawn on an app and fed to it wirelessly. A better and efficient design in modern robotics is the output of this research work, based on Autonomous and Manual navigation of Multifunctional Eye Robot. The OCR deployed video streaming over Wi-Fi (which is carried out using Multithreading in our coding) and long range control over Robot now will reduce the response time in the event of both war or peace and elevate performance of the Space and Military Robots and eventually the profit.

We evaluated the robot through different phases and tests and carried some rigorous and heavy objects through that robotic arm. Additional work is needed to enable the robotic arm to carry heavy objects smoothly. This model is implemented to integrate wireless communication in a wide range robot, which can stream instant video output regarding the surveillance. Video output or snapshots are recorded and observed lately even when the person is cut off completely from the system and having no way to access the system for monitoring purpose. More work is needed to determine the usefulness of these measures.

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