iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 **Issue:** VII **Month of publication:** July 2020

DOI: https://doi.org/10.22214/ijraset.2020.30298

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue VII July 2020- Available at www.ijraset.com

Autonomous Surveillance Robot (ASaR)

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Abstract: India has a very large and complex land border. Thus, managing our borders with effective security monitoring against intrusions, infiltrations and other potential threats becomes a challenging task. This project aims to implement a smart border management system which will overcome these shortcomings and will help in securing our frontiers and safeguarding our nation from the risks involved across the border. The overcoming of this problem will enable us to provide unmanned surveillance at the borders as well as sensitive unattended critical sites, where the site can be remotely monitored such as airports, seaports and industries. The method involves implementation of smart fences which consists of several switches, which gets activated when any force is applied over the fence and alerts the control room. The robot runs over the rail structure which is attached to the fence and is controlled by Raspberry Pi 4 development board. The robot consists of a PTZ camera, a fixed camera, a LiDAR module, a DC motor which are interfaced with Raspberry Pi 4. Finally the target is detected by the smart fence, LiDAR or motion detection using the method of image processing. The robot simultaneously alerts the control room and continuously tracks the target until it moves away from the fence.
***Keywords**: Raspberry Pi 4, smart fence, motion detection, image processing, PTZ camera, fixed camera, LiDAR module.*

I. INTRODUCTION

India has a large, complex land border and shares this border with seven other countries covering an area of approximately 15,106.7 km. In recent decades, a rising trend in smuggling, trafficking, crime, terrorism and illegal migration across the borders has been noticed. As we know border management is a difficult task due to topology and challenging relations with some countries. Surveillance systems provide the capability of collecting authentic and purposeful information and forming appropriate decisions to enhance safety [1]. Video surveillance has a large market as the number of installed cameras around us can show. This work introduces a new classification for smart video surveillance systems depending on their commercial applications [2]. Surveillance robots can provide many benefits like greater efficiency and enhanced safety of security personnel. Thus, the current requirement is a smart border management system which provides unmanned surveillance along with intrusion recognition, detection and tracking.

II. LITERATURE REVIEW

Arjun et al. [3] present a survey of Wireless Sensor Networks (WSN) for Border Surveillance and Intruder Detection. The paper put forth the possibility to design a multi-sensing system to provide effective surveillance and detection of human intruders, for varying border scenarios such as at border areas, dry leaves, and river/pond crossings. For detection of human intrusion different sensors like geophone, microphone, hydrophone, passive infrared (PIR) and camera sensors are discussed. Harish et al. [4] present a paper which provides useful methodology for intruder detecting systems which also provides the behaviour and the activities performed by the intruder. Construction of ontology enhances the spatial and temporal relations between the objects or features extracted. To detect the intruder, ontology and semantic content with the general object tracking methods based on
Region of Interest (ROI) is used. Finally, Semantic Content Extraction (SCE) results in recognising the intruder. Jisha et al. [5] present a system to develop a computer application that will identify moving objects using WSN. PIR sensors which are connected to MICAz sensors are used. The system is expected to detect the moving path, average speed and direction of the human intruder. Sagar et al. [6] present a paper which focuses on implementing a robotic home security system using image processing technique for intruder detection. The robot is controlled using Raspberry Pi via Arduino to which an Ultrasonic sensor, a PIR sensor and a Universal Serial Bus (USB) Web Camera are connected. The proposed system is able to detect faces, signboards and provide notifications to the user if any intruder is detected. It can be used in real-time monitoring and data transmission from remote location. Dushyant and Dharmender [7] present an automatic intruder combat system. It uses features of optical flow information. Use of a simple horizontal feature for fence detection makes system simple and faster to work in real-time. At the time of intrusion, relative position of the intruder with respect to the fence is checked and suitable action can be taken. If the intruder crosses the fence auto-firing can be also activated. Jianhua et al. [8] present a method to detect moving target using the technique of background subtraction and shadow removal.

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The method is applied for Red, Green and Blue (RGB) colour space. Metrically trimmed mean, Mean Absolute Deviation (MAD) and chromaticity, brightness difference acts as estimators for background subtraction and shadow removal respectively. Deshmukh et al. [9] proposes a system which consists of three layers of lasers, cameras and a central monitoring system. The system heavily depends on extensive use of lasers and consists of three layer of lasers, running parallel behind each other. Background Subtraction, frame differencing and
thresholding are used for intrusion detection. Finally, a Global System for Mobile communication (GSM) module is used for sending notification to the end user. Ghanem et al. [10] presents a Raspbian operating system based spy robot platform with remote monitoring and control algorithm through Internet of Things (IoT). This IoT application is developed by python, Hyper Text Markup Language (HTML) and Javascript. The spy robot system comprises of Raspberry Pi, night vision pi camera and sensors. The information regarding the detection of living objects by PIR sensor is sent to the users through the web server and pi camera captures the moving object which is posted inside the webpage simultaneously. The user in the control room is able to access the robot with wheel drive control buttons on the webpage. The movement of the robot is also controlled automatically through obstacle detecting sensors to avoid collisions.

III. PROPOSED METHODOLOGY

Considering all the existing security systems for detection and prevention of intrusion, we propose a smart border management system which will act as a first responder to any intrusion and other activities like trafficking of people and goods. It will monitor the activities around the border and alert the control station. It will provide us with effective coordination and communication with all security agencies. We think of making use of a robot which will run on a dual-rail structure attached to the fence .The robot will be equipped with the Raspberry Pi 4 development board, a fixed camera, a Pan-Tilt-Zoom (PTZ) camera, a 12 V DC motor and a laser scanner (LiDAR). All the movement of the robot and working of cameras and the laser scanner will be controlled by the main development board. The cameras and the laser scanner will help in providing the control room with live feed and also will help in motion detection of any subject or intruder in the environment.

We also propose a smart fencing system which will increase the security if the robot is unable to detect activities as the robot will be in constant movement across the perimeter. The fence if touched by any subject will then get activated and the signals from the fence will be given to the development board which will alert the control station.

The robot will be running on a dual-rail structure attached to the fence by using pulley's which will be rotated with the help of a 12V DC motor controlled by the development board. If any intrusion is detected by smart fence, the signal will go to the development board to move the robot to the site of intrusion. Actions then can be taken accordingly by the control room to send the security forces or detecting just a false alarm. The robot will be powered by a 12V battery which will be placed inside the inner section of the robot.

IV. SYSTEM DESIGN

A. Robot Body

The robot body is divided into sections for placing various components. The interior part of the robot body was designed using SolidWorks and the exterior part was designed based on stability factor of the robot on the rail. The design is done such that the robot body can handle weights of the components like battery, motor, shafts, pulleys**.**

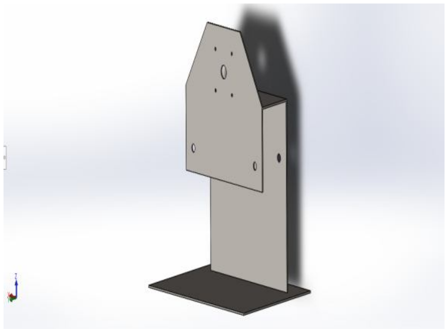

Fig 1: Design of Interior part of robot body using Solidworks

B. Pulley

The pulleys which will slide on the dual-rail structure were designed in SolidWorks and were manufactured on the lathe machine. The material used for fabrication was Nylon. We used Nylon pulleys instead of Metal pulleys since we required pulleys which were large in size so that we could slide the robot on the rail structure and since Nylon pulleys have less weight compared to the ordinary Metal pulleys which in turn reduces the robot weight thereby increasing the speed with which the robot can move.

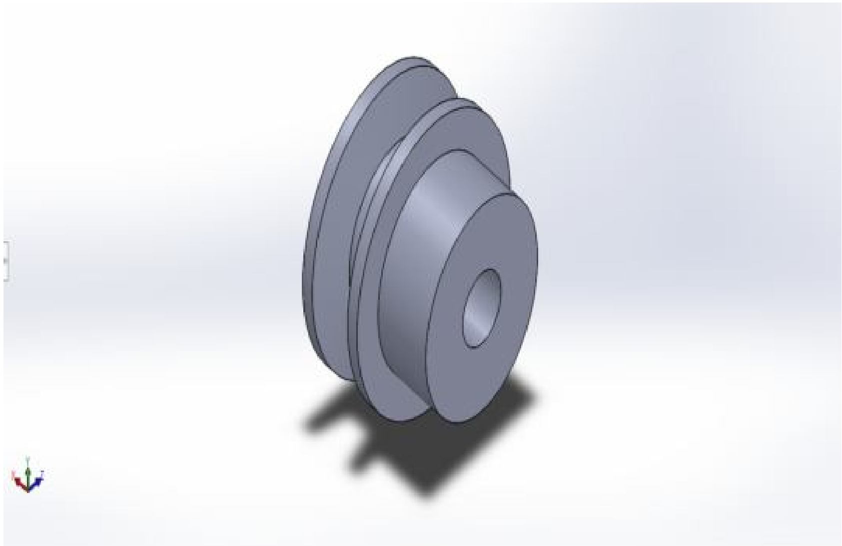

Fig 2: Design of Nylon Pulley using Solidworks

C. Smart Fence

The smart fence is equipped with switch which acts similar to a Single Pole Double Throw switch. SPDT switch has a single input and can connect to switch between 2 outputs. Any force applied on the fence will cause the switch to oscillate. During oscillation, the switch will come in contact with the ground plates and produce current signal which will be sent to the Raspberry Pi.

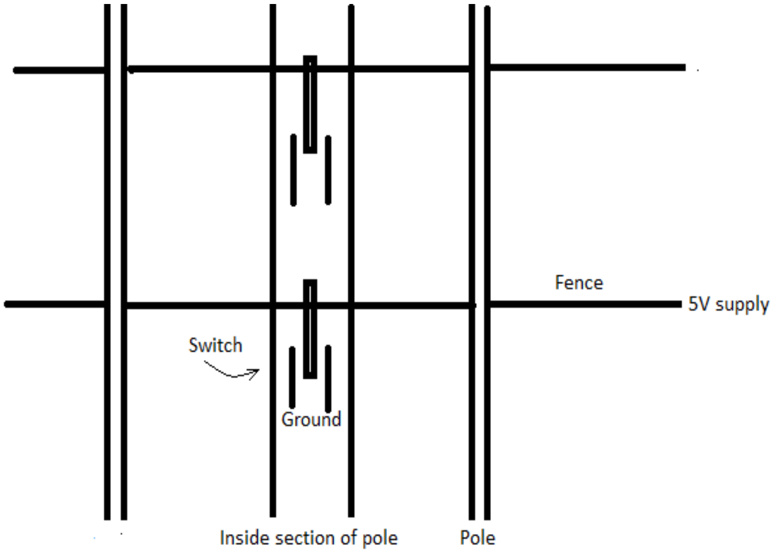

Fig 3: Smart Fence Switch

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
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D. Internal Circuitry

Various components like L298N motor driver, 12V DC motor, fixed camera, PTZ camera, Lidar module are interfaced with Raspberry Pi 4 for intrusion recognition, detection and tracking.

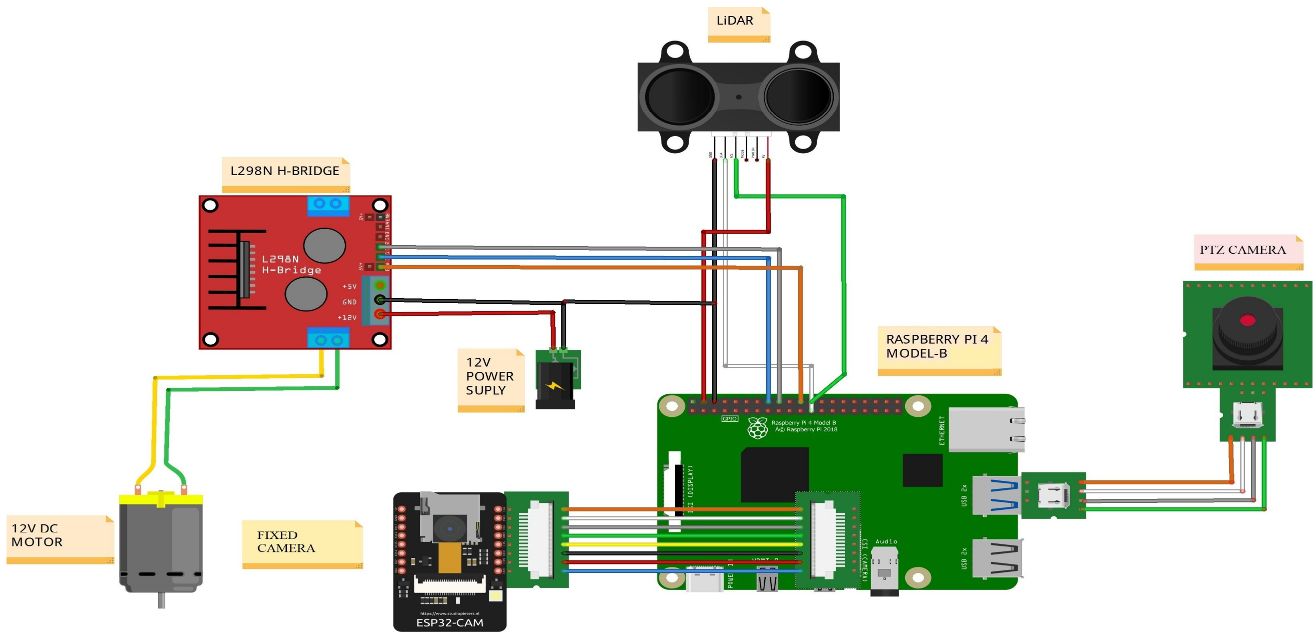

Fig 4: Internal circuitry of the robot

V. IMPLEMENTATION

A 3D model of the robot body was designed using Solidworks, for the purpose of balancing the robot on the rail, visualising the correct shape of the body for placement of components and dimensions of construction. The body is implemented such that it can balance on the rail holding necessary components.

A. Proposed Block Diagram

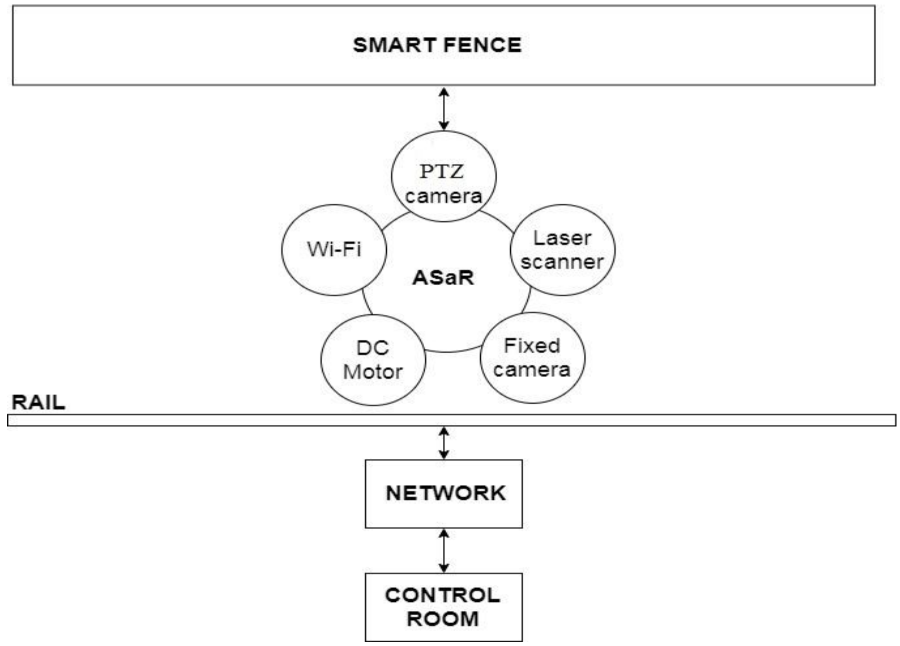

Fig 5: Block Diagram

B. Working

The robot is powered by a battery, which travels along a rail, which is attached to the smart fence. The Wi-Fi module ensures constant connection between robot and control room. The fixed camera and the PTZ Camera are equipped with IR Illuminator which is used for threat verification. Also the images and video captured by the cameras undergoes image processing for clear and better images and videos. LiDAR is used for detection of the target, and to monitor constant changes across the fence.

C. Flowchart

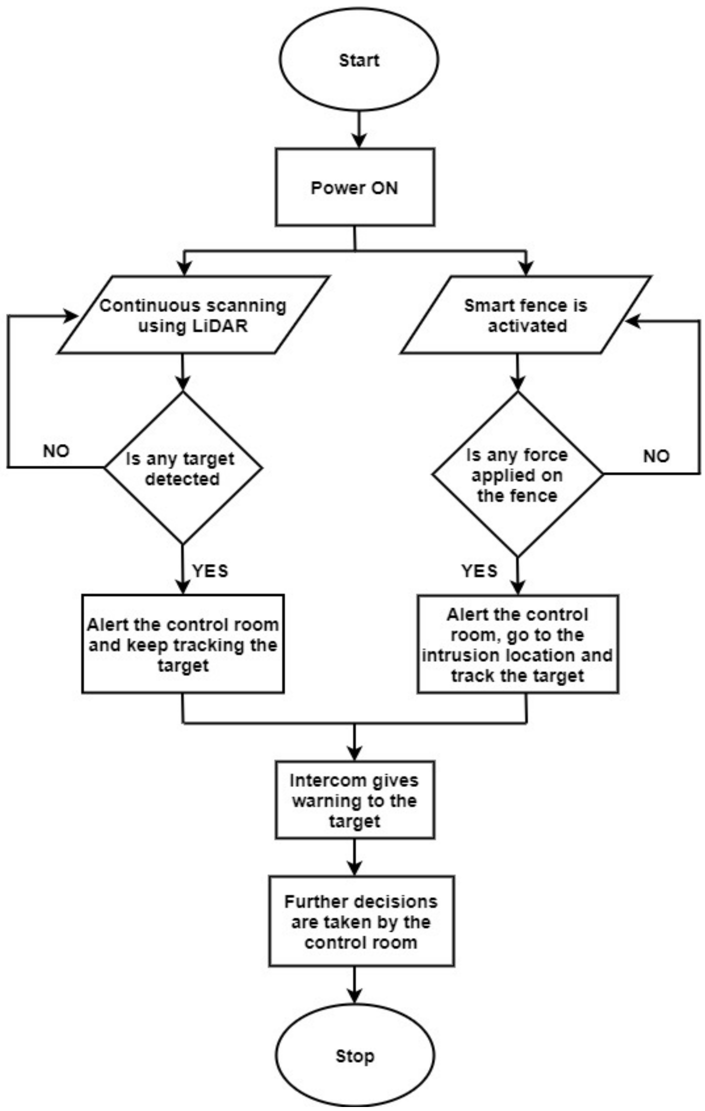

Fig 6: Flowchart

As soon as the robot is powered using the battery, the robot starts sliding on the dual-rail structure, scanning the fence and two operations starts simultaneously i.e.

1) *Continuous scanning using LiDAR*: While scanning the fence the robot checks if any target is detected or not using LiDAR. If any target is detected the robot alerts the control room and keeps tracing the target else it keeps scanning the fence.
2) *Smart fence is activated*: As the smart fence is activated, any force applied on the fence will give an alert of intrusion to the control room. As soon as force is applied on the fence the intrusion location is traced and the robot moves towards the intrusion site.

For both above actions further decision will be taken by control room.

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VI. RESULT

A. Motor

After interfacing the motor with Raspberry Pi 4, we could rotate the pulley connected to the motor's shaft. This in turn resulted in the movement of the robot body. The RPM of the motor was good enough to move the robot body.

B. LiDAR

After interfacing the Lidar with Raspberry Pi 4, we could calculate the distance of the object from the robot body, based on the time the laser took to return from the object to the LiDAR module.

C. Smart Fence

After designing the switch of the smart fence, we could send data to the control room whenever force was applied on the fence. As soon as force was applied the switch touched the ground plates and current signal was generated which was transferred to the Raspberry Pi.

D. Camera

After interfacing the cameras with Raspberry Pi 4, we could capture live images and also live streaming was possible.

E. Image Processing

We successfully implemented the method of image processing using OpenCV library to the captured images and the recorded videos in real time which helped us to detect the intruder using motion detection.

1) *RGB Components:* We successfully implemented the RGB colour model. An illustration which shows the captured image along with the red, green, blue components on the screen is shown in Fig 7.

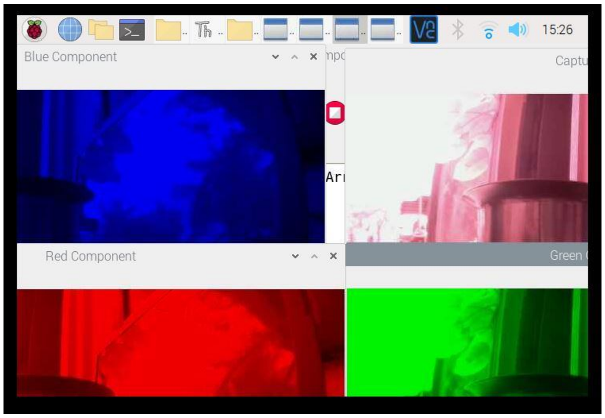

Fig 7: Red, Green, Blue components

2) *Continuous Motion Detection:* We successfully implemented the method of continuous motion detection. An illustration of the captured image and the processed image is shown in Fig 8 and Fig 9.

Fig 8: Captured Image

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Fig 9: Processed Image

3) *Current Motion Detection:* We successfully implemented the method of current motion detection. An illustration of the captured image and the processed image is shown in Fig 10 and Fig 11.

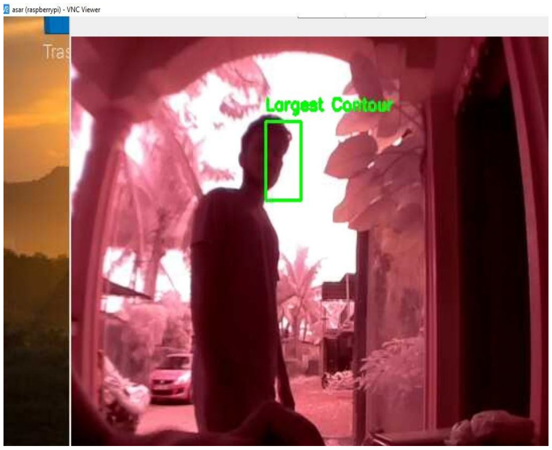

Fig 10: Captured Image

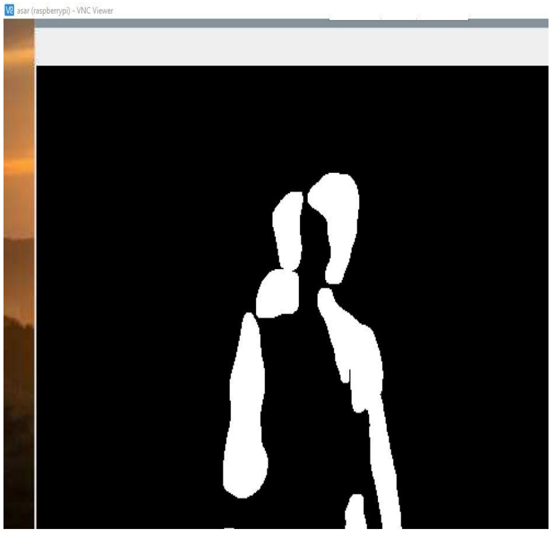

Fig 11: Processed Image

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F. Prototype

After designing the 3-Dimensional model of the prototype, it was successfully implemented. The top section of the body has a camera, a motor pulley attached to shaft of the motor. The centre section has shafts, pulleys, driving pulley connected to the motor pulley with the help of a pulley belt. The bottom section has an inner compartment for holding the battery.

On one of the centre shaft three pulleys are placed. The third pulley and the driving pulley are connected with a help of a belt. As soon as the motor is powered the pulley on the motor starts rotating which in turn will rotate the driving pulley on the centre shaft and help the robot to slide on the rail.

Fig 12: Prototype of the robot with fixed camera installed

VII. CONCLUSION

A wireless automatic outdoor intruder security system was developed which runs on the dual-rail structure and responds to the intrusion alerts. The LiDAR module used for detection constantly monitors the changes across the fence and gives us the accurate distance between the intruder and the robot. The smart fence detects the intrusion whenever any force is applied on the fence. The intruder could be also detected by motion detection using image processing. The 12V DC motor allows us to control the speed of the robot. The robot designed is applicable for security purpose at borders, sensitive unattended critical sites such as airports, seaports, industries, farms and it can be also used in societies. Thus, a smart border management system which provides unmanned surveillance along with intrusion recognition, detection and tracking was successfully designed and implemented.

VIII. FUTURE WORK

We can enable a link for communication between the robot and the intruder by installing an intercom within the robot thus enabling direct conversation between the control room and the intruder. We can also build recharging stations at certain intervals, where the battery would get automatically replaced and will enable the robot to provide continuous surveillance. For safety purpose we can provide Ingress Protection (IP) 68 Enclosures - IP rated as dust tight and protected against complete, continuous submersion in water so that the prototype can be also used in harsh weather. The high definition cameras can be further used for improving the quality of the captured images and videos in real time and long-range LiDAR for detecting intruders.

IX. ACKNOWLEDGEMENT

It is our privilege to express our sincerest regards to our project guide, Prof. Devendra Sutar, Assistant Professor, Goa College of Engineering for his valuable inputs, able guidance, encouragement, whole-hearted cooperation and constructive criticism throughout the duration of project. We deeply extend our sincere thanks to Dr. Krupashankara M. S., Principal, Goa College of Engineering, Dr. H.G. Virani, Head of Department, E & TC Dept. and Dr. Akshay V. Nigalye, Workshop Superintendent, Mechanical Dept. for encouraging and allowing us to present and conduct the project at their premises for partial fulfilment of the requirements for the project. We take this opportunity to thank all our teachers, laboratory assistants and non teaching staff who have directly or indirectly helped our project. We pay our respects and love to our parents and all other family members and friends for their love and encouragement throughout our career.

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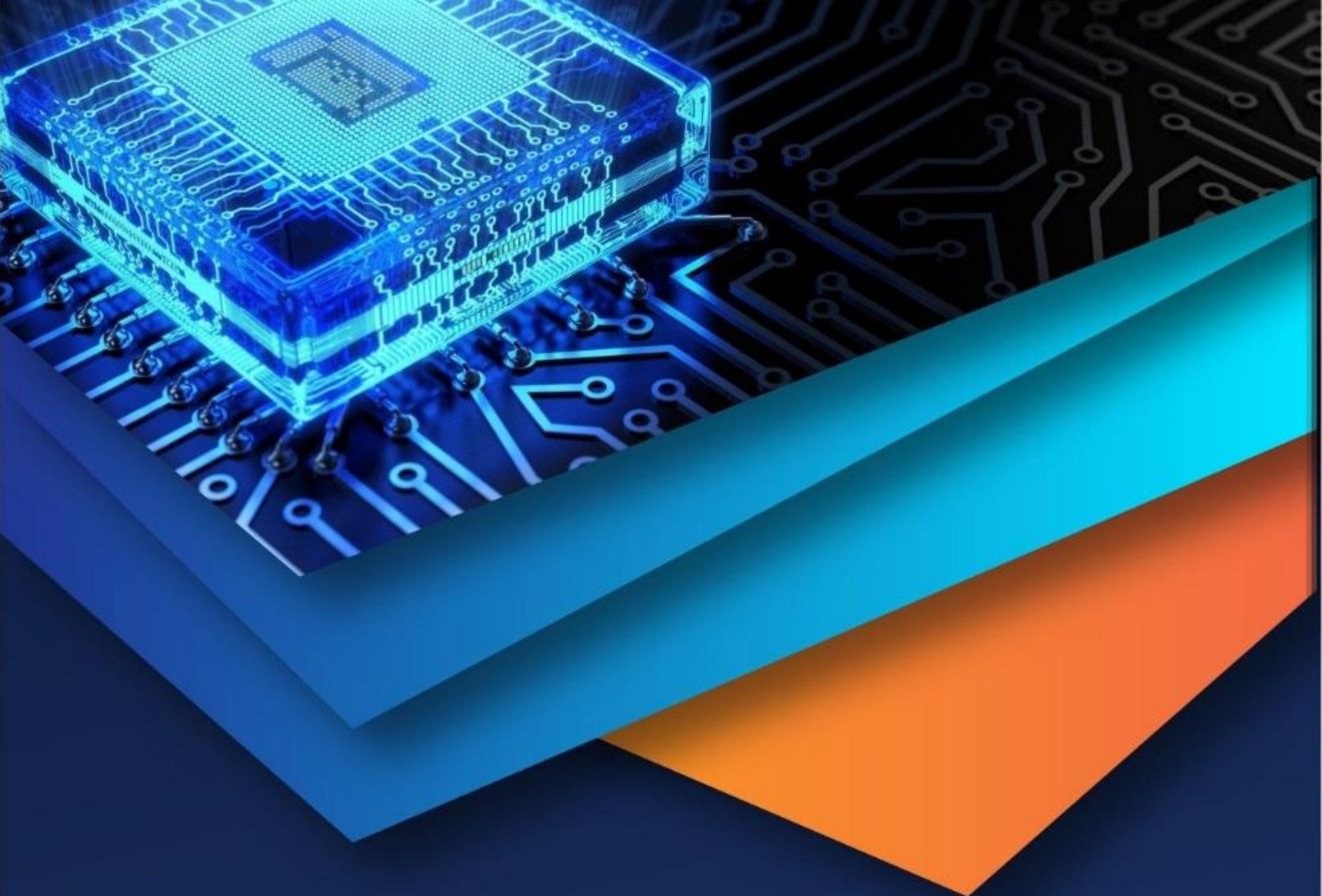

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