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Intelligent Surveillance Robot for Monitoring International Border Security

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Abstract—*Due to the fact that the risk factor in the international border is very high, it causes threats affecting soldiers' lives, border military facility and state security. In fields where there are difficulties for people to go or where human life may be endangered (such as places that contain the harmful gases and explosive things). Human guards may be substituted by a robot system that is designed for the purpose of taking care of the dangerous tasks of surveillance. The main objective of this paper is to build an intelligent surveillance robot with high accuracy to detect intrusions, easy to use and inexpensive. This paper includes a new contribution by integrating intelligent algorithms into monitoring systems and robotics technology, which is a strong addition to the research through the accuracy of the system. The system provides a modern monitoring method for detecting and recognizing faces using a robot equipped with a pi camera, sensors and a control panel. The result of the proposal is a system that uses face detection and recognition by utilizing HAAR algorithm, and CNN algorithm, the system percentage accuracy becomes 99.87%.and the loss is 0.013. The proposed have high accuracy, effective, easy to use, with low cost, can be used to guard critical infrastructures, large facilities, and national borders.*

Index Terms— *Autonomous Mode, CNN, HAAR, Robot, Surveillance System, Ultrasonic sensor.*

I. INTRODUCTION

Nowadays surveillance in military fields is necessary, however, that surveillance's quality is not up to the expectation levels. Soldiers' lives are endangered, which is why, for the purpose of improving quality there has to be a level of the dynamic surveillance. There must be a system that may be mobile anywhere with the effective surveillance [1]. These systems have the ability for interpreting videos, mining information with the use of algorithms of computer vision for extracting usable data like the identities, movements, and event times from raw videos. Biometrics applications require automatic and reliable personal identification for the requirements of the effective application. [2]. Facial recognition is one of the very complex problems, due to of the morphology of the face that could be simply varying within the effect of several factors, such as lighting, posture and speech.

Surveillance may be done effectively by using video transmissions of high-quality. Rather than the exposure of the soldier to the dangerous situations, this paper demonstrates the designed a robot that will effectively do the same job [3]. This paper is concerned with developing a mobile robot that has the ability to capture the real-time images and videos for the surveillance. Robots can go beyond the enemy lines and get their identities and secrets for the added tactical advantages for its user. The main robot factor is its Mobility and the fact that it must surpass the current hurdles in mobile robotics area.

The surveillance robots are designed to be multi-tasking, feasible and cost efficient machines, which may be carried out for military purposes. Those machines substitute soldiers and the army dogs that are utilized at borders throughout war times, saving lives from enemy forces and from the environmental conditions, like the extreme heat and cold [4]. Which is highly significant due to the

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fact that it is offers reliability and privacy on both sides. It was authenticated and encrypted on the recipient side; which is why, it can only provide the individual that is concerned to view details [5].

II. RELATED WORK

Several earlier related studies have been chosen:

a. In 2016, S. A Joshi, A. Tondarkar, et al [6]. They have suggested a new surveillance approach at borders or remote areas utilizing the multifunctional robots that have been based upon the current IOT that have been utilized in the military and defense applications. Those robotic vehicles had the capability for substituting soldiers at the borders for the purpose of providing the surveillance. This multi-sensory robot has been deployed for the detection of the presence of the enemy, capturing it on camera and giving live streaming to authorized persons. The surveillance has a fundamental impact while working on the border area, which is why, there is a robot that can be used for the surveillance purposes. there is a robot that can be used for surveillance purposes Such a smart surveillance robot has been utilized for military applications using the Raspberry Pi. Raspberry pi programming has been performed using python programming. Experimental results have shown that video has been streamed up to 15frame per second.

b. In 2017, H. Kavalionak, and C. Gennaro [7], presented systems of Video surveillance became indispensable way for security and organization of the private as well as the public areas. Most current commercial systems of video surveillance are dependent upon a conventional client/server model to perform object and face recognition. In this study, the authors have proposed an innovative distributed protocol for a system of face recognition, utilizing the surveillance devices' computational capabilities (in other words, the cameras) for performing the recognition of persons. With the use of the simulations, they have shown that their algorithm has the ability of reducing up to 50% of load from server without any adverse impacts on the quality of the surveillance service.

c. In 2017, Z. Shaikh, et al [8], they present in this suggested model also has the ability to capture the real-time images, audio and video for the purpose of providing the surveillances for particular area or individual. A processor of Raspberry Pi is utilized to control the robot through a ZigBee network for uninterrupted processing and transmission of the data. This robot has been found beneficial for the applications of the military area, such as monitoring an area or an individual of interest, providing tactical advantages in the hostile grounds or throughout the hostage situations. It has the ability to walk on different surfaces and providing the monitoring over an area by the use of the image processing that has the ability of analyzing and manipulating a digitized video or image. The suggested system includes one unit, which will have the capability of monitoring the Environment for a variety of the dangerous conditions and providing the video feedback.

d. In 2018, M. F. Alvi, et al [9]. Have suggested in their paper a surveillance robot Robot-cop that has been controlled by the use of a web-page and may be remotely accessed. The Robot-cop is a surveillance robot type that was modeled for capturing and monitoring environment via the provision of a live video stream, eliminating the necessity for a human after being thrown at a place and has the capability of covering the rough terrains too. It has the ability to withstand shocks and pressures during work or falls from a specified distance and has the ability to balance its position in the event of landing in the wrong direction. In the areas where there is a difficult for the humans to go or where human lives may be endangered, the Robocop may be utilized. By testing, it has been concluded that the Robocop has the ability of bearing pay load of about 12KGs. These surveillance robots have numerous different applications and may be deployed in military, civilian security, and human rescue.

e. In 2019, P. S Suryavamsi & A. A. Selvakumar [10], have presented a user friendly and smart surveillance robot, capable of overcoming the disadvantages of traditional CCTV (closed circuit

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television) approach. That obstacle avoiding robot has an ability of monitoring the whole house status, whereas the resident has been away, detecting the presence of the gas leakages or burglars from the LPG (liquefied petroleum gas) Cylinders. The robot design includes transmission of monitored data to Thing-Speak IOT (internet of things) Cloud Server as well, from where resident can receive instant emails in a case of hazardous situations that are detected by this robot. The aim of this robot is monitoring a house, however, it may be utilized as well at other places such as the offices, factories, and so on. Which is why, this robot has been designed to be user friendly and support the real time monitoring, which may be beneficial for the general tasks of the surveillance.

f. In 2020, Ahamed Yasar Z, Dinesh Kumar R and other [11], they put forth a bogus argument, and explains what a border monitoring system is. Computer vision is utilized to do this. A camera, a Raspberry Pi, an Arduino Uno, and a Buzzer are all needed. The live movements are documented with the use of a digital camera. Open CV (computer vision) software detects positive and negative objects and faces using the obtained information/records as an input on the raspberry pi. Any time the pi module detects an object or face that isn't quite right, a signal is automatically transmitted from the pi. It is possible to send an arbitrary signal to a central authority or monitoring room.

III. CONTRIBUTIONS

The significant Contributions of this proposed system are:

- This study presents a powerful proposal that contributes to the discovery of illegal entry into the country or any large infrastructure.
- This proposal can be used by the Ministry of Defense, interior or student monitoring, any other places that need monitoring, home border monitoring and any other building for the purpose of securing the state's border and reducing the human energy on the borders.
- In this proposed system, some changes were made in the CNN algorithm, where the mask size (32*32) to reach the maximum accuracy and increase number of epochs to 500. And HAAR cascade algorithm by split the features into small rectangle.

IV. SURVEILLANCE SYSTEM OPERATION

The abovementioned surveillance system operation includes the steps below:

Step1: at first, a digital surveillance camera provides the input to controller module.

Step2: concerning the design, the 1st objects have been detected in live video. Which can be done through the use of the software tools like the python and open-CV. Through importing important library files, several known objects in a frame may be detected.

Step3: throughout the detection of objects, in the case of detecting any individual, then the face recognition is performed.

Step4: In facial recognition, the face that is detected will be matched with pre-trained / loaded images (or) faces. The size of datasets may be thousands of facial images.

Step5: in the case where the captured face has been known, no more initiatives should be taken, the live video continues. However, in the case where a face has not been known, at receiver's end, an alert signal is generated. Which is performed with the use of the receivers and transmitters. Those are steps involved in the following project of surveillance system.

V. PROPOSED SYSTEM

The aim is to make an intelligent surveillance robot system using Raspberry Pi along with a PIR (Passive infrared sensor) and ultrasonic sensor and Raspberry Pi-Camera and dc motors. The idea is integration of these devices with artificial intelligence algorithms, which is one of the modern ideas in building intelligent robots.

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A. Robot Movement

The ultrasonic sensor is used to avoid obstacles, it has been noticed that if in the case of detecting any obstacles through condition distance less than 60 cm it stops and turns right and starts moving in that orientation, and in the case where there has been an obstacle on the right it turns left and starts moving in that way and in the case where there has been an obstacle on all of the sides then it goes back to the previous direction depend on the condition (>60 cm). The PIR sensor is used to detect the motion whenever someone comes within its range. The PIR Sensor detects the motion of the object. *Fig. 1* illustrates the flowchart of robot movement.

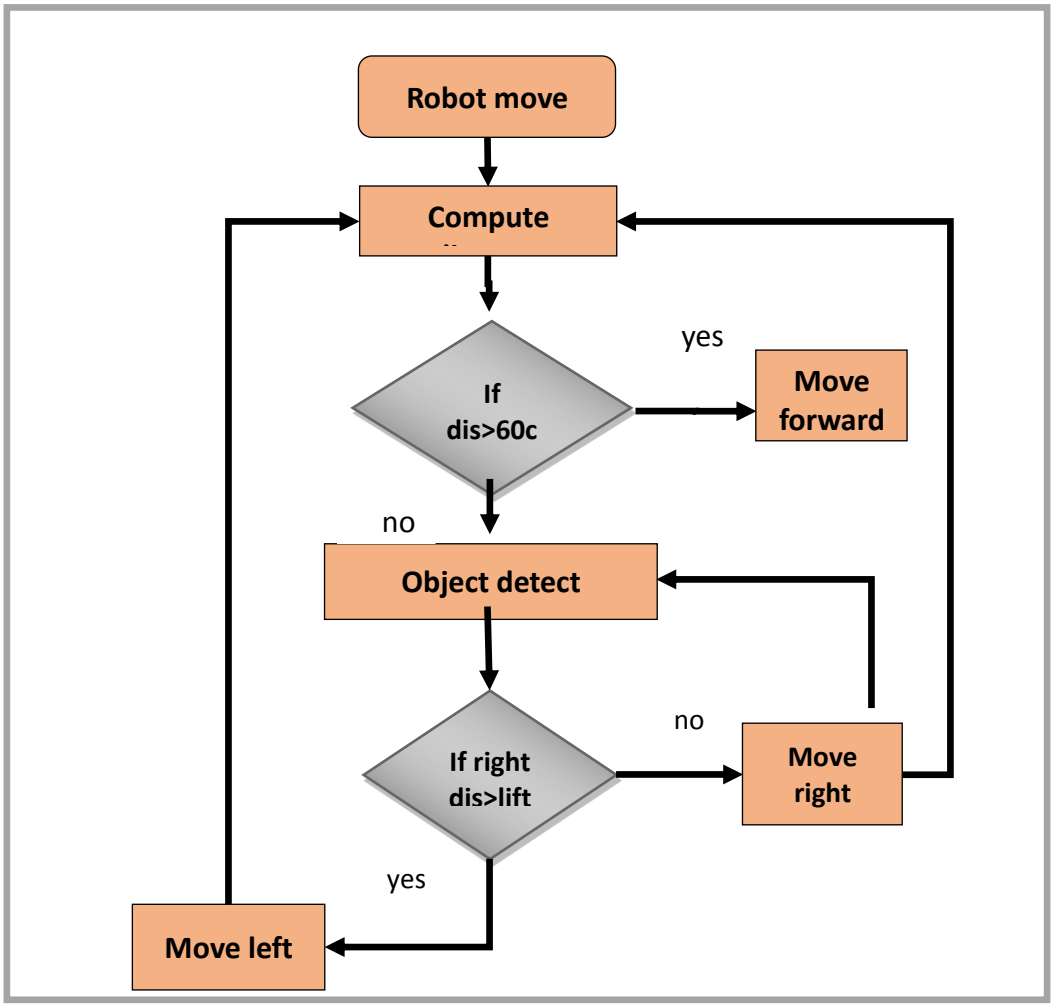

FIG. 1. FLOWCHART FOR ROBOT MOVEMENT

B. Intelligent Surveillance Monitoring

The surveillance system has been designed with the use of the Raspberry Pi as the controller and camera pi as a unit to the input image and then coded in Open-CV-Python programming language to implement various monitoring functionalities of the system.

Raspberry pi activates the Pi-Camera and captures an image from real-time video. the image captured from the video is processing by detecting the human face and cropping and feature extracted by HAAR algorithm. and adapter Wi-Fi he sends the processing image to the system. The detected human face is then compared with the faces that were stored in data-base utilizing CNN algorithm for face recognition. In the case where a face matches with the faces that are in the data-base no alerts are generated else the host gets a text message on the monitoring center via using a Wi-Fi adapter. Thereby, this system is helpful in the identification of only the unauthorized individuals. Which is

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helpful for overcoming the drawbacks of the Motion Detection and CCTV systems which only monitor or alert hosts based upon the detected motion whether it's an unauthorized person or otherwise. *Fig. 2* illustrates the flowchart for surveillance systems.

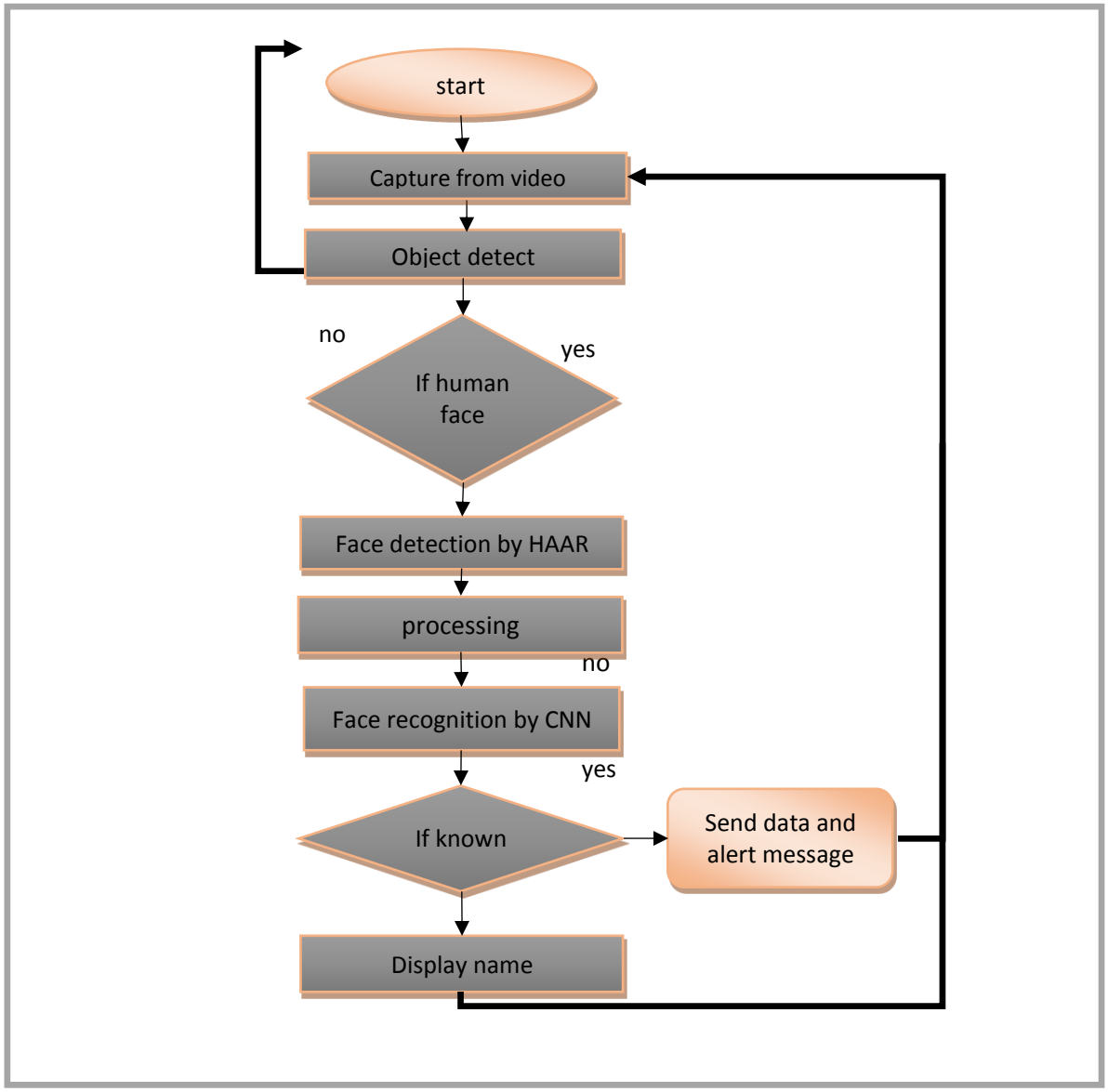

FIG. 2. FLOWCHART FOR SURVEILLANCE SYSTEMS

C. Architecture of Surveillance Robot

The raspberry pi board is connected with various accessories. It connects the raspberry pi, SD card, keyboard, camera module, DC motor, and power supply, ultrasonic sensor, PIR sensor, Wi-Fi adapter. The diagram of surveillance robot is as can be seen from *Fig. 3*.

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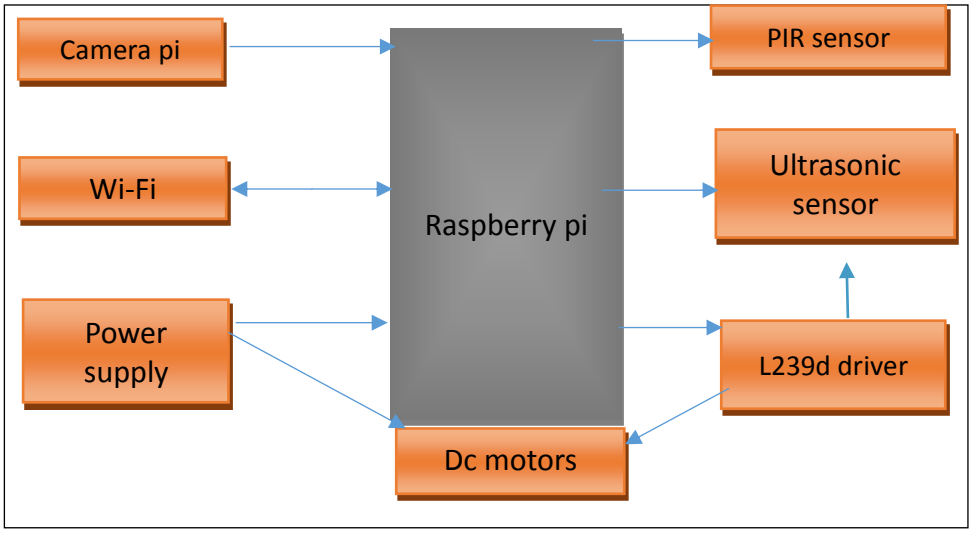

FIG. 3. BLOCK DIAGRAM OF SURVEILLANCE ROBOT

VI. SYSTEM HARDWARE DESIGN

In this part, it consists of a group of devices that have been assembled and programmed. It will be explained in several points as shown in the *Fig. 4* and final design is shown in *Fig. 5*.

FIG. 4. THE COMPONENT OF ROBOT.

i. Raspberry Pi

The Raspberry Pi4 operates on the forthcoming Debian10 Buster.

a. RAM – 1 GB, 2 GB or 4 GB LPDDR 4-2400 SDRAM (based **on** model)
b. CPU – Broadcom BCM 2711, Quad core Cortex-A 72 (ARM v 8) 64bit SoC @ 1.5 GHz.
c. WIFI – 2.4GHz and 5GHz IEEE802.11 ac wireless, Bluetooth 5.0, BLE. Ethernet – Gigabit.
d. USB – 2USB 3.0ports; 2USB 2.0ports [12].

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ii. DC Motor

Dc motor is utilized for the purpose of driving robot for that Use 500rpm 4dc motor. The motor speed depends upon the diameter of the wheel and the motor's Rpm (Resolution per min). Rpm is inversely proportionate to the torque. In the case where the motor speed gradually increases the motor torque will decrease [13].

iii. Camera Module

Face detection by use of the camera module. Its 5MP clearly visible picture quality camera module by invention by the raspberry pi foundation. It's easily affordable to any inventor for camera projects [14].

iv. Unmanned Ground Vehicles (UGV)

The production and the development of the inspection and intervention mobile robots, which is these remote-controlled unsupervised vehicles include a platform of mobility with the computers, sensors, software (which includes the modules for the perceptions, navigations), transmission link, power system, and additional equipment – based upon the vehicle's purpose [15].

v. Motor Driver l293d

L293-D can be defined as a typical Motor driver or Motor Driver IC, allowing the DC motor for driving on either one of the directions. L293D is a 16pin IC that is capable of controlling a group of 2 DC motors in a simultaneous manner in any direction. It indicates the fact that that one is capable of controlling 2 DC motors with one L293D IC. It operates on the H-bridge concept [16].

vi. Router

To activate the VNC for Raspberry Pi, we connect it to the router to send the data [17].

vii. Ultrasonic Ranging Module HCSR-04

A noncontact measurement that reads in a range from (2cm to 400cm) is provided through the HCSR-04 module. This module includes four pins that act as transmitter and receiver, which are referred to as trigger or echo [18].

The main concept of its work is:

It emits short as well as high frequency sound pulses at regular intervals of time.

-Those waves travel with the speed of the sound.

-It is reflected back to the echo in the case of encountering an obstacle, echo is received by the sensor through the echo pin $Distance = Time * Speed\ of\ Sound \backslash 2$.

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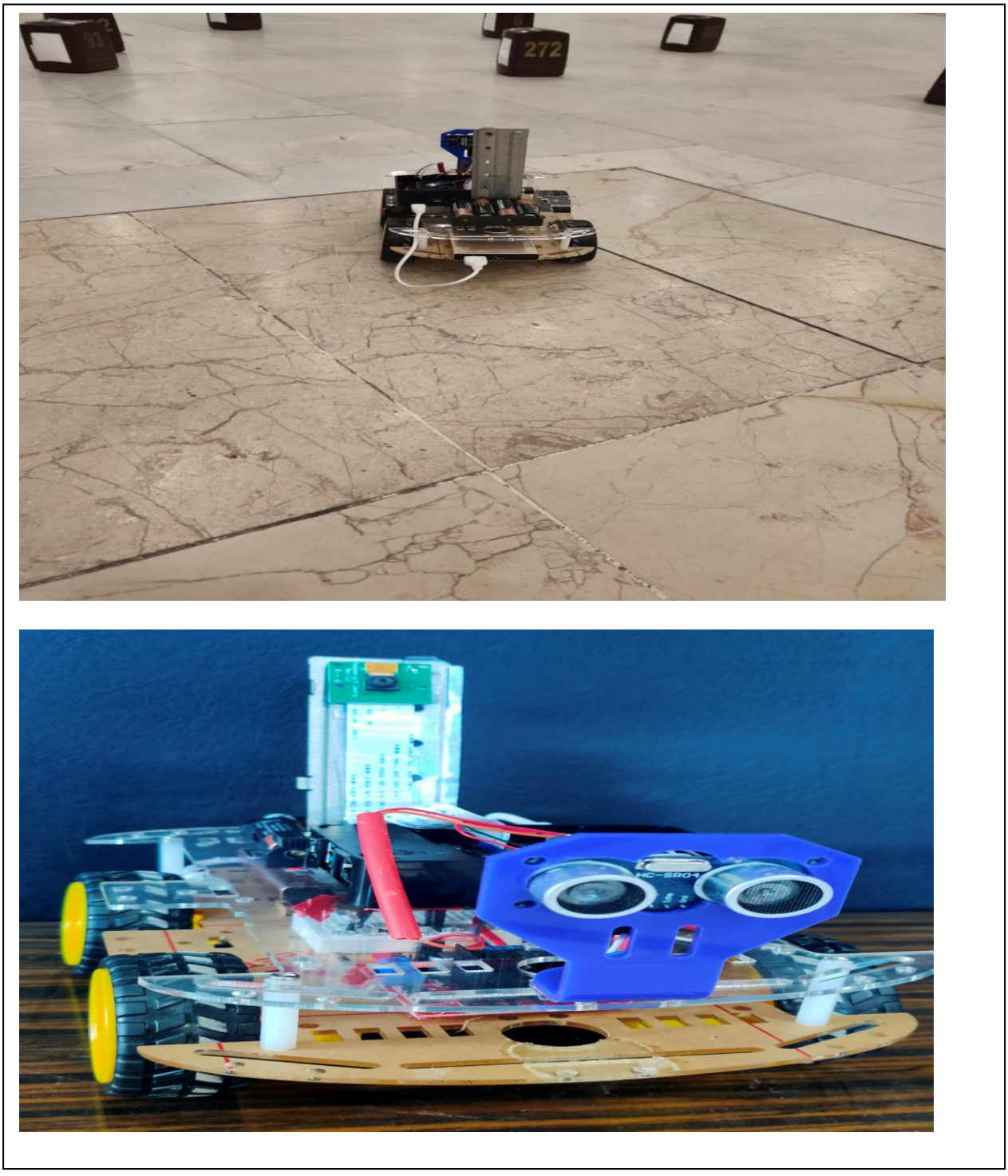

FIG. 5. FINAL DESIGN OF INTELLIGENT SURVEILLANCE ROBOT

VII. SYSTEM SOFTWARE DESIGN

Software used: -

a. Linux: - as an OS for the raspberry pi modules, which operates as a working environment.
b. Python: - as programming language, it is helpful for coders in creating and debugging codes without compiling.
c. Open cv: - as an open source computer vision that is helpful for capturing and processing the image [19].

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d. The part face detection and recognition are performed with the use of certain Linux commands that are as follows:

- sudo su # for switching to the root user.
- ctrl+c # for giving the key-board interrupt and stop image capturing following a desired number of images of a face are captured.
- python capture-positive.py # for the creation of the data-base of images.
- python train.py # for training captured images and extracting the features from it, through the separation of the face (i.e., positive images) from background or non-face image (i.e. negative images) and thereby creating a .xml file.
- python project2.py # for detecting and recognizing which face is present before web cam. It performs the calculation of confidence value and matches the status of the flag [20].

VIII. EXPERIMENTAL RESULT

Concerning the analyses in this paper, following the successful detection of the humans faces and objects, the activation of the face recognition is performed.

A. For process of face recognition, a specific number of the images have been taken and saved with the wanted name as that face's label. The performance of surveillance system when test the dataset at the number of iteration between (0 – 50) in this paper accuracy and loss Illustrate in *Fig.* 6 and Table I.

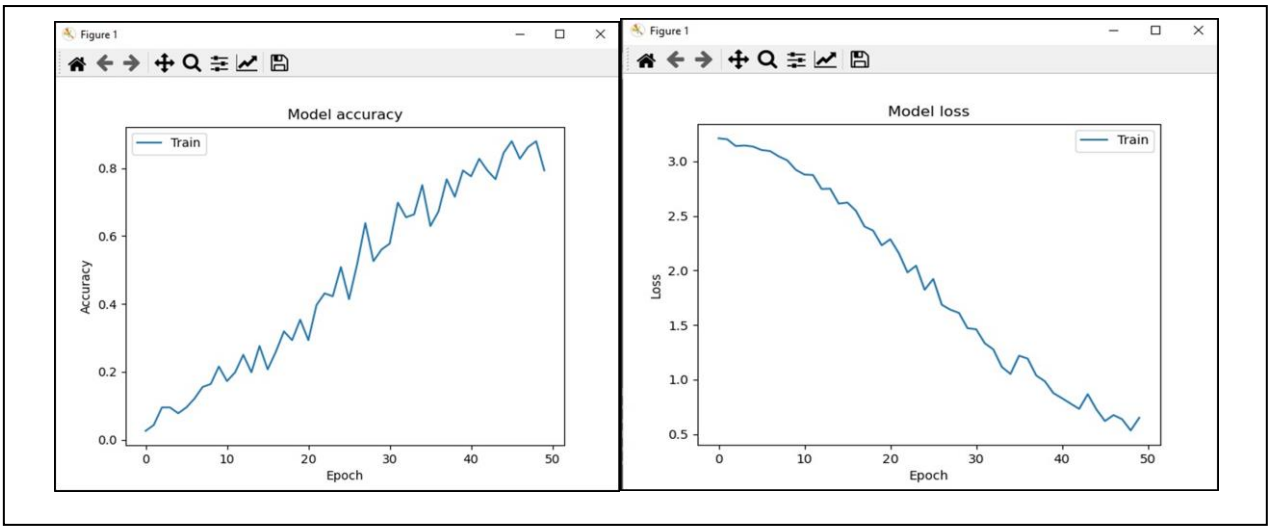

FIG .6. NUMBER OF ITERATION (0-50)

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when increase the number of iteration to (0-100) and (0-500) we note increase the accuracy and valid accuracy and decreased in loss as illustrated in *Fig.* 7 and *Fig.* 8 and Table I.

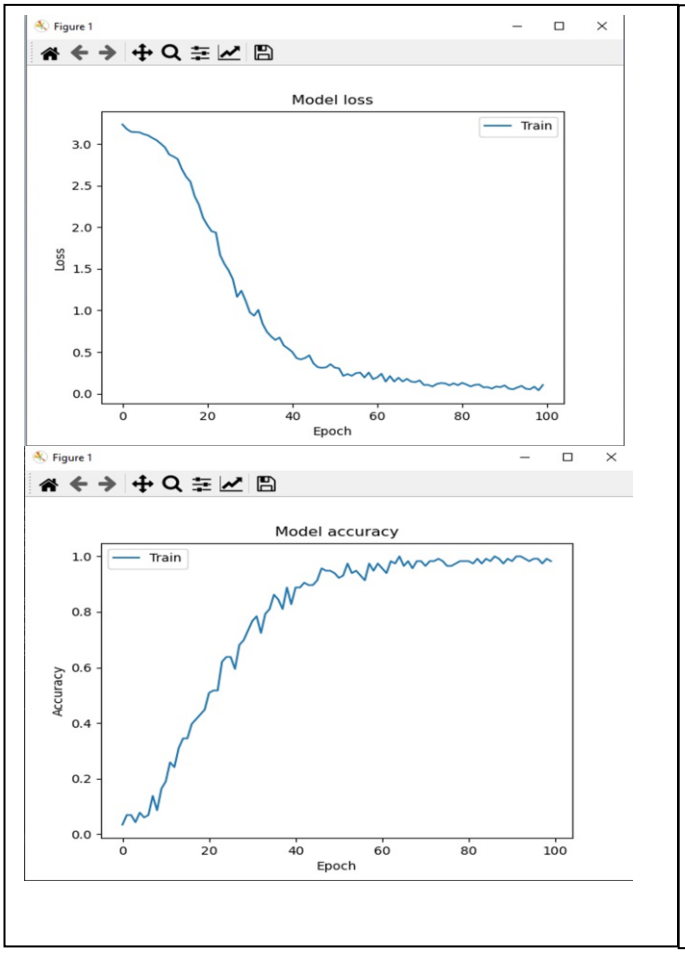

FIG. 7. NUMBER OF ITERATION (0-100)

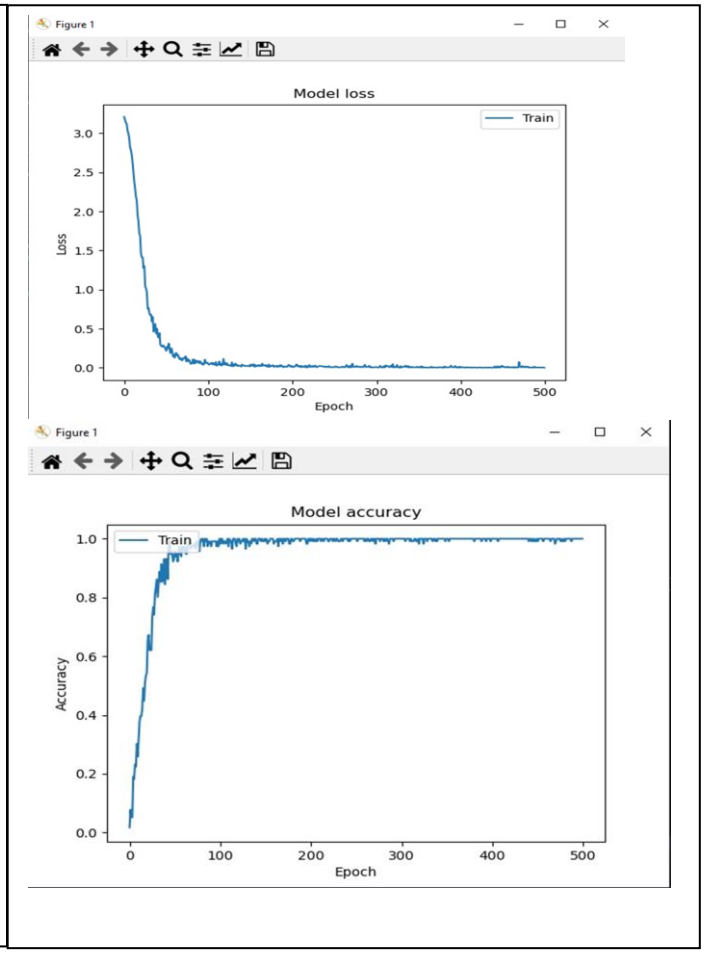

FIG. 8. NUMBER OF ITERATION (0-500)

This table shows the results for accuracy, valid accuracy loss and valid loss for the different number of training iterations, which start from (0-50) iteration and (0-100) iteration to (0-500) iteration. The result Illustrates in Table I.

TABLE I. THE RESULT OF FACE RECOGNITION

	No. Iteration (0-50)	**No. Iteration (0-100)**	**No. Iteration (0-500)**
Loss	0.6503	0.1030	0.0013
Accuracy	0.7931	0.9882	1.0000
Val-loss	0.7356	0.1648	0.0017
Val-accuracy	0.7931	0.8276	0.9987

The outcomes of accuracy of the suggested system were compared to other available methods outcomes of accuracy, where in proposed work was tested in two methods. These systems were work in different datasets. The comparison is illustrated in Table II.

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TABLE II. A COMPARISON BETWEEN THE SUGGESTED METHOD AND A FEW AVAILABLE ONES IS MADE BY USED ALGORITHM AND RESULT ACCURACY

Author	Year	Algorithm	Accuracy
Teddy surya	2017	Eigen face and face	90%
Jiang lu	2017	HAAR feature and cascade classifiers	85.7%
Munir	2019	HAAR feature and cascade classifiers	96%
Proposed work	2021	CNN and HAAR	99.8%

B. the robot was tested in the autonomous mode where it moved freely around the area with no human guidance and also evaded the obstacles. It has been noticed that in the case where it detected any obstacles it stops and turns right and starts moving in that way and in the case where there has been an obstacle on the right side it turns left and starts to move in that way and in the case where there has been an obstacle on all of the 3 sides then it would go back to its preceding position. *Fig*. 9 illustrates the distance between the object and ultrasonic sensor.

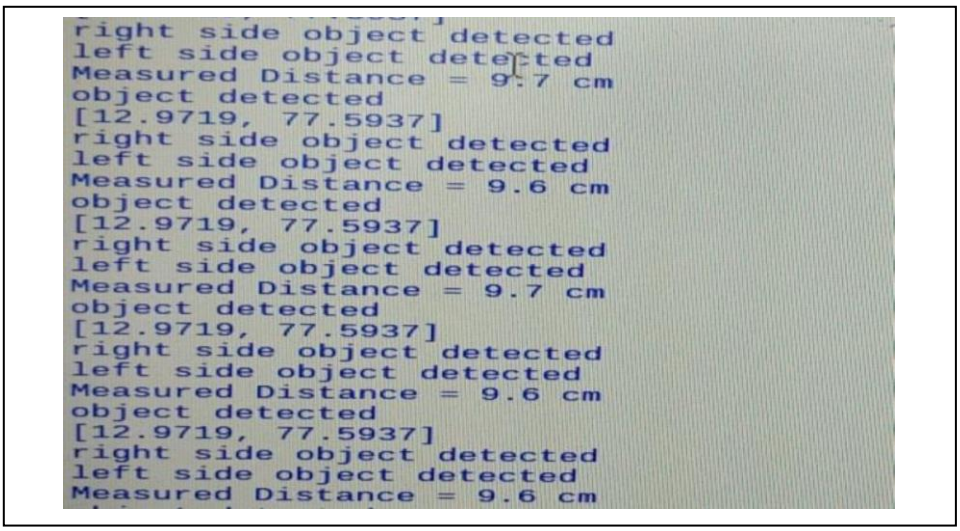

FIG. 9. ULTRASONIC MEASURED DISTANCE

IX. CONCLUSIONS

In this paper demonstrate, the intelligent surveillance and security solution, incorporating robots has been presented as well as computer vision. Robots decrease the risks for the humans, implementing this project for resolving the issue of the substitution of the humans by the surveillance robots due to the fact that this results in the reduction of the human resources' harm. The advantage of the robots increased their flexibility with being able to perform various applications and tasks. The robot is more accurate and consistent compared to the human workers Robots allow as well for the increase in the production and profit margins due to the fact that they are capable of completing the tasks in a shorter time.

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X. FUTURE WORK

Since the intelligent surveillance robots are implemented at border region, they have to be designed to be waterproof and must have the be able to loco mote on rugged surface and those systems have to be sufficiently adaptable for the purpose of automatically adjusting and coping with changes in environment such as the lighting, scene activity or scene geometry. Due to the fact that they replace the humans at the region it is important that the robot will be defending themselves and protecting the area. A future challenge is developing a wide-area distributed multisensory surveillance system that has robust, real-time computer algorithms capable of performing.

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