Robotic Border Surveillance System using LBP Algorithm (RBSS-LBP)

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Abstract— **The surveillance of International border areas has been one of the major concerns all across the globe. It is very essential that unauthorized people should not enter inside the restrained areas. The supervision of these restricted areas by border guarding forces is impossible at each and every moment. The proposed work presents a design and development of a new security solution which integrates vision, machine intelligent algorithm and multipurpose smart robot technology. Wireless camera for continuous monitoring of the restricted area form the base station and through machine intelligent algorithm harmful gases, fire, metal sensors, GPS (Global Positioning System) to locate the robotic vehicle is mounted on the robot, these information are continuously transmitted and displayed in the base station to alert the anomalies appearing in the border vicinity. The framework of this robot is that, it can be operated by both Automatic and Manual mode. Ultrasonic sensors are functional for automatic action whereas Joy stick is interfaced with Raspberry pi 4 controller to operate in Manual mode. Robotic Arm is used for pick and place of any object and to capture the enemies. Base station is equipped with advanced biometric security system i.e Face Recognition (FR) using Local Binary Pattern (LBP) algorithm. In Addition, a GSM (Global System for Mobile) module is interfaced to alert the Authority if there is any intruder who is trying to access the control. The proposed work would create a revolution in military applications as a surveillance and inspection robot.**

Keywords- Global Positioning System (GPS) , Autonomous Driving System (ADS), Convolution Neural Network (CNN) , Global System for Mobile (GSM), Short Message Service (SMS), Analog to Digital Converter (ADC), Face Recognition (FR).

I. INTRODUCTION AND BACKGROUND

Nowadays robotics field is growing drastically; some of the common applications are in the industries, defense, academic and research communities. It is defined as a machine programmed by the computer capable of performing a complex series of actions automatically. This system might not fully replace the responsibility of the soldiers, but manages to take the supreme reliability and thus reduces human mistakes on the border.[1]

Passing on individual's character, human face assumes an essential part in our social association. Utilizing the human face as a key to border security, "Biometric Confront Acknowledgment Innovation" has gotten tremendous consideration because of its potential for a wide assortment of utilizations.[2] A facial acknowledgment framework is one which captures facial pictures and confirms the character of a man using a propelled camera, the application uses to distinguish person using computerized vision.[3]

The proposed system is divided into two parts 1. Robotic vehicle and 2. Base station. The robotic vehicle uses Embedded C Language to program the ARM Controller and the Sensory network involves Metal detector for detecting metals at the border areas because parameters like mines, bombs, pistols, electronic circuits are made up of metals, Temperature sensor measures the temperature of outside environment. . For every sensors one GPIO pin in the controller is SET.[4] When any deviation from the original state, according to fed algorithm robot transmit the signals to the base station through Xbee transceiver where authority can take necessary actions. Wireless camera is used for continuous monitoring and wireless control which provides additional benefits including increased flexibility and reduced installation cost.[5]

Base station uses Python language to program the Raspberry Pi 4 controller board. Developing a set of image acquisition for database and recognition is done using LBP algorithm. The design of the system use microprocessor Broadcom BCM2711 as main control unit. The aim is to develop a base station with face recognition as a biometric security that is quick, fairly straightforward, and correct in affected environments like an workplace or a social unit.[6]

II. METHODOLOGY AND WORKING OF PROPOSED BOARDER SECURITY SYSTEM:

A. Robot Module Mechanism

The proposed module shown below in Fig 1:Vehicle Side Block Diagram, Arm Cortex M3 LPC1768 Microcontroller acts as the heart of the Robot Module. The Xbee transceiver module i.e CC2500 is used for the wireless communication between the robot and the base station. It is communicated via

UART 0 port of the ARM board with the help of Serial Interfacing (I/O) commands and Networking commands.

The sensor network consists of Metal sensor, Temperature sensor, GPS, Gas sensor and Ultrasonic sensor.[7] All these sensors are interfaced with the microcontroller and when the system is initialized, the data fetched from these onboard sensors are transmitted to the base station through Xbee transceiver. Robotic ARM is also interfaced with the microcontroller through Relay board with driver IC L2963D to perform necessary actions like pick and place of heavy objects or to capture enemies in the restricted area based on the data fetched from the onboard sensors. [8]

The Wireless camera which mounted on the Robotic vehicle is used for the continuous surveillance of the restricted area; the audio microphone installed in the same package is used for the speech communication from the base station. The real time video and audio signals are transmitted through transmitter and the receiver outputs the collected signal to computer or laptop.

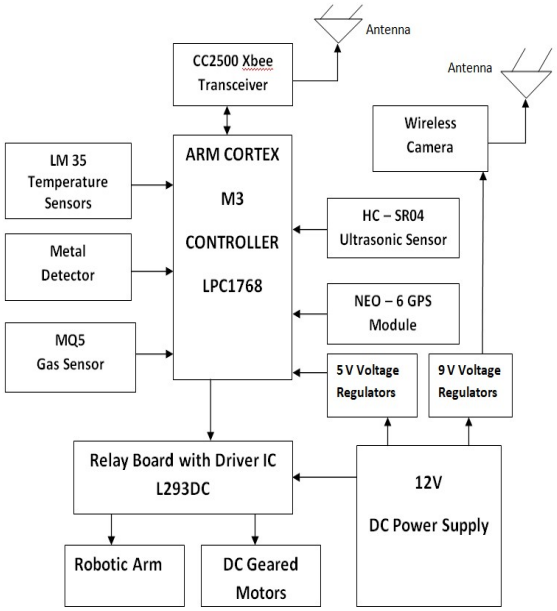


Fig 1: Vehicle Side Block Diagram

B. Base Station Mechanism

The proposed module shown below in Fig 2:Base Station Block Diagram, Raspberry PI 4 Model B acts as a heart of the base station.[9] Firstly the access to the base station can be achieved by the latest biometric i.e Face Recognition (FR), this is divided into two steps. First step is to capture the image of the authorized person and creating a database. By using "Eigen faces methodology" features are extracted from the images captured in different location with various light intensity i.e totally 100 images are stored in the database. Second step is to compare these images stored in the database with live captured image. If the output is positive, the remote is unlocked and authority is accessed to the base station. If negative, the "AT and ATD commands" are sent to the Global System for Mobile (GSM) to alert the authority by sending SMS (Short Message Service) and CALL if the intruder is trying to access multiple times.[10]

Two Joy Sticks are interfaced to controller through ADC (Analog to Digital Converter), Joy Stick no.1 to control the DC geared motors connected to the wheels for the directions of the vehicle and Joy Stick no.2 to control the movement of the Robotic ARM.[11] CC2500 Xbee transceiver for wireless communication with the vehicle and Push Buttons, Automatic/ Manual mode dd88545switch is interfaced with the controller. When the push button is activated, an interrupt is raised on the Vehicle side and the values from the Onboard Sensors are displayed on the 20X4 LCD display. Except for the Metal detector, there is no interrupt raised and the information is continuously transmitted and displayed.[12]

Automatic / Manual mode switch is used to shift between the two states. In manual state Joy stick is used to control the directions of the robotic vehicle manually. Whereas in Automatic state, according to the algorithm fed to ARM Cortex the ultrasonic sensors are used to control the directions of the robotic vehicle. The shift between these two states is very fast without any delay.[13]

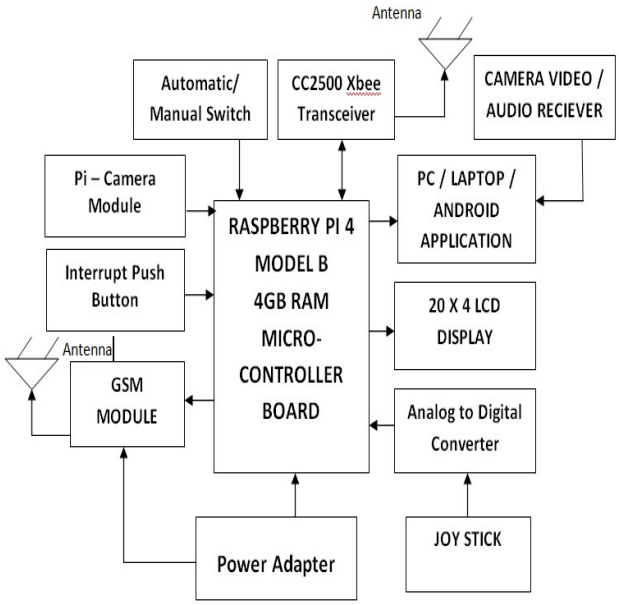


Fig 2: Base Station Block Diagram

III. INTELLIGENT APPROACH ON VEHICLE SIDE

The below Fig 3: Flow Chart of Vehicle Section shows the intelligent approach on vehicle section and the data flow in the robot section is as shown below

Step 1: Start the process.

Step 2: Initializing all the sensor modules and fetch the data from the following modules.

Step 2.1: Temperature value from LM 35 (Temperature sensor) in Degree Celsius.

Step 2.2: MQ 5 Gas Sensor to detect Methane, LPG and other harmful gasses ranging from 100 – 3000 ppm.

Step 2.3: Metal Detector to detect Bombs, iron, brass.

Step 2.4: NEON - 6 GPS which gives signals of pseudorandom code, Ephemeris data and Almanac data.

Step 3: Transmit the onboard Sensor values through Xbee transceiver to the base station.

Step 4: Receive command from the base station about the following mode**.**

Step 4.1: Automatic Mode **-** Operates as per the logic used as shown in Fig 5: Algorithm used for Autonomous Driving System (ADS)

Step 4.2: Manual Mode – Operates based on the user input from the base station.

Step 5: Return to Step 2.

Step 6: Stop the process.

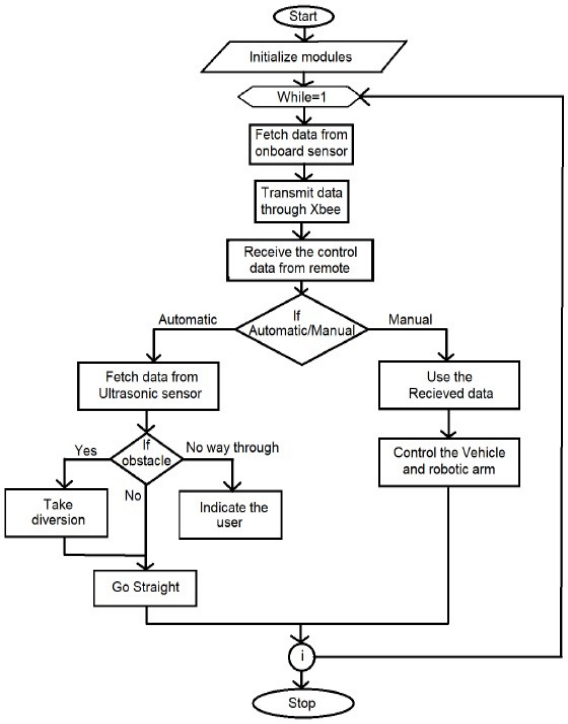


Fig 3: Flow Chart of Vehicle Section

A. Implementation of Autonomous Driving System(ADS)

The implementation of this mode is also referred as Autonomous Driving System (ADS).[14]When the Automatic mode is enabled, depending on the algorithm defined in the microcontroller the vehicle moves. For any obstacle in path two Ultrasonic sensors are installed in the front side of the vehicle and the sensors are triggered and echo signals are received continuously and the distance is calculated. Both sensors are programmed to detect obstacle within 30cm range. then the vehicle operates as per the logic shown bellow in the Fig 4: Algorithm used for Autonomous Driving System (ADS), thus avoiding collision.[15]

```
15
16 if(distance1<=29&&distance2>=30)     // Change the direction
17    {
18      LPC_GPIO1->FIOCLR = 0x0F000000;
19      LPC_GPIO1->FIOSET = 0x09000000;     // Go Right
20        delay(400000);
21        LPC_GPIO1->FIOCLR = 0x0F000000;
22        LPC_GPIO1->FIOSET = 0x0A000000;   //Go staight
23        delay(400000);
24        LPC_GPIO1->FIOCLR = 0x0F000000;
25        LPC_GPIO1->FIOSET = 0x02000000;   // Go Left
26       delay(400000);
27    }
```

Fig 4: Algorithm used for Autonomous Driving System (ADS)

B. Implementation of Manual mode

In this mode of operation, the user can control the vehicles directions and robotic arm manually through joy stick from the base station by sending the RF (Radio Frequency) signal of 2.5 GHz to the vehicle side. Even in this mode all the onboard sensors work normally when an interrupt is raised. And Wireless camera is used for real time monitoring to control the robot. This mode is useful if vehicle in Automatic mode malfunctions.

The 2 axis in the Joy stick indicates directions of vehicle i.e Forward, Backward, left, Right respectively. If the joy stick position is in the centre, it indicates Neutral. The logic used in controller in this mode is if the voltage value is 2.5v then vehicle in in stop position, is the voltage is greater than 2.5V (>2.5V) the vehicle moves forward/ Right based on the axis and if the voltage value is less than 2.5V (<2.5V) then vehicle moves Backward / left. The voltage values w.r.t Joy Sticks position are shown bellow in TABLE I. Voltage to Direction based on Joy Stick position

TABLE I. Voltage to Direction based on Joy Stick position

Joy stick Position	**Voltage reference**	**Direction indication of joy Stick 1**	**Direction indication of joy Stick 2**
+ ve X-Axis	5 v	Front (F)	Fire (f)
-ve X- Axis	0 v	Back (B)	Release (r)
Centre (Origin)	2.5 v	Neutral (N)	Neutral (n)
+ ve Y-Axis	5 v	Right (R)	Hold (h)
-ve Y- Axis	0 v	Left (L)	Release (r)

IV. FLOWCHART AND ALGORITHM USED IN BASE STATION

The bellow Fig 5: Flow Chart of Base station shows the step by step intelligent approach in Base station and the data flow of this section is as shown below:

Step 1: Start the process
Step 2: Initialize camera when the person stands in front of it.
Step 3: Detecting face using "Haar cascade classifier" and storing it in the database.
Step 4: Comparing the live captured image with the existing database using LBP algorithm.
Step 5: If the o/p is negative, AT AND ATD commands are sent to GSM module to alert the authority.
Step 6: If the o/p is positive Communicate through Xbee perform following actions:

Step 6.1: Raise an interrupt and receive the data from the sensors

Step 6.2: Receive commands from joystick.

Step 6.3: Display on Joy Stick**.**

STEP 8: STOP

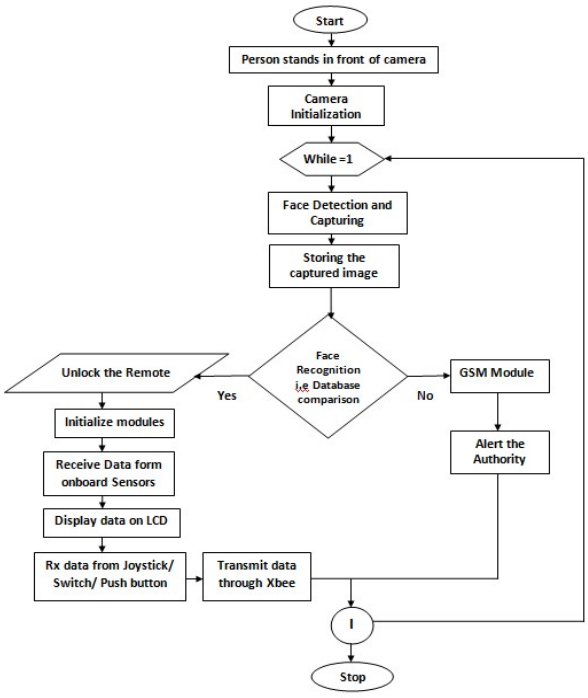


Fig 5: Flow Chart of Base station

A. The Fcae Recognition Algorithm

The implement face recognition, the proposed system uses Local Binary pattern (LBP) algorithm. It is a bit wise transition from 0 or 1 which is used to describe the local neighboring texture of grayscale image.[16] The threshold value of the center pixel is compared with the gray value of the neighboring 8 pixels, if the neighboring pixel value is bigger than the center pixel value, the position of this pixel is marked as 1, otherwise it's marked as 0. LBP is formally defined as:

$$LBP(x_c, y_c) = \sum_{p=0}^{p-1} 2^p s(i_p - i_c)$$

where (Xc,Yc) is the center pixel and its brightness is ic , and the brightness of adjacent pixels are ip . s(.) is a sign function:

$$s(x) = \begin{cases} 1 & if \quad x \geq 0 \\ 0 & else \end{cases}$$

The details of original LBP is shown in Fig 6: The principle diagram of the original LBP.[17]

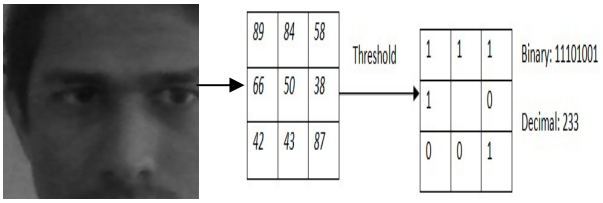


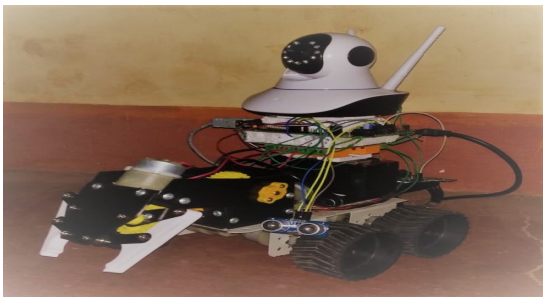
Fig 6: The principle diagram of the original LBP.

Input to the model is filtered Training Image. The features are extracted from the training face and is compared with the center pixel and is compared with the unknown face image which is the live captured image from the Pi camera.[18] The logic is as depicted bellow:

1. Initialize temp =0
2. For each training image I
   Initialize H =0 (Histogram)
3. For each center pixel tc € I
4. Compute the label pattern LBP(1)
5. END For
6. Find the highest LBP feature and combine to single vector
7. Compare 6. With trained image.
8. If it matches with the database then the remote is unlocked
9. Else go back to 1.

V. RESULT AND SNAPSHOTTS

In this, we depict the results and snapshots of the proposed border security system. The Robotic Arm, Wireless camera, Onboard sensors, Xbee transceiver and the power supply can be depicted in Fig 7: The rare view of the Robot for survivalence system.



In the Fig 8: Base Station prototype, it depicts the implementaton of Joy sticks, Xbee transciever and the output of the Onboard sensors displayed 20X4 LCD .

Fig 8: Base Station prototype

The output of the Face recognition System is depicted in Fig 9: Output obtained when Face not found. This is the first convolutionn neural network where the features of the image is extracted and compared with the database before executing the Dense neural network of the convolutoin model which recognizes the face and further unlocks the remote.

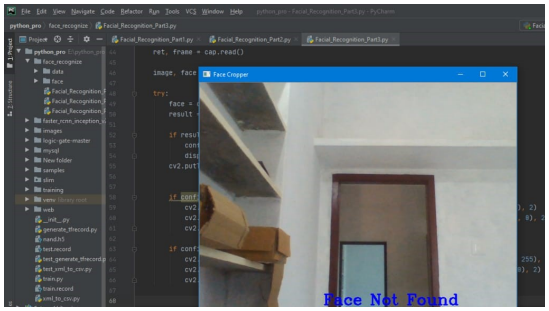


Fig 9 : Output obtained when Face not found

The Fig 10 : Output obtained for Unauthorised person depicts the output when an unauthorized person tries to access the remote, which remains unlocked and capures the image for furher verification and in Fig 11 : Output obtained for Authorised person, depicts the result when an Authorised person stands in front of the camera, thus the dense nural network recognizes the face and unlocks the remote to access the base station.

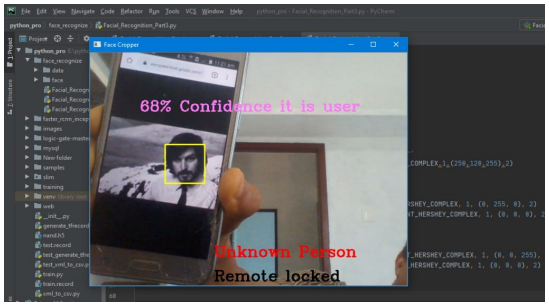


Fig 10 : Output obtained for Unauthorised person

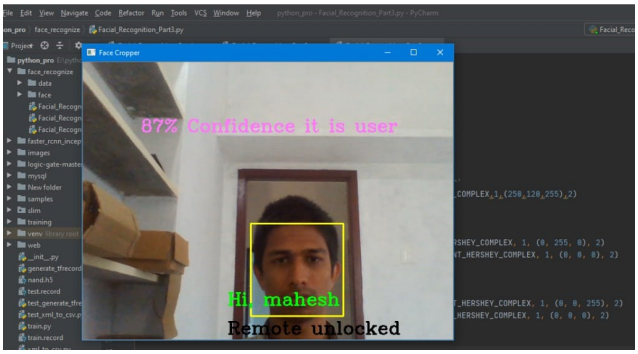


Fig 11 : Output obtained for Authorised person

VI. CONCLUSSION

This paper presents the intelligent approach for border Surveillance System using the concepts of Robotics and Image processing. A big idea of multipurpose, remote controlled smart robot is designed and developed, which is the wireless control through the base station and the implementation of Autonomous Driving System (ADS) and manual mode of operation of vehicle is discussed. This system will reduce the work effort of soldiers in the border.

A face recognition system using LBP algorithm for Intelligent remote unlocks in the base station is designed and implemented in this paper. This system realizes the fast recognition, high accuracy and efficiency for human face.

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