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A Smart Semi-Automated Multifarious Surveillance Bot for Outdoor Security Using Thermal Image Processing

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Abstract: Unauthorized entry in restricted areas represents an obvious security issue. Therefore, strict monitoring is highly required in order to ensure security. This research presents a smart surveillance bot for highly restricted areas with (1) automatic surveillance of an area specified by the user and obstacle detection and avoidance using Ultrasonic Sensor (2) human detection using Infrared (IR) thermal camera and identification of friend or foe (IFF) using RFID tags (3) live video surveillance using camera and manual remote control mode. The bot has the ability to detect human presence in an area using thermal image processing. If the bot detects and human presence while operating in surveillance mode, it confirms whether the person is a friend or foe by reading RFID. If the bot identifies the person as foe, it automatically sends the user a notification of intrusion and turns on live video streaming. The user would be able to take total control of the bot remotely in order to verify and judge on the situation using live video streaming. It also exhibits warning message in its display and points a toy gun at the intruder. In real life cases, the toy gun can be replaced with actual ones. The user bears the authority to decide whether to shoot or not. Due to having tank rover chassis, the robot has the ability to maneuver in rough terrains which enhances its versatility and usability.

Keywords: Smart Bot, Surveillance, Raspberry Pi, Ultrasonic Sensor, RFID, Thermal Camera, Pixy Cam, Image Processing, Outdoor Security

1. Introduction

Due to mountainous technological progression, systems tend to become smart, intelligent and automated. [1]. Maintaining strict security in restricted area nowadays require utilization of automated smart systems and devices in order to manage things in efficient manner. In response to need, numerous automated and semi-automated smart systems have evolved [2].

Surveillance using for robots have become quite popular in the recent years due to maneuverability and various smart features [3]. Such smart features include movement detection, human face detection, obstacle detection, intrusion detection, live streaming based monitoring, remote control of bot and many more. Moreover, it is safer to perform insecure and risky job of surveillance in sensitive areas by robots. As per demand of security, numerous surveillance bots have emerged, each having several smart features integrated using hardware and complex processing methods [4].

Nowadays, Bluetooth based wireless data transfer methodology has become popular for implementing bots [5-6]. However, in case of range, Wi-fi based systems offer better service [7-8].

Integration of various sensors have brought about a great change in the field of robotics [9]. For instance, human detection can be achieved by using Passive Infrared (PIR) sensor which is greatly used in surveillance bots nowadays [9]. Moreover, camera enables us to see live video streaming of an area which makes it quite suitable for the purpose of surveillance [10-12]. Moreover, modern devices such as thermal-cameras, IR sensors and ultrasonic sensors have largely contributed towards developing smart and compact robots for security and surveillance purpose [13-21].

In this research, we have developed a smart surveillance bot with multifarious abilities. The features of the bot include automatic surveillance, human detection by thermal image processing, identification of friend or foe, live streaming, obstacle avoidance using ultrasonic and manual remote control. The smart features in equipped in with the bot enables user to easily monitor restricted area.

2. Existing Surveillance Bots and Their Features

Dual Tone Multi Frequency (DTMF) based remote control bots are considered as early stage surveillance systems [3]. Later, DTMF based bots were equipped live video streaming and voice instruction based which enabled the user to monitor an area remotely [5]. Although DTMF offers wide range of operation, the technology has low precision due to poor noise immunity.

Bluetooth based wireless data transfer systems for surveillance bots in [6] offer higher precision than DTMF technology. However, due to low operating range, Bluetooth controlled bots can be only utilized for the purpose of home surveillance [7]. Therefore, such sort of surveillance bot is not suitable enough for security purpose in restricted areas which require large area coverage. Using Wi-Fi module rather than Bluetooth offers wide range of operating range [8].

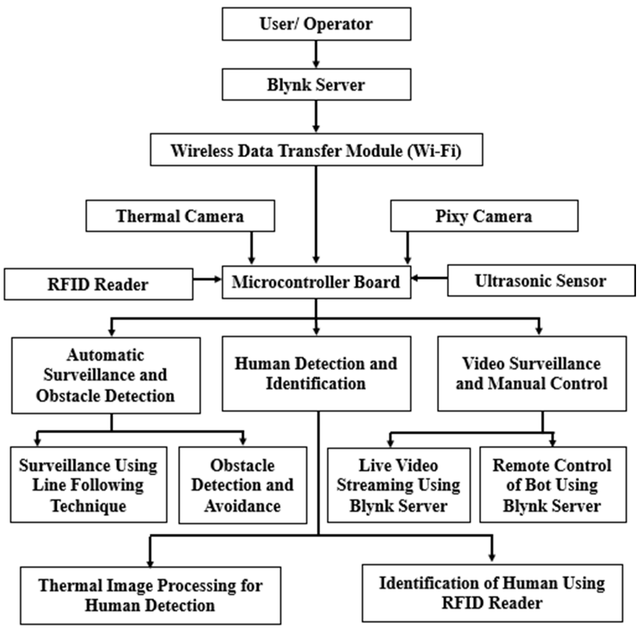

Figure 1. *Block diagram of proposed surveillance bot.*

Modern Surveillance bot are not only limited to remote control and live video streaming, rather they are equipped with smart features to detect intrusion too. For instance, researchers in [9] used Passive Infrared Ray (PIR) sensor to detect intrusion in smart home systems. PIR based intrusion detection are quite simple, handy and requires very low hardware cost. Due to evolution of complex-algorithm based image processing, surveillance systems nowadays tend to utilize intrusion detection technique using video-camera based image processing [10-11]. For example, surveillance bots in [12-15] employ image-processing based face recognition and identification in order to detect any intrusion. These face recognition systems are quite suitable for indoor monitoring where there is plenty of light around. However, for outdoor applications these systems are quite inappropriate for identification since due to absence of abundant amount of light, the systems might fail to operate.

In addition, image-processing based face detection do not have 100% accuracy. Hence, where identification of friend and foe need foremost accuracy in sensitive cases, utilization of face recognition systems might appear as fatal security issues.

The limitation of image processing using normal camera under low light intensity can be removed by utilizing thermal image processing technique which requires thermal camera [16]. In [17], Lens based thermal camera has been utilized which make it extremely expensive. IR based thermal is a good option in order to cut down cost. Various IR thermal camera based human detection are presented in [18-21]. Among them, [18-21] are suitable for human detection in night. However, their efficiency significantly decreases while applied during daylight. The researchers in [21] takes into account thermal criteria and conditions both for day and night time. Hence, thermal image processing in [21] is considered as more efficient than the others.

All the researchers stated above only focused on a small part of surveillance system. However, in order to obtain the ultimate result, practical implementation in quite important where it is necessary to integrate those features into one and consider real life issues. This research aims to integrate various smart features within a single surveillance bot considering real life cases.

3. Design Methodology of Proposed Surveillance Bot

Block diagram of the propose design is represented by Figure 1. Details on various smart features of our surveillance bot is presented in the following sub-sections.

3.1. Automatic Surveillance and Obstacle Detection

For automatic surveillance, the system divides the whole restricted area into different zones. The operator/user can send instruction to the bot to go into a particular zone for surveillance. The bot uses line following technique to move from one zone of the area into another [22]. Although majority of line following robots use IR sensors, the proposed bot utilized PixyCam [23]. The reason behind this are: (1) the robot already needs a camera for video streaming (2) PixyCam has special feature of color detection which is highly effective for line following.

In real life cases, any obstacle can be present on the line which the bot follows. So, an obstacle detection and avoidance technique need to be applied. Ultrasonic Sensor (Sonar) has been utilized for this purpose [24-25]. Although the PixyCam can be used for obstacle detection, camera-based image processing is not reliable in unexpected situations such as foggy or smoky environment around. Algorithm for automatic surveillance and obstacle detection has been obtained from [26]. The algorithm has been modified in order to comply with the proposed surveillance bot which follows line using PixyCam rather than using IR sensors. In case that the bot gets cannot find the line and gets lost, then it stops and send notification to the user to take control over it manually.

3.2. Human Detection and Identification

In order to detect human, IR based thermal camera has been utilized in this research for both day and night time human detection. Since, the thermal image processing technique [21] considered both day and night time detection issues, it is more convenient and efficient to utilize this technique for our bot. However, the process described in [21] accounts for only human detection. No identification is considered by the research conducted in [21]. For surveillance purpose in highly restricted areas, it is necessary to consider both detection and identification of human in order to distinguish between friend and foe. Hence, the technique in [21] have been modified and extended to further steps in order to solve human identification issue.

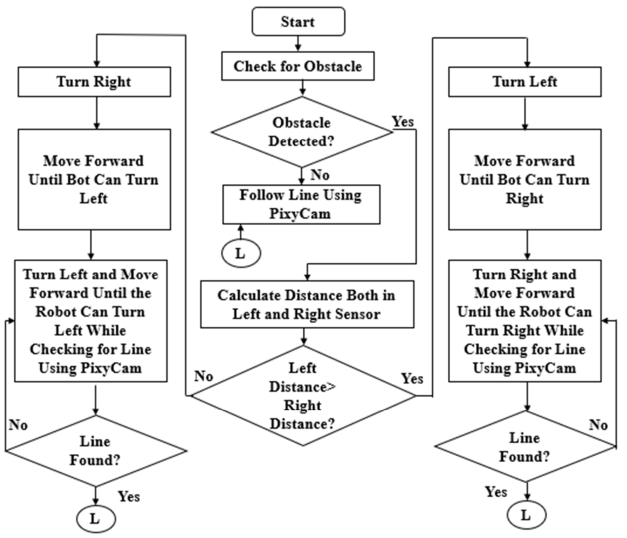

Figure 2. *Algorithm for obstacle detection and avoidance in line following technique using Pixy Cam Camera.*

PIR sensor can be considered as a low-cost handy device for human detection [9]. However, PIR sensor detects movement of any sort of thermal body which emits IR ray. Moreover, PIR sensor can only sense IR ray within the sensor range, however, cannot tell exactly from which direction the IR ray is coming from. Therefore, the IR based thermal image processing has been considered for human detection rather than using PIR sensor.

Block diagram of human detection and identification is represented by Figure 3. The steps are explained in the following paragraphs.

3.2.1. Background Subtraction

The image obtained for processing is thermal image and it is necessary to convert it to grayscale. The formula for thermal to greyscale conversion is given below:

$$I_c(x,y) = \frac{(I_T(x,y) - VT_{min})L_{max}}{VT_{min} - VT_{max}} \quad (1)$$

where

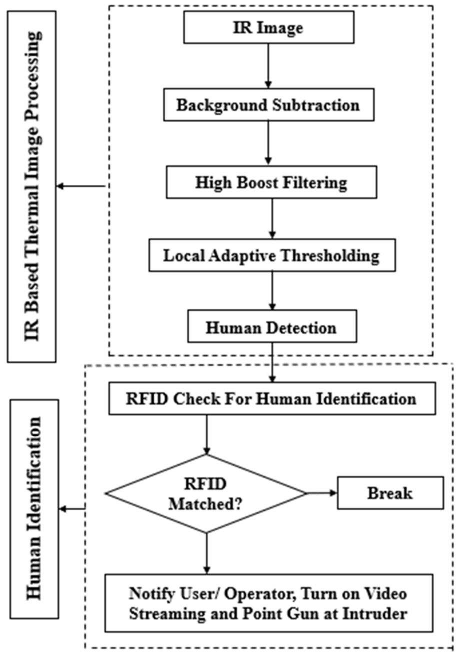

Figure 3. *Flowchart of human detection using thermal image processing and human identification using RFID.*

$I_c(x,y)$=grayscale image (converted)
I_T =thermal image
VT_{min} =minimum value in I_T
VT_{max} =maximum value in I_T
L_{max} =bit numbers required for coding for each pixel

Then, eq. (1) is rewritten in the following form where foreground and background information are separate.

$$I_c(x,y) = P(x,y) + Q(x,y) \quad (2)$$

Here,
$P(x,y)$ =foreground information
$Q(x,y)$ =background information

Now, $P(x,y)$ in eq. 2 contains all the necessary information. $Q(x,y)$ contains unnecessary information which needs to be vanquished for eq. 2. To do this, at first the grayscale of $Q(x,y)$ is obtained by utilizing the Histogram's peak. Then subtracting it from image pixel leads to the desired form of equation. The process is interpreted using the following equation (eq. 3).

$$I_{cx}(x,y) = \begin{cases} I_c(x,y) - H_p, & if\ I_c(x,y) \geq H_p \\ 0, & otherwise \end{cases} \quad (3)$$

Where,

$$I_{cx}(x,y) = foreground\ of\ image$$

$$H_p = histogram\ images'\ peak\ (estimated)$$

Elevation of human detected objects are then elevated. Following step includes suppression of background and enhancement of Signal to Noise Ratio (SNR).

3.2.2. High-Boost Filtering

After background subtraction, the intensity of human objects gets reduced. Therefore, high-boost filtering of the obtained image becomes necessary. This process is only applied to the parts of the image. No low frequency part is eliminated while performant high-boost filter. The mathematical expression is presented by eq. (4).

$$I_{cxe}(x,y) = I_{cx} * H(x,y) \quad (4)$$

Where,

$$I_{cxe}(x,y) = enchanted\ image$$

$$H(x,y) = high\ boost\ matrix$$

The term * in (4) does not represent multiplication. Rather it represents convolution operator.

3.2.3. Adaptive Thresholding and Human Detection

In this step, only the required/expected targets are recognized which accounts for human detection. In order to detect only the required targets, the unwanted targets are required to be removed.

In order to remove unwanted targets, let us define adaptive threshold AT and AT_1. Here, Gaussian distribution are used to define the terms AT and AT_1 which have the following mathematical expressions.

$$AT = \mu - \kappa\sigma$$

$$AT_1 = \mu + \kappa\sigma$$

Where,

$\kappa = a\ scalar$, μ =mean and $\sigma =$ variance of $I_{cxe}(x,y)$.

In order to calculate κ adaptive mathematical approach has been used. To calculate κ adaptively, different investigations have been applied on $I_c(x,y)$. The investigations applied various intensity value of the image such as minimum, maximum, mean value etc. Moreover, different types of value of the image other than intensity such as entropy, variance, standard deviation etc. Due to having low fluorescence and low SNR, it was observed in the investigation that majority of the trials do not end up getting expected result. Based on the investigation, it has been observed that calculating κ using entropy yields better result. Entropy in this case is a measure of quality and texture of the converted grayscale image $I_c(x,y)$. This is expressed in the following mathematical expression.

$$\kappa = -\sum_{x=1}^{M-1} PI_c(x) * log_2 \times PI_c(x)$$

where

PI_c =probability.

This probability is calculated from the number occurrence number of x got in $I_c(x,y)$.

M =maximal value of pixel level obtained in $I_c(x,y)$.

For detection of brightness pixels, the following mathematical expression is used.

$$I_h(x,y) = \begin{cases} 0, & if\ I_c(x,y) \geq H_p \\ 1, & otherwise \end{cases}$$

Where,

$I_h(x,y)$ =final resultant human pixel of the image.

3.2.4. Human Identification

For human detection, thermal image processing has been used and for identification purpose, RFID tags has been utilized. It might come into mind that RFID has very small range for which it cannot be utilized in surveillance bots for long range identification. However, based on types, operating range of RFID are quite different. Classification of RFID is presented by Figure 4. From Figure 4, it can be seen that RFID has low-high range based on frequency and power source. For the proposed design, Passive Ultra-High Frequency RFID tags have been utilized which have 15 m range of operation. Each authorized person has RFID tag attached to their uniform by which identification can be done. The Surveillance bot contains a RFID reader in order to look for RFID tags.

When the surveillance bot detects any human, at first it looks for RFID for identification, If the identification fails, the bot considers it as an intrusion. It aims a toy gun at the intruder and notifies the user wirelessly about the intrusion. The user/ operator then can turn on live video streaming for further identification. The decision whether to shoot or not using the gun attached with the bot lies in the hands of the operator.

3.3. Video Surveillance and Manual Control

In case that the operator needs to have a look into the surrounding area, he/she can turn on live video surveillance and take control of the surveillance bot manually. In order to enable user to take control of the bot manually and wirelessly, Blynk software has been used to create a local server network which utilizes Wi-Fi as the medium of wireless data transfer. Blynk is a digital to build Graphical User Interface (GUI) simply.

In order to control the surveillance bot, one needs to access the local server network by proving user ID and password which provides security from unauthorized use.

4. Hardware Implementation

Final implemented version of the proposed surveillance bot is represented by Figure 5. Raspberry Pi has been utilized in this research as the microcontroller board which is much faster and can deal with larger data rate compared to Arduino [27-30].

To capture thermal image, Adafruit AMG8833 IR thermal camera has been utilized. For live video surveillance purpose, PixyCam CMU Cam5 has been used. The chassis model is Rover Tank 5 which has 4 motors attached to it along with 4 encoders. The design of the tank rover and its 4 motors provide strong driving capability and high torque to the bot which enables it to maneuver in rough terrains [31-32]. For obstacle detection, ultrasonic sensor model HC-SR04 has been adder which has a detection range between 2cm and 450 cm [33-34]. For wireless data transfer, NodeMcu ESP8266 Wi-Fi has been added to the bot which provides wide range of operation than Bluetooth [35-36]. The Wi-Fi module has a maximum range around 470 meters (nearly half a kilometer). The UHF RFID reader module's model is CF-MU801 which operates at the frequency 865 MHz-868 MHz. Is has a RFID reading range of 15 m and it is fully compatible with Arduino, Yourduino and Raspberry Pi [37-39]. In order to connect the module with the Raspberry Pi, an interface board is required and RS232 serial port interface board serves this purpose [40-42]. In addition, an antenna is required to be connected with CF-MU801 through a SMA connector in order to sense RFID signals. CF-RA4040 antenna has been utilized for this purpose which has a gain of 3 (dBi). Model number of the RFID tags compatible with CF-MU801 RFID module are G9201, G9305, G9307, G9505, G9508 etc. In this research, G9305 has been used. Complete list of hardware and modules of the surveillance bot developed in this research is represented in Table 1.

5. Result Analysis

The surveillance bot in this research is equipped with all the necessary features which are compulsory for maintaining security in restricted areas. The surveillance bot can automatically monitor a specified and maintain its security. None of the existing surveillance bots discussed in this research is equipped as much features as ours. Practical results on different features of our surveillance bot is presented in the following sub-sections.

5.1. Obstacle Detection and Avoidance

For obstacle detection and avoidance, we have tested the surveillance bot with various types obstacles having different sizes and shapes. In total, we had 100 test runs and the success rate was 87%.

5.2. Human Detection and Identification

Various steps of thermal image processing of the surveillance bot have been depicted in Figure 6. To measure the efficiency of the thermal image processing, the bot has been tested under various weather conditions. In total we have taken 100 test runs and the human detections process successfully worked for 91 cases. Hence, the overall efficiency of the human detection technique using thermal image processing is 91%.

For human identification part using RFID tags, the bot has been tested for different distance and results have been listed in Table II. It has been observed that the RFID tags reading efficiency for 13-15 m distance is quite low although the maximum rated distance is 15 m.

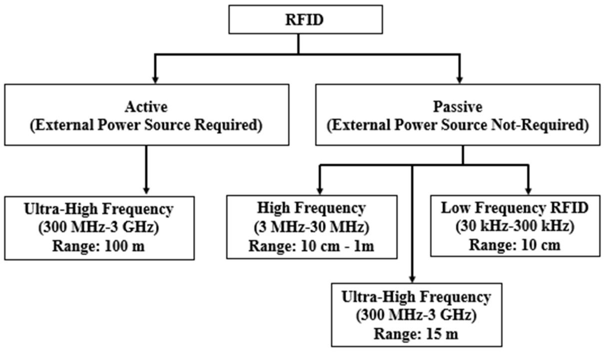

Figure 4. *RFID classification according to frequency and power source.*

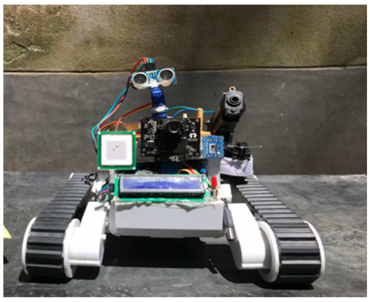

Figure 5. *Surveillance Bot developed in this research.*

Table 1. *Cost Breakdown of Proposed Surveillance Bot.*

No.	Type	Model	Price (USD)
1.	Microcontroller Board	YourDuino RoboRed	17
2.	Thermal Camera	Agafruit AMG8833	44
3.	Surveillance Camera	Pixy CMUcam5	60
4.	Chassis	Rover Tank 5	56
5.	Ultrasonic Sensor	HC-SR04	0.8
6.	Wi-Fi Module	NodeMcu ESP8266	6
7.	RFID Module	CF- MU801	140
8.	RFID Interface Connector	RS232	21
9.	RFID Antenna	CF-RA4040	19
10.	RFID Tags	G9305	3
11.	Miscellaneous	…………………….	10.2

Total Price = 377 (USD)

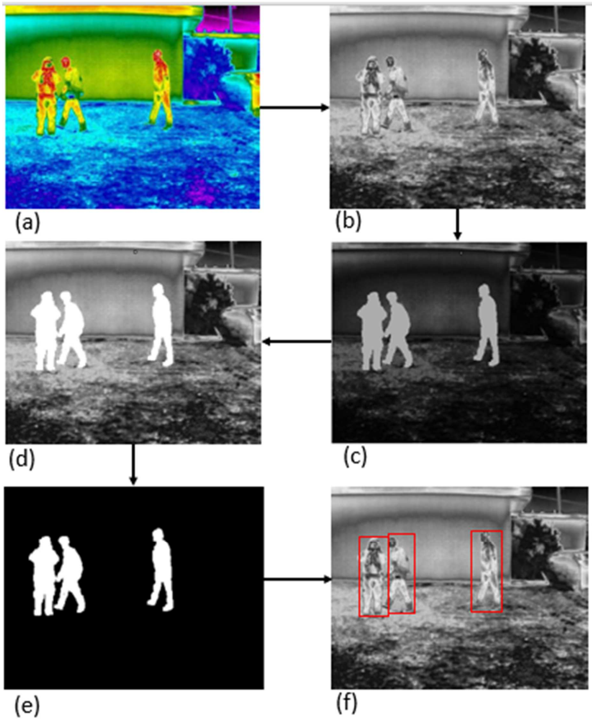

Figure 6. *Various steps in thermal iage processing. (a) original thermal image (b) greyscale converted image (c) Background substraction (d) high-boost filtering (e) local adaptive thresholding (e) human detected image.*

Table 2. *Efficiency of the RFID Human Identification System.*

Distance (m)	Number of Test Runs	Number of Successful Identifications	Efficiency (%)
0-6	25	25	100%
7-9	25	25	100%
10-12	25	25	100%
13-15	25	16	64%

6. Discussion and Comparison

DTMF based remote controlled bot in [3, 5] is vulnerable to noise during transmission and receiving section for which usage of DTMF based remote control systems has been largely reduced. Bluetooth and wireless based remote control systems have brought about a great change in development of complex remote-controlled bots. The proposed bot controls wireless based data transfer system in order to enhance the operating range [8].

In case of human detection, PIR sensor can be a low-cost choice for surveillance bots. However, for security purpose, high precision and live surveillance option is required [9-11]. Facial recognition-based image-processing for human identification in [12-15] are convenient for indoor operations. For outdoor operations, surveillance bots in [12-15] will not work effectively at night due to lack of sufficient light. Hence, the proposed bot utilized thermal image processing rather than processing image from normal camera.

For line following, the proposed bot used PixyCam rather than using IR sensor as in [22]. Since PixyCam offers both line following and live surveillance option, it helped the proposed bot to become more compact using less hardware [23].

The proposed surveillance bot developed in this work offers multifarious abilities with wide range of smart features. The existing surveillance bots mentioned in the literature review part does not have as much features as the bot developed in this work [3-8, 12, 13, 15, 20, 22-24, 26, 31, -3, 35, 36 39]. Hence, due to the smart features and the multifarious abilities, the surveillance bot developed in this work is quite effective for utilization in real life for security purpose.

7. Conclusion

A smart semi-automatic surveillance bot for highly restricted areas has been developed in this research. The surveillance bot is equipped with multifarious abilities in order to cope up with different security issues. Automatic monitoring, human detection and identification, live video streaming and manual remote control of the surveillance bot in this research can comply with the demand of high security issues in restricted areas. Moreover, the bot has the ability to maneuver in any terrain due to the tank chassis equipped with high torque motors. Hence, the surveillance bot is quite suitable for utilization in restricted areas for surveillance and security purpose.

References

[1] M. Hasan, M. H. Anik and S. Islam, "Microcontroller Based Smart Home System with Enhanced Appliance Switching Capacity," 2018 Fifth HCT Information Technology Trends (ITT), Dubai, United Arab Emirates, 2018, pp. 364-367.

[2] M. Hasan, P. Biswas, M. T. I. Bilash and M. A. Z. Dipto, "Smart Home Systems: Overview and Comparative Analysis," 2018 Fourth International Conference on Research in Computational Intelligence and Communication Networks (ICRCICN), Kolkata, India, 2018, pp. 264-268.

[3] P. Kuruba, A. Arjun, S. Aravind Kumar, A. L. Santosh Kumar and M. Prakash, "Surveillance Rover for Remote Areas," 2018 8th International Conference on Cloud Computing, Data Science & Engineering (Confluence), Noida, 2018, pp. 14-15.

[4] A. Hampapur, L. Brown, J. Connell, S. Pankanti, A. Senior and Y. Tian, "Smart surveillance: applications, technologies and implications," Fourth International Conference on Information, Communications and Signal Processing, 2003 and the Fourth Pacific Rim Conference on Multimedia. Proceedings of the 2003 Joint, Singapore, 2003, pp. 1133-1138 vol. 2.

[5] M. T. Rashid, P. Chowdhury and M. K. Rhaman, "Espionage: A voice guided surveillance robot with DTMF control and web based control," 2015 18th International Conference on Computer and Information Technology (ICCIT), Dhaka, 2015, pp. 419-422.

[6] S. M. Shaikh, K. Sufiyan, A. Ali and M. Ibrahim, “Wireless Video Surveillance Robot Controlled Using Simple Bluetooth Android Application,” International Journal of Advanced Research in Computer Science, vol. 6, no. 2. pp. 100-103, 2015.

[7] P. S. Shrungare, A. A. Bokde, N. U. Kashte and S. S. Raut, “Smart Phone Based Robot for Domestic Purpose Using Bluetooth,” International Research Journal of Engineering and Technology (IRJET), vol. 5, no. 1, pp. 694-697, 2018.

[8] D. Singh, P. Zaware and A. Nandgaonkar, "Wi-Fi surveillance bot with real time audio & video streaming through Android mobile," 2017 2nd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT), Bangalore, 2017, pp. 746-750.

[9] D. Priyanka and V. Karthik, “Wireless Surveillance Robot with Motion Detection and Live Video Transmission and Gas Detection,” International Journal Scientific Engineering and Technology Research, vol. 4, no. 17, pp. 3099-3106, 2015.

[10] Q. A. Kester, O. W. Chibueze and A. D. Asisat, “A Surveillance Wireless Camera Sensor Network for Intrusion Detection Using Image Processing Techniques,” APRN Journal of Engineering and Applied Sciences, vol. 10, no. 17, pp. 7394-7399, 2015.

[11] D. D. O. Golcalves and D. G. Costa, “A Survey of Image Security in Wireless Sensor Network,” Journal of Imaging, vol. 4, no. 30, pp. 1-30, 2015.

[12] H. R and M. H. Safwat Hussain, "Surveillance Robot Using Raspberry Pi and IoT," 2018 International Conference on Design Innovations for 3Cs Compute Communicate Control (ICDI3C), Bangalore, 2018, pp. 46-51.

[13] A. Vinay, A. Singh, N. Anand, M. Raj, A. Bharati, K. N. B. Murthy and S. Natarajan, “Surveillance Robots Based on Pose Invariant Face Recognition Using SSIM and Spectral Clustering,” Procedia Computer Science, vol. 133, pp. 940-951, 2018.

[14] A. Vinay, A. R. Deshpande, B. S. Pranathi, H. Jha, K. B. Murthy and S. Natarajan, “Effective Descriptors Based Face Recognition Technique for Robotic Surveillance Systems,” Procedia Computer, vol. 133, pp. 968-975, 2018.

[15] F. P. Mahdi, M. M. Habib, A. A. R. Ahad, M. Susan, A. S. M. Moslehuddin and P. Vasant, “Face Recognition-Based Real-Time System for Surveillance,” Intelligent Decision Technologies, vol. 11, no. 1, pp. 79-92, 2017.

[16] S. K. Sharma, R. Agrawal, S. Srivastava and D. K. Singh, "Review of human detection techniques in night vision," 2017 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET), Chennai, 2017, pp. 2216-2220.

[17] K. Lenac, I. Maurovi´c and I. Petrovi´ c, “Moving Object Detection Using a Thermal Camera and IMU on a vehicle,” 2015 International Conference on Electrical Drives and Power Electronics (EDPE), The High Tatras, 2015, pp. 212-219.

[18] D. ALshukri, V. L. R, S. E. P and P. Krishnan, "Intelligent Border Security Intrusion Detection using IoT and Embedded systems," 2019 4th MEC International Conference on Big Data and Smart City (ICBDSC), Muscat, Oman, 2019, pp. 1-3.

[19] M. Teutsch, T. Mueller, M. Huber and J. Beyerer, "Low Resolution Person Detection with a Moving Thermal Infrared Camera by Hot Spot Classification," 2014 IEEE Conference on Computer Vision and Pattern Recognition Workshops, Columbus, OH, 2014, pp. 209-216.

[20] Y. Khandhediya, K. Sav, V. Gajjar, Human detection for night surveillance using adaptive background subtracted image, 2017. Doi: arXiv:1709.09389.

[21] R. Soundrapandiyan, P. V. S. S. R. C. Mouli, “Adaptive Pedestrian Detection in Infrared Images Using Background Substraction and Local Thresholding,” Procedia Computer Science, vol. 58, pp. 706-713, 2015.

[22] D. Nikolov, G. Zafirov, I. Stefanov, K. Nikov and S. Stefanova, "Autonomous navigation and speed control for line following robot," 2018 IEEE XXVII International Scientific Conference Electronics - ET, Sozopol, 2018, pp. 1-4.

[23] M. D. B. Isa, A. R. B. Mohammad and M. Z. B. M. Hanifah, “Vision Mobile Robot System with Color Optical Sensor,” APRN Journal of Engineering and Applied Sciences, vol. 12, no. 4, pp. 1291-1295, 2017.

[24] S. Arumugam, A. P. Forsido and D. Adane, “Ultrasonic Sensor Based Obstacle Detection for Automobiles,” International Journal of Recent Treands in Engineering and Research, vol. 2, no. 5, pp. 268-274, 2016.

[25] M. Hasan, M. J. Hossein, U. K. Saha, M. S. Tarif, “Overview and Comparative Performance Analysis of Full Adder Cells in 90 nm Tecnology,” 2018 4th International Conference on Computing, Communication and Automation (ICCCA), Greater Noida, India, 2018, pp. 1-6.

[26] S. Polina, P. K. Barathula and K. P. P Rao, “Autonomous Obstacle Avoiding and Line Following Rover,” International Journal of Pure and Applied Mathematics, vol. 114, no. 9, pp. 272-279, 2017.

[27] M. Hasan, M. J. Hossein, M. Hossain, H. U. Zaman and S. Islam, “Desing of a Scalabel Low-Power 1-Bit Hybrid Full Adder for Fast Computation,” IEEE Transactions on Circuits and Systems II: Express Briefs, Early Access Preprint, 2019, doi: 10.1109/TCSII.2019.2940558.

[28] M. Hasan, M. H. Anik, S. Chowdhury, S. A. Chowdhury, M. T. I Bilash and S. Islam, “Low-Cost Appliance Switchong Cirucit for Discarding technical Issues of Microcontroller Controlled Smart Home,” International Journal of Sensors and Sensor Networks, vol. 7, no. 2, pp. 16-22, 2019.

[29] S. Chowdhury, F. R. Wasee, M. S. Islam, H. U. Zaman, “Bengali Handwriting Recognition and Convertion to Editable Text,” 2018 International Conference on Advances in Electronics, Computer and Communication (ICAECC), Bangalore, 2018, pp. 1-6.

[30] M. Z. Talukder, S. S. Towqir, A. R. Remon and H. U. Zaman, "An IoT based automated traffic control system with real-time update capability," 2017 8th International Conference on Computing, Communication and Networking Technologies (ICCCNT), Delhi, 2017, pp. 1-6.

[31] M. A. Islam, W. Ahad, M. Faisal and H. U. Zaman, "A cost-effective design and development of a surveillance robot," 2015 International Conference on Advances in Electrical Engineering (ICAEE), Dhaka, 2015, pp. 259-262.

[32] H. U. Zaman, M. M. H. Bhuiyan, M. Ahmed and S. M. T. Aziz, "A novel design of line following robot with multifarious function ability," 2016 International Conference on Microelectronics, Computing and Communications (MicroCom), Durgapur, 2016, pp. 1-5.

[33] H. U. Zaman, M. S. Hossain, M. Wahiduzzaman and S. Asif, "A novel design of a robotic vehicle for rescue operation," 2015 18th International Conference on Computer and Information Technology (ICCIT), Dhaka, 2015, pp. 507-510.

[34] M. Hasan, U. K. Saha, M. S. Hossain, P. Biswas, M. J. Hossein and M. A. Z. Dipto, "Low Power Design of a Two Bit Mangitude Comparator for High Speed Operation," 2019 International Conference on Computer Communication and Informatics (ICCCI), Coimbatore, Tamil Nadu, India, 2019, pp. 1-4.

[35] H. U. Zaman, T. A. Khan, S. R. Falgunee, G. S. Rashid and F. H. Talukder, "Autonomous Firefighting Robot With Optional Bluetooth Control," 2018 4th International Conference on Computing Communication and Automation (ICCCA), Greater Noida, India, 2018, pp. 1-4.

[36] H. U. Zaman, A. A. Joy, K. M. Akash and S. T. Fayad, "A simple and effective way of controlling a robot by hand gesture," 2017 International Conference on Intelligent Computing and Control Systems (ICICCS), Madurai, 2017, pp. 330-333.

[37] H. U. Zaman, J. S. Hossain, T. T. Anika and D. Choudhury, "RFID based attendance system," 2017 8th International Conference on Computing, Communication and Networking Technologies (ICCCNT), Delhi, 2017, pp. 1-5.

[38] R. Hossain, M. Ahmed, M. M. Alfasani and H. U. Zaman, "An advanced security system integrated with RFID based automated toll collection system," 2017 Third Asian Conference on Defence Technology (ACDT), Phuket, 2017, pp. 59-64.

[39] H. U. Zaman, J. Khisha, N. Zerin and M. H. Jamal, "Speech responsive mobile robot for transporting objects of different weight categories," 2017 18th International Conference on Advanced Robotics (ICAR), Hong Kong, 2017, pp. 395-400.

[40] M. Hasan, U. K. Saha, A. Sorwar, M. A. Z. Dipto, M. S. Hossain, H. U. Zaman, "A Novel Hybrid Full Adder Based on Gate Diffusion Input Technique, Transmission Gate and Static CMOS Logic," 2019 10th International Conference on Computing, Communication and Networking Technologies, Kanpur, 2019.

[41] M. Hasan, P. Biswas, M. S. Alam, H. U. Zaman, M. Hossain and S. Islam, "High Speed and Ultra Low Power Design of Carry-Out Bit of 4-Bit Carry Look-Ahead Adder," 2019 10th International Conference on Computing, Communication and Networking Technologies, Kanpur, 2019.

[42] R. Hossain, M. Ahmed, H. U. Zaman, "A Cost Effective Security Technology Integrated with RFID Based Automated Toll Collection System," Advances in Science, Technology and Engineering Systems Journal Vol. 2, no. 3, pp. 1777-1783, 2017.