Journal of Electrical Engineering and Automation (ISSN: 2582-3051)
www.irojournals.com/iroeea/

RoboSpy: Autonomous Night Vision Surveillance Robot with Spying Camera for War Field Operations

Jeffrey Sham R S.[1], Yashwanth M G.[2], Vamshi Krishna Y[3]

Department of Electronics & Instrumentation Engineering, Dayananda Sagar College of Engineering Bangalore, India

Email: [1]jeffreysham03@gmail.com, [2]mgyashwanthc4@gmail.com, [3]vamshikrishna8827@gmail.com

Abstract

RoboSpy is an autonomous surveillance robot designed for war field operations, equipped with night vision capabilities and a spying camera. Its primary goal is to provide real-time intelligence, enhance situational awareness, and reduce risks to soldiers by conducting reconnaissance in hazardous conditions. RoboSpy integrates advanced sensors, hardware, and software to navigate complex environments, detect obstacles, and transmit critical data to remote operators. The system architecture features a Raspberry Pi as the processing unit, ultrasonic sensors to detect objects, and a high-resolution night vision camera for real-time video capture. The software utilizes an intelligent HAAR Cascade classifier algorithm for object detection, path planning algorithms for navigation, and enhanced image processing techniques to capture the moving image. The RoboSpy provides real-time support for security forces to monitor the movement of intruders in the restricted area. This research discusses the design, implementation, and potential military applications of RoboSpy, emphasizing its role in reducing human intervention during high-risk reconnaissance missions.

Keywords: Autonomous Robot, Night Vision, HAAR Cascade, Remote Monitoring.

DOI: https://doi.org/10.36548/jeea.2024.4.004
Received: 17.12.2024, received in revised form: 19.01.2025, accepted: 01.02.2025, published: 12.02.2025

1 Introduction

In modern warfare, the demand for sophisticated surveillance technology is at an all-time high. Ensuring the safety of military personnel and gaining strategic advantages requires continuous monitoring and intelligence gathering, especially in challenging and hostile environments. This research introduces "RoboSpy," an autonomous night vision surveillance robot equipped with advanced human detection capabilities. Designed for war field operations, RoboSpy combines the technology to provide real-time surveillance and critical intelligence.[1] The primary objective of RoboSpy is to enhance situational awareness and operational efficiency in war zones. With its robust night vision system and high-resolution spying camera, RoboSpy is capable of operating effectively in low-light and nighttime conditions. Its autonomous navigation system, powered by machine learning algorithms and an array of sensors, allows it to maneuver through rough terrains and complex environments without human intervention. RoboSpy's human detection system is a key feature that sets it apart. Utilizing sophisticated image processing techniques and thermal imaging, the robot can accurately identify human presence even under camouflage or adverse conditions[2]. This capability is crucial for detecting enemy personnel and preventing surprise attacks, thereby increasing the safety of military operations. The spying camera's high optical zoom and infrared capabilities ensure detailed imaging and target identification from significant distances. Secure and encrypted wireless communication ensures that the data collected by RoboSpy is transmitted safely to remote command centers, maintaining operational security.

2 Literature Survey

The advancements in autonomous surveillance systems, particularly in remote surveillance applications, have gained significant attention in recent years. Various approaches and technologies have been explored to enhance surveillance capabilities, improve safety for military personnel, and reduce operational costs. This literature survey reviews key studies and developments in the field, highlighting advancements in autonomous robots, night vision systems, human detection techniques, and mobile surveillance platforms.

2.1 Autonomous Surveillance Systems

Autonomous surveillance robots have been explored in various contexts, including indoor application[3], military, surveillance[4], industrial, and security operations. Research in this area focuses on enabling robots to perform complex tasks without direct human control. Some notable studies, such as those demonstrate the potential of autonomous robots for military surveillance, particularly in environments where human presence is risky or impractical.[5] Their work emphasizes the use of machine learning algorithms and sensor fusion techniques for navigation and obstacle avoidance, which are the essential need for effective field operations.

3 Methodology

The implementation of RoboSpy involves the integration of various hardware and software components to create a fully functional autonomous surveillance robot

3.1 Hardware Setup

The main components of the hardware setup include Raspberry Pi 4, DC Motors and L293N Motor Driver, Camera, and Ultrasonic Sensors. RoboSpy is an autonomous vehicle capable of identifying intruders. The autonomous vehicle's movement can be monitored and controlled by the central processor based on the input from the sensors [6, 7].

The Raspberry Pi 4 **is** the main processing unit for RoboSpy. It manages data processing tasks, motor control, obstacle avoidance, image processing, and communication. Installed with Raspbian OS and configured to interface with sensors, motors, and the camera. DC Motors and L293N Motor Driver provide mobility for the robot[8]. Enable forward, backward, and directional movements. The motor driver controls the speed and vehicle’s direction. The DC motors are interfaced with Raspberry Pi to receive control signals for motor operation. The camera captures real-time video and images. Used for surveillance and human detection. The Raspberry Pi communicates with the camera through a USB port or camera interface. Ultrasonic sensors measure the distance to obstacles. It enables obstacle detection and avoidance.

3.2 Software Setup Operating System and Libraries

Raspbian OS. Installed on the Raspberry Pi 4. The necessary libraries are used for the implementation. OpenCV for image processing, RPi GPIO for GPIO pin control, and other necessary Python libraries for sensor interfacing and motor control. Artificial intelligence is now part of every application. Image processing is applied in various domains in engineering, medical, and agriculture fields [9]. There are diverse algorithms available to perform various calcifications. One of such AI-based Image Processing and Object Detection algorithms used in the research is HAAR Cascade Classifiers. HAAR Cascade Classifiers detect humans and objects in real-time video feed. Pre-trained HAAR Cascade models are used to identify specific features of humans and objects. It enables RoboSpy to detect and recognize targets during surveillance missions.

Path Planning A-star Algorithms, that is available in Python libraries is used to calculate optimal paths for navigation and HAAR Cascade assists in path planning to ensure that the robot can move through robust environments without collisions. Ultrasonic sensor data provides real-time distance measurements and is used to sense and avoid obstacles dynamically. Obstacle Avoidance adjusts the robot’s path to prevent collisions. Feedback from ultrasonic sensors is used to update the robot's movements. The wireless data transfer system communicates the data to remote operators. It ensures that the real-time videos and sensor data’s are available to military personnel for strategic decisions

4 System Architecture

The Raspberry Pi 4, acts as the main processing unit, managing data processing tasks, motor control, obstacle avoidance, image processing, and communication. It is installed with Raspbian OS and configured to interface with sensors, motors, and the camera. The Raspberry Pi USB camera[10] captures real-time images or video of the robot's environment, providing visual data for HAAR Cascade classifiers,[11] and the camera is directly connected to the Raspberry Pi 4 through a USB port. Ultrasonic sensors calculate the distance to objects ahead of the robot, ensuring obstacle detection and avoidance by providing real-time distance readings to the processor. The basic architecture is illustrated in Figure.1.

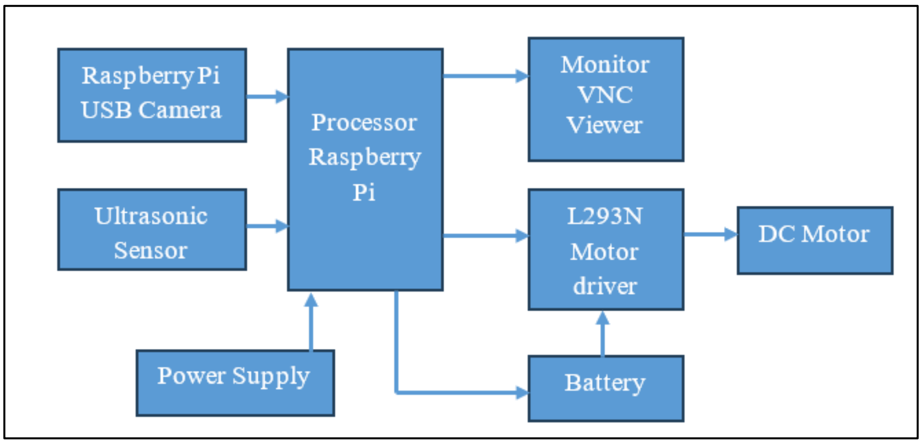

Figure 1. Architecture of Surveillance System

The L293N motor driver controls the speed and vehicle direction, it receives control signals from the Raspberry Pi to dictate the robot's movement. The DC motors provide movement for the robot, enabling it to move forward, backward, and turn, and are driven by the L293N motor driver. A monitor (VNC Viewer) allows remote monitoring and control of the Raspberry Pi, providing a visual interface for monitoring the robot's status and operations, accessed via VNC (Virtual Network Computing) viewer software. The power supply, typically provided by a power bank or a battery pack, supplies power to all the components of the system, ensuring continuous operation of the Raspberry Pi 4, USB camera, ultrasonic sensors, and motor driver. The battery provides portable and continuous power to the motor driver and motors, ensuring mobility and operational independence from fixed power sources, and is connected to the L293N motor driver.

The software development involves installing Raspbian OS on the Raspberry Pi 4 and utilizing libraries, such as OpenCV [12]for image processing and RPi.GPIO for GPIO pin control. HAAR Cascade classifier detects humans and objects in real-time video feed from the USB camera. Path planning algorithms calculate optimal paths for navigation, while ultrasonic sensor data provides real-time distance measurements for dynamic obstacle avoidance. Python scripts direct the speed and the vehicle direction based on navigation algorithms, with continuous feedback from ultrasonic sensors used to adjust the robot’s path and prevent collisions. Wireless communication transmits data to remote operators, ensuring real-time video and sensor data are available, and encryption secures the data transmission to maintain operational security.

4.1 HAAR Cascade Model

HAAR cascade classifiers detect faces[13, 14], bodies, and other predefined objects. In the RoboSpy project, HAAR cascade classifiers were used for detecting intruders with the help of surveillance footage captured by the night vision camera. HAAR cascade classifiers are a type of technique that is used to detect objects in images through various stages, where each stage is a classifier that can quickly determine whether an image region contains the object of interest or not. Image Input (Pre-processing). The first step in the HAAR Cascade algorithm involves capturing or loading an image or video frame in which object detection is to occur.

The input image is usually converted to grayscale because HAAR cascade classifiers require the images depending on the difference in light intensities, which is independent of color information[15]. The OpenCV converts the input image into a grayscale image by the weighted averaging method. Before applying HAAR-like features, the input image is converted into an integral image[16], also known as the summed-area table. The converted image allows rapid calculation of feature values, reducing the computational cost of evaluating the features over multiple regions of the image.

4.2 Software Implementation

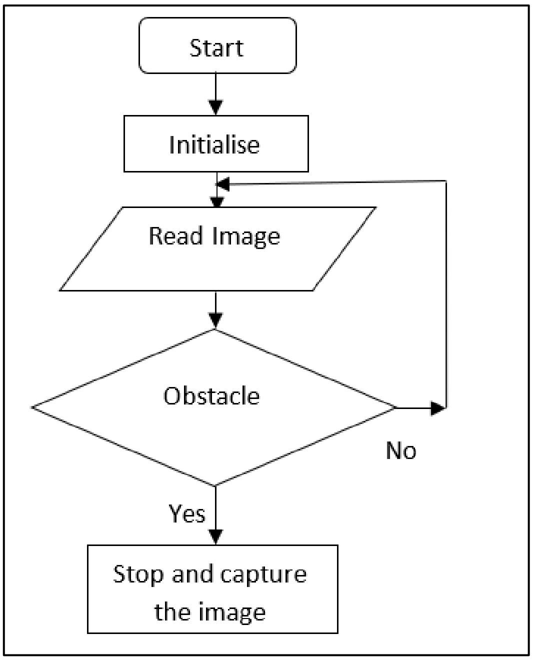

Figure 2. Flow Chart for Video Surveillance

The flowchart shown in Figure. 2. illustrates the function of surveillance algorithm.

Initialize: Set up and initialize all necessary components, such as sensors, motors, cameras, and communication modules.

Data Acquisition: Continuously monitor the surroundings using the ultrasonic sensor to detect obstacles.

Decision: If Obstacle is Detected

○Yes (Obstacle Detected)

Halt the Robot's Movement: Capture an image using the camera and send it through email. After sending the email, return to the main loop to continue monitoring the surroundings.

○No (No Obstacle Detected)

The robot's movement continues and keeps monitoring the surroundings with the ultrasonic sensor.

End. This is the end of one cycle. Again the process loop back to continue monitoring and responding to obstacles.

5 Prototype Development and Hardware Integration

The integration of ultrasonic sensor, camera, and motor driver with the Raspberry Pi is clearly illustrated in the Figure.3. The developed autonomous surveillance robot is capable of working in challenging and dynamic environments, with the capacity to detect human presence in low-light and complex settings. The RoboSpy implementation requires setting up the hardware with a Raspberry Pi running Raspbian OS. Connect a camera module to the Raspberry Pi for visual surveillance and integrate a thermal imaging sensor to detect human presence in low-light or camouflage scenarios. The motors are controlled through L293N motor driver, allowing precise navigation through rough terrain with the help of ultrasonic sensors that detect objects.

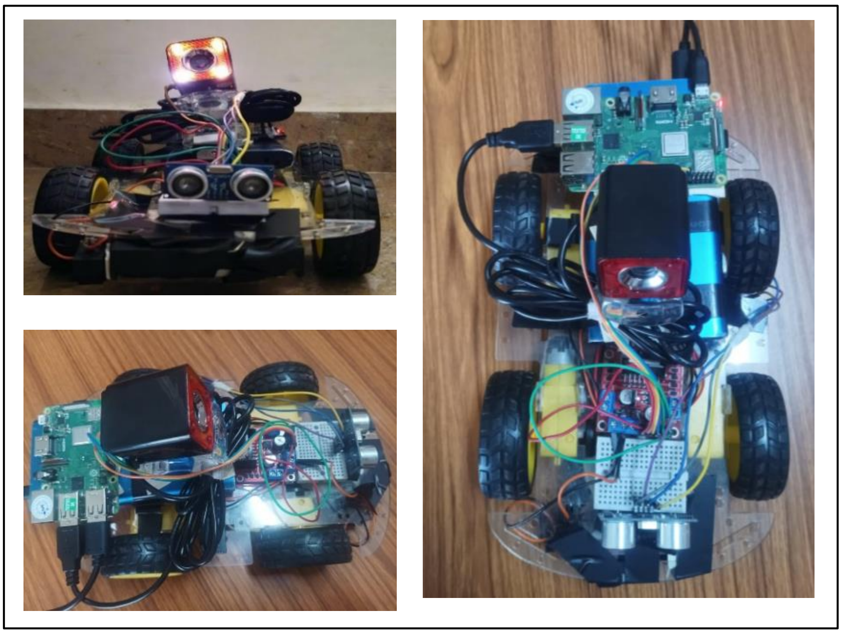

Figure 3. Prototype Image Showcasing Multiple Views

The OpenCV [17] will be used for real-time image processing. The entire system will operate autonomously, and a web interface will allow remote control and monitoring of the robot. Python will serve as the primary programming language to coordinate sensor data, motor control, and image processing in real-time. The goal is to enable the robot to navigate robust environments without human intervention while detecting and recognizing human.

```
camera = cv2.VideoCapture(0) # Open the USB camera (index 0)
SMTP_SERVER = 'smtp.gmail.com'
SMTP_PORT = 587
EMAIL_ADDRESS = 'mgyashwanth4@gmail.com'
EMAIL_PASSWORD = 'mjprwgjjuktthtab'
RECIPIENT_EMAIL = 'jeffreysham03@gmail.com.com'
# Face detection setup
face_cascade = cv2.CascadeClassifier('/home/pi/project
    /haarcascade_frontalface_default.xml')
```

Figure 4. Configuring SMT Protocol for Image Transfer

A Simple Mail Transfer Protocol (SMTP) ensures the captured images are send to the recipient’s electronics mail from the sender electronic mail. The SMT Protocol works through the Transmission Control Protocol (TCP). SMTP server controls the mail transfer to the recipient's electronic mail during the process. SMT protocol configuration is shown in the Figure. 4. The recipient and the sender's email id are entered in the code to ensure the transfer of the image.

6 Conclusion and Future Scope

RoboSpy is one of the solutions intended to address surveillance challenges. It’s camera system delivers high-resolution imagery even in the darkest conditions, enabling continuous real-time surveillance. It transmits video feeds to command centers, allowing for instant analysis of battlefield conditions. With its ability to remain undetected and traverse difficult terrains, RoboSpy can be an invaluable tool for military intelligence, covert operations, and enhancing battlefield awareness during nighttime missions. This research provides the avenues for the researcher to extend this mission in a multiple way. The data transfer mechanism can be incorporated with a sophisticated algorithm to transfer the image to any messaging platform with unique alarms, so that the concerned authorities may initiate the action immediately. The methodology may be used in the agriculture field to detect the movement of wild animals. The HAAR classifier may be applied in autonomous vehicle control systems to detect various parameters. The above advancements and technologies surely pave the path for research in smart surveillance and automation.

References

[1] Kanagaraj, R., Amsaveni, M.M., Binsha, S., Chella Keerthana, S.: Raspberry Pi-Based Spy Robot with Facial Recognition. In: Pandian, A.P., Palanisamy, R., Narayanan, M., and Senjyu, T. (eds.) Proceedings of Third International Conference on Intelligent Computing, Information and Control Systems. Springer Nature Singapore, Singapore (2022). 29–40.

[2] Jayakumar, A.J.K., Muthulakshmi, S.: Raspberry Pi-Based Surveillance System with IoT. In: Thalmann, D., Subhashini, N., Mohanaprasad, K., and Murugan, M.S.B. (eds.) Intelligent Embedded Systems. Springer Singapore, Singapore (2018). 173–185.

[3] Chang, Hsing-Cheng, Yu-Liang Hsu, Ching-Yuan Hsiao, and Yi-Fan Chen. "Design and implementation of an intelligent autonomous surveillance system for indoor environments." IEEE Sensors Journal 21, no. 15 (2021): 17335-17349.

[4] Witwicki, Stefan, Jose Carlos Castillo, Joao Messias, Jesus Capitan, Francisco S. Melo, Pedro U. Lima, and Manuela Veloso. "Autonomous surveillance robots: A decision-making framework for networked muiltiagent systems." IEEE Robotics & Automation Magazine 24, no. 3 (2017): 52-64.

[5] Zhao, Yanfei, Peng Xiao, Jingchuan Wang, and Rui Guo. "Semi-Autonomous Navigation Based on Local Semantic Map for Mobile Robot." Journal of Shanghai Jiaotong University (Science) (2023): 1-7.

[6] Sushma, R., and J. Satheesh Kumar. "Dynamic vehicle modelling and controlling techniques for autonomous vehicle systems." Journal of Electrical Engineering and Automation 4, no. 4 (2023): 307-315.

[7] Sushma, R., and J. Satheesh Kumar. "A survey on autonomous vehicles-benefits and drawbacks." Journal of Electronics and Informatics 4, no. 4 (2023): 237-245.

[8] Jishma, C. P., B. V. Praharshitha, Arpita Laxmi, S. K. Anusha, and J. Satheesh Kumar. "Development of Intelligent Driver Assistant System for Cognitive Cars." Journal of IoT in Social, Mobile, Analytics, and Cloud 4, no. 2 (2022): 108-118.

[9] Farhood, Helia, Ivan Bakhshayeshi, Matineh Pooshideh, Nabi Rezvani, and Amin Beheshti. "Recent advances of image processing techniques in agriculture." Artificial Intelligence and Data Science in Environmental Sensing (2022): 129-153.

[10] Youssef, Almoatazbellah, Andreas Rosenwald, and Mathias Tillmann Rosenfeldt. "TelePi: an affordable telepathology microscope camera system anyone can build and use." Virchows Archiv 485, no. 1 (2024): 115-122.

[11] Gaur, Sachin, Milind Pandey, and Himanshu. "Realization of Facial Recognition Technology for Attendance Monitoring Through Biometric Modalities Employing MTCNN Integration." SN Computer Science 5, no. 7 (2024): 862.

[12] Wang, Y., Wang, H.: A face template: Improving the face generation quality of multi-stage generative adversarial networks using coarse-grained facial priors. Multimed Tools Appl. 83, (2024). 21677–21693.

[13] Shetty, Anirudha B., and Jeevan Rebeiro. "Facial recognition using Haar cascade and LBP classifiers." Global Transitions Proceedings 2, no. 2 (2021): 330-335.

[14] Obukhov, A.: Haar classifiers for object detection with CUDA. GPU Computing Gems Emerald Edition. 517–544 (2011).

[15] Tasyurek, Murat, and Ertugrul Gul. "A new deep learning approach based on grayscale conversion and DWT for object detection on adversarial attacked images." The Journal of Supercomputing 79, no. 18 (2023): 20383-20416.

[16] Abirami, S.P., Kousalya, G., Balakrishnan, Karthick, R.: Varied Expression Analysis of Children With ASD Using Multimodal Deep Learning Technique. Deep Learning and Parallel Computing Environment for Bioengineering Systems. 225–243 (2019).

[17] Culjak, I., Abram, D., Pribanic, T., Dzapo, H., Cifrek, M.: A brief introduction to OpenCV. In: 2012 Proceedings of the 35th International Convention MIPRO. (2012). 1725–1730.