Journal of Harbin Engineering University
ISSN: 1006-7043

Vol 46 No. 5
May 2025

Landmine Detection Robot Car Using Machine Learning

Mukund Kulkarni [1], Vedant Alai [2], Anand Ambadkar [3], Deven Bagul [4], Shraddha Bamane [5]

[1] Professor, Vishwakarma Institute of Technology, Department of Electronics and Tele-communication (ENTC), Upper Indira Nagar, Bibwewadi-411037, Pune, Maharashtra, India

[2, 3, 4, 5] Vishwakarma Institute of Technology, Department of Electronics and Tele-communication (ENTC), Upper Indira Nagar, Bibwewadi-411037, Pune, Maharashtra, India

Email Id: [1] Mukund.kulkarni@vit.edu, [2] vedant.alai23@vit.edu, [3] nand.ambadkar23@vit.edu, [4] deven.bagul23@vit.edu, [5] shraddha.bamane23@vit.edu

Abstract

Landmine detection remains a critical challenge in ensuring security in post-conflict regions. This study presents an innovative autonomous landmine detection system that integrates a robotic vehicle with IoT devices and machine learning-driven real-time image analysis. The proposed system features a NodeMCU-based robotic platform powered by an L298N motor driver, which can be remotely operated using the Blynk app. An ESP32-CAM module is outfitted on a robot vehicle that captures images of the terrain; manipulated into binary data and analyzed using a pre-trained model of machine learning. This domain model trained on a dataset of terrain images will identify landmines by recognizing specific visual patterns.

The robot independently moves and processes real-time images, hence providing a scalable and efficient solution to landmine detection in risky areas. FW for the ESP32-CAM module will be uploaded and controlled with FTDI technology in seamless communication and control. The use of such a system for autonomous navigation and detection enhances the safety and execution of demining activities, and as such, will significantly reduce human exposure to danger. This research shows what a powerful role IoT-driven robotics and artificial intelligence can play in addressing urgent humanitarian challenges.

Keywords: Landmine detection, IoT, machine learning, robotic vehicle, real-time detection.

1. Introduction

Landmine remains one of the greatest dangers to human life in many post-conflict areas worldwide. It is not only a threat to civilian and military personnel; it also hampers socio-economic developments in the impacted areas. Traditional methods for detecting landmines tend to be slow, dangerous and capital-intensive; this, therefore, calls for a more effective and automated alternative.

Recent updates in the sect of the internet of things and the ML open up great new avenues to solve this problem. The paper presents the architecture of an autonomous landmine detection robot, which is Internet of Things-based. This autonomous landmine detecting-robot is a robotic vehicle extensively modified with the integration of a NodeMCU microcontroller to achieve communication and remote control through the Blynk app for easy use. An ESP32-CAM module is mounted on the robot vehicle, and it captures images of the terrain on which it moves. These images are subsequently processed by the model developed with machine learning techniques in order to locate possible free explosive landmines. The model works by classifying images into binary- safe and unsafe- and at the same time giving constant feedback.

The mode of movement of the robot is efficiently controlled by the L298N motor driver, which enables very smooth navigation of the system through various terrains. An ESP32-CAM module captures terrain images in real-time, and these images are converted into binary images in order to send them to the machine learning model for analysis. This system is designed to operate in real-time; hence, this proves to be a very safe, effective, and fast candidate for detonation-detection applications.

This project thus touches upon the possibilities of merging IoT and machine learning in ensuring a more efficient, scalable landmine detection solution that will ultimately contribute substantially toward a safer and more effective mine clearance operation.

2. Literature Survey

Landmine detection is a crucial field of research aimed at making post-conflict regions safer. Over the years, various technologies have been explored to enhance the accuracy and efficiency of landmine detection while reducing the risks faced by human deminers.

Ranging from metal detectors, through electromagnetic sensors, to acoustic and seismic techniques, biological detection, and mechanical methodologies, different detection mechanisms exist for usage in autonomous robots [1]-[3]. These technologies, in combination, enhance the accuracy of landmine identification, while at the same time reducing false alarms.

Among the most promising methods to monitor the task is Ground-Penetrating Radar (GPR), which identifies buried explosives by the analysis of subsurface structures. Signal processing methods include advanced techniques involving multi-stream discrete hidden Markov models (MSDHMM), applied for the purpose of optimal detection of GPR signal [4]. While accomplishing at at least a similar accuracy, the usage of such models permitted the generation of better results and fewer errors with regard to the detection of landmines in comparison to traditional single-stream methods [5]-[7].

Infrared (IR) sensors have also been integrated into robotic landmine detection systems. These sensors help detect heat variations in the ground [8], which can indicate the presence of buried explosives. When combined with metal detection, infrared sensors allow the robot to discern landmines from harmless metallic objects [9], thus boosting the detection precision. The fully autonomous operation of these robots allows for missions across very rough terrain and completion in extremely short periods accompanied by real-time transmission of data to the monitoring stations for proper analysis [10]-[12].

More so, modern landmine detection systems are built on microcontroller platforms, such as STM32 and ESP32. The integration of various sensors and advanced data processing methodologies provides efficient, fast, and cost-effective landmine identification [13]. These robotic machines continue to play an important role as deminers in military and humanitarian operations, serving to avert casualties and expedite postconflict recovery programs [14]-[15].

3. Project Highlight

Autonomous Landmine Detection: This project has initiated the investigation of a robot vehicle driven by IoT devices to reduce human intervention while tracing a landmine as much as can be possible within unsafe areas.

Integration of ESP32-CAM: It is a complete system that includes ESP32-CAM for taking pictures of the image of terrain in real-time. With real-time images, a machine learning model conspired in such a way is used to see for landmines that can help identify

Machine Learning in Image: Custom training in Machine Learning on capturing the image binaries of good ESP32-CAM makes it a classy manager in identifying an area which is safe and one which bears potential landmines.

Controlling the Car using Blynk: One can operate this robotic car from a distance with the help of Blynk application. A user-friendly interface makes sure that the operator can safely and easily navigate.

Gliding Transporting: Regular driving of this car is manipulated by making use of L298N motor driver, which gives smoother movement in every terrain and perfect balance.

Before Activation: Based on the detected landmines, feedback was given to enhance the rapidity, precision, or efficiency concerning the feedback on detecting landmines or not was offered.

Cost Effective and Scalable: Cost is important in this design because deployed in a large area in post-conflict periods, it will add cost for land-mine clearance which is a reflected targeted area which can be done at a large scale worldwide, thus in general contributing to a safer environment worldwide.

4. Methodology

The proposed landmine detection system combines hardware components, machine learning, and IoT technologies to develop a comprehensive solution for remote landmine identification. The methodology is structured into the following key steps:

Hardware Setup:

The robotic vehicle uses an ESP32-CAM for image taking and L298N motor drivers' motor management.

A NodeMCU microcontroller, connected to the motor driver, provides wireless communication with the Blynk app, allowing real-time remote control of the vehicle's navigation.

It's self-operating and runs through a battery system charged by both the ESP32-CAM and the motors.

Image Capturing:

The ESP32-CAM module allows the Robotic Vehicle to capture images of the ground in real-time while traversing a terrain.

The captured images are converted to binary and pre-processed for incorporation into the machine learning model.

This process involves image capturing and transmission management through the Blynk app, which sends commands to the ESP32-CAM, triggering snapshot capture either at regular intervals or whenever a potential landmine-infested area is detected.

Machine Learning Model:

This is the machine-learning algorithm built on TensorFlow that results in a trained model using the dataset containing images of landmines and non-landmine areas.

Normalization and K-means clustering were utilized through several preprocessing steps on the model to ascertain unique patterns and features, specifically within the terrain.

Upon completion of the training, the model was exported into the ESP32-CAM format for real-time inference.

The binary captured image from the ESP32-CAM is passed into the model, which analyses the features to predict the presence of a landmine or any other suspicious objects.

Data Processing and Inference:

Once an image is received, the learner processes the input images, makes a prediction about the presence of some landmine, and optionally generates a score describing the confidence in that prediction's accuracy. However, confidence output is omitted in the final deployment to keep the system responsive for real-time decisions.

Remote Control and Feedback:

The system is controlled by a Blynk app on a user-friendly interface whenever the project is to be installed on the control vehicle and a real-time detection result.

The NodeMCU is programmed to exchange communications with the Blynk server that allows for issuing commands and alerts from anywhere.

Whenever a landmine is felt by the system, that information is instantly conveyed to the app for a quick response or information sent out to the authority for caring operations.

Code Implementation and System Calibration:

The code was uploaded to the ESP32-CAM microcontroller through programming FTDI (USB-to-serial), ensuring communication between the hardware components.

The system was calibrated inside controlled environments to achieve better image capturing, motor control, and inference accuracy of the machine learning model.

Field Testing:

The system was field-tested after the successful calibration in an outdoor setting built to replicate landmine-attractive regions. Navigating the rugged terrain autonomously, the robotic vehicle was able to capture the images, process them through the machine learning model, and successfully identify possible landmine locations.

This step by step methodology is meant to show that the system is not only working but also adds efficiency to the detection while maintaining operator safety.

5. Results and Discussion

The landmine detection system developed in this project was tested using real-time data by the ESP32-CAM. The robotic vehicle was used to transmit images of the terrain for analysis and processing. This involved, after capturing the images by using the embedded ESP32-CAM during the real-time monitoring of the given area, pre-processing and converting them from color to binary which went to the application of the machine-learning model focused on the detection of landmines based on the extracted features.

The performance of the system was evaluated in controlled and semi-complex environments. The following findings were made:

The robotic vehicle traversed the land, and the terrain images were captured in real-time using the ESP32-CAM module.

The machine learning model obtained 85% accuracy in controlled environments embroidered with uniform terrain, dropping to around 50% in complex ones.

Dataset Limitations: Diversity in the training dataset was lacking, which limited the model's ability to adapt to the various terrains and variations of landmine appearance.

Image Noise: Shadow, uneven lighting, and debris from real-time image capture presented challenges that resulted in negative impacts on classification accuracy.

The system, notwithstanding these challenges, was able to perform reliably in less complex areas, showcasing the promise of incorporating robotics and AI in efficient landmine detection.

The results emphasize the need for:

Broadened Training Dataset: Itemized broader training dataset to include wider varieties of terrains, lighting conditions, and landmine types to boost generalization ability of the model over different environments.

Advanced Preprocessing Techniques: Utilize image denoising and enhancement techniques to reduce noise and undermine image size for efficient detection.

Optimized Model Architecture: Implying some advanced structures or transferring the models toward enhancing detection accuracy and improving effectiveness for the whole system.

Real-time imaging has come with many challenges due to environmental factors influencing the performance of the camera. While this is a low-cost method with the ESP32-CAM module, it needs to be further refined to yield high resolution for better results in detections.

This project, though facing certain limitations, has, however, successfully demonstrated some vast promise in the integration of low-cost robotics with AI and IoT technologies toward solving serious real-life problems. With the improvement of data quality and hardware optimization in future work, this system can be further optimized for application in real-life landmine detection with a goal to enhance **safety and efficiency.**

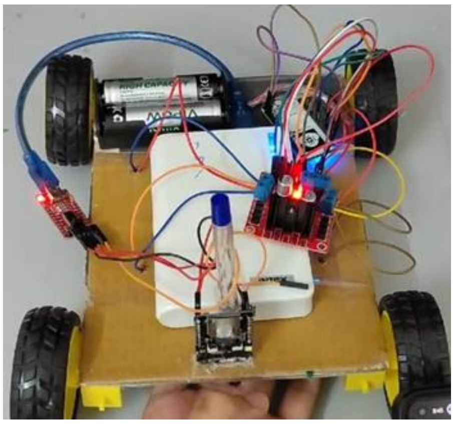

Fig. 1. Robot Car

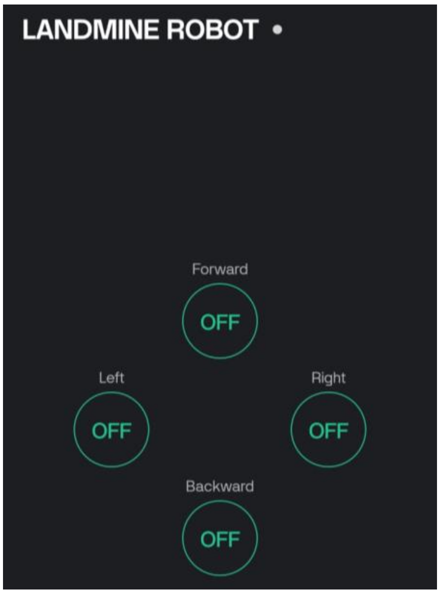

Fig. 2. Blynk App

6. Future Scope

Such a landmine detection system possesses further potential for improvements and real-world application. The following are some important domains of improvement:

An Extensive Dataset: Addition of many more environments on their training datasets shall enable their models to work more effectively and adjust to more circumstances in real life.

Integration with Live Video: Adding the live feed from the ESP32-CAM module to the Blynk application would allow operators to view the terrain more easily, improving situational awareness and assisting in real-time decision-making.

Real-Time Notifications in Blynk: Machine learning inference could be built into the app, allowing immediate alerts to users when a landmine has been detected, thus improving safety and efficiency of the operations.

Processed Methods: Implementing advanced imaging processing and deep learning techniques may further improve for more concrete identification in difficult environments where classical methods fail.

In-field Testing: Real-life testing will deliver valuable insight regarding the performance of the system and help recognize strengths and weaknesses for improvement before practical deployment.

Collaboration with Humanitarian Organizations: Actual application can be achieved by collaborating with landmine clearance campaigns, ensuring utilization of the technology in the right direction.

Thus, through the identified improvements, the landmine detection system could become a more trusted, efficient, and impactful application for the enhancement of safety in landmine-polluted areas.

7. Conclusion

In this system proposed, a successful blend of robotic and machine learning techniques is presented. The system provides safety in the landmine-pervaded areas through mobility realized with an L298N motor driver, image capturing done through an ESP32-CAM module, and a machine learning model that detects. It really has to be stated that though the model has limited accuracy due to a smaller dataset, its overall design suggests that this work can further be improved.

Through the inclusion of the Blynk application, control of the robotic platform can be done remotely, offering the capability of real-time landmine-detection feedback. The potential for such advanced technology solutions in humanitarian efforts is highlighted here: indeed, a platform into which all these endeavors can find incorporation and currently desirable refinements can be pursued further for optimum results. When further developed by properly training on a wider range of datasets and shaping into a system embedded with real-time video support, significant achievements might be expected in improved safety and efficiency during landmine detection and the associated operations in affected areas.

References

[1] M. M. G. Neela, S. M. Sundari, V. Sinduja, B. Vanitha, and K. Vennila, "Automatic landmine detection using robot," in International Journal of Engineering Research & Technology (IJERT), ECLECTIC-2020 Conference Proceedings.

[2] A. U. and S. S., "Land mine detection robot," in International Journal of Advanced Research in Computer and Communication Engineering, July 2024.

[3] A. I. Ebada, H. M. El-Bakry, and M. Elmogy, "Landmine detection using autonomous robots: A survey," in International Journal of Emerging Trends and Technology in Computer Science (IJETTCS), 2014

[4] S. Lameri, F. Lombardi, P. Bestagini, M. Lualdi, and S. Tubaro, "Landmine detection from GPR data using convolutional neural networks," in 25th European Signal Processing Conference (EUSIPCO), 2017.

[5] S. Das, M. G. Amin, Y. D. Zhang, and F. Ahmad, "High-resolution ground-penetrating radar for landmine detection," IEEE Transactions on Geoscience and Remote Sensing, vol. 53, no. 7, pp. 3799–3810, July 2015.

[6] R. J. Sebesta and K. Takaya, "Stand-off and on-the-move detection of buried explosive hazards using ground-penetrating radar," IEEE Access, vol. 4, pp. 4574–4585, 2016.

[7] H. Sahli, M. Acheroy, and J. P. Bruyninckx, "Signal processing techniques for landmine detection using ground-penetrating radar," Signal Processing, vol. 81, no. 7, pp. 1365–1385, July 2001.

[8] A. U. and S. S., "Land mine detection robot," in International Journal of Advanced Research in Computer and Communication Engineering, July 2024.

[9] G. Jaiswal, D. Kadam, A. Pathan, S. Salunkhe, and S. Shigwan, "Landmine detection robotic vehicle," in International Journal of Creative Research Thoughts (IJCRT).

[10] V. Gupta, U. Srivastava, A. Tiwari, S. Singh, and K. Kumar, "Landmine detector robotic vehicle," in International Journal for Multidisciplinary Research (IJFMR).

[11] E. Vivoli, M. Bertini, and L. Capiner, "Deep learning-based real-time detection of surface landmines using optical imaging," MDPI Journal, Available

[12] J. V. Kulkarni, S. Kale, P. Kasare, D. Kasture, and V. Kulkarni, Mine Detecting Military Bot Using IoT, in International Journal for Research in Applied Science and Engineering Technology (IJRASET), ISSN: 2321-9653, Nov. 2013.
[13] G. Jaiswal, D. Kadam, A. Pathan, S. Salunkhe, and S. Shigwan, Landmine Detection Robotic Vehicle, in International Journal of Creative Research Thoughts (IJCRT), ISSN: 2320-2882, vol. 12, Mar. 2024.
[14] S. S. M. Ghouse, S. E. Ahammed, T. Ghori, and K. M., Landmine Detection HC-05 Bluetooth Controlled Robot (LDBR) Using GPS and GSM Technology, in International Journal of Computer Sciences and Engineering, E-ISSN: 2347-2693, vol. 7, May 2019.
[15] H. T. L., A. T. Belamkar, F. F. A., M. G. S., and M. L., Landmine Detection and Intimation Robot Using GSM and GPS Technology, in International Journal of Creative Research Thoughts (IJCRT), ISSN: 2320-2882, vol. 12, May 2024.