**SAR: Search & Rescue Rover**

**Capstone Project Proposal**

**Submitted by:**

102203010 - MOKSHIT SANDHU

102203058 - VAISHNAVI GERA

102203364 - TANISHQ GOYAL

102203396 - UDHAV BANSAL

102215102 - ISHU KUMAR

**BE Third Year- COE**

**CPG No. 268**

Under the Mentorship of

Dr. Tarunpreet Bhatia

(Associate Professor)



**Computer Science and Engineering Department**

**Thapar Institute of Engineering and Technology, Patiala**

**Feb, 2025**

**TABLE OF CONTENTS**

|  |  |
| --- | --- |
| * Mentor Consent Form | 3 |
| * Project Overview | 3 |
| * Problem Statement | 4 |
| * Need Analysis | 5 |
| * Literature Survey | 6 |
| * Objectives | 8 |
| * Methodology | 9 |
| * Project Outcomes & Individual Roles | 10 |
| * Work Plan | 12 |
| * Course Subjects | 12 |
| * References | 13 |

**Mentor Consent Form**

I hereby agree to be the mentor of the following Capstone Project Team

|  |  |  |
| --- | --- | --- |
| **Project Title:** SAR: Search & Rescue Rover | | |
| **Roll No** | **Name** | **Signatures** |
| 102203010 | MOKSHIT SANDHU |  |
| 102203058 | VAISHNAVI GERA |  |
| 102203364 | TANISHQ GOYAL |  |
| 102203396 | UDHAV BANSAL |  |
| 102215102 | ISHU KUMAR |  |

NAME of Mentor: Dr. Tarunpreet Bhatia

SIGNATURE of Mentor: . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

**Project Overview**

In disaster-stricken or hazardous environments, rapid and efficient situational awareness is critical for effective rescue operations. This project aims to develop a hardware prototype of an Unmanned Ground Vehicle (UGV) designed to autonomously navigate through difficult terrains while collecting real-time data using multiple onboard sensors. Equipped with LIDAR, thermal cameras, GPS, and environmental sensors, the UGV will identify obstacles, map unknown terrains, and detect human presence in rescue scenarios. Its rugged design and autonomous navigation will allow it to operate where human intervention is unsafe or impractical.

To enhance its capabilities, the UGV will integrate an ensemble-based Computer Vision system for fire detection using deep learning models. Sensor fusion techniques will process LIDAR data, creating real-time 3D maps to assist rescue teams. The UGV will incorporate automated movement control and human presence detection, ensuring optimized path planning and efficient exploration. Machine learning algorithms will interpret sensor data, improving situational awareness.

A key component of this project is a real-time integrated dashboard, allowing rescue personnel to access site information remotely. It will visualize fire hazards, human locations, terrain maps, and sensor readings, providing a comprehensive environmental overview. Through AI-driven automation and real-time analytics, this UGV will enhance rescue operations, improving response times and operational efficiency in disaster relief missions.

**Problem Statement**

The primary challenge in disaster rescue operations is the lack of real-time situational awareness, which results in delayed response times and increased risks to human rescuers. Current methods rely heavily on manual intervention, limiting their effectiveness in hazardous environments. By developing an AI-driven UGV, this project aims to bridge the gap between traditional rescue methods and modern technology-driven solutions, enhancing both efficiency and safety.

In many disaster scenarios, first responders struggle with poor visibility, debris-covered landscapes, and inaccessible areas. The integration of LIDAR for 3D mapping, thermal imaging for detecting trapped individuals, and AI-based fire detection enables the UGV to gather critical environmental data that human rescuers might miss. Additionally, automating movement and terrain analysis ensures effective coverage of affected areas, reducing time delays and improving the overall success rate of rescue missions.

**Need Analysis**

Rescue missions in disaster-prone or hazardous environments pose significant risks to human responders. Natural disasters like earthquakes, wildfires, floods, industrial accidents, and building collapses create complex terrains and extreme conditions that make manual search-and-rescue efforts difficult. Limited visibility, unstable structures, and unpredictable fire outbreaks further hinder rescue operations, often leading to delays in locating and assisting survivors. There is a pressing need for an autonomous system that can navigate these challenging environments and provide real-time situational awareness to rescue teams.

Traditional rescue methods rely on human intervention, which can be slow and dangerous. An AI-powered Unmanned Ground Vehicle (UGV) equipped with computer vision, LIDAR-based mapping, and real-time analytics can significantly improve search-and-rescue efficiency. By automating navigation, detecting fires, and identifying human presence, the UGV can reduce risks to rescue personnel and speed up victim identification. Moreover, its ability to process and relay sensor data in real-time through a centralized dashboard ensures better coordination, informed decision-making, and optimized resource allocation during emergency response efforts.

**Literature Survey**

The following section deals with the survey of the existing systems, tools, and technologies used for autonomous disaster response, focusing on Unmanned Ground Vehicles (UGVs), sensor fusion, AI-driven fire detection, and autonomous navigation.

**Theory Associated with the Problem Area**

Unmanned Ground Vehicles (UGVs) equipped with advanced AI, robotics, and sensor technologies have proven critical in disaster response. UGVs are utilized for navigating hazardous terrains, detecting fire hazards, and mapping complex environments with real-time data integration. Automating disaster response systems reduces human risks and enhances operational efficiency, making this an essential research area.

Unmanned Ground Vehicles (UGVs) have become an integral part of disaster response operations, thanks to their ability to navigate hazardous terrains with precision and efficiency. These vehicles are equipped with advanced sensors such as LIDAR, thermal cameras, and GPS, which work together to create detailed 3D maps of disaster zones. By integrating AI-driven algorithms, UGVs can identify obstacles, detect hazards, and optimize navigation paths in real-time. This automation reduces the reliance on human intervention in high-risk areas, ensuring the safety of rescue personnel while accelerating critical response efforts. UGVs are also designed to operate in dynamic environments, adapting quickly to changing conditions and unforeseen challenges.

In addition to navigation and hazard detection, UGVs play a pivotal role in streamlining communication and decision-making during disaster scenarios. Real-time data collected by UGVs can be transmitted to centralized dashboards, enabling rescue teams to visualize the affected area, prioritize tasks, and allocate resources effectively. Recent research findings have reinforced the effectiveness of UGVs in disaster response, with key studies highlighting improvements in SLAM robustness, real-time mapping accuracy, and survivor detection.

**Research Findings from Existing Literature**

Liu et al. [1] enhanced LiDAR-inertial SLAM for UGVs in search and rescue by using a particle swarm filter and loop closure, improving localization accuracy. Tested in real-world environments, the system showed high efficiency and robustness.

Singh et al. [2] integrated YOLOv8-Seg with ORB-SLAM3 to remove dynamic objects, achieving a 78.80% improvement in trajectory accuracy, ensuring stable robotic navigation in dynamic environments.

Zade et al. [3] developed a deep learning system for real-time survivor detection in UAV thermal imagery, improving search and rescue efficiency with high human detection accuracy.

Hasan et al. [4] introduced an explainable AI-enhanced YOLOv8 model for fire detection, achieving 98% fire accuracy and 99.1% mAP, ensuring reliable hazard recognition.

Li et al. [5] proposed the TAD-RRT\*-Smart algorithm for UGV path planning, optimizing route selection for efficient and stable maneuverability in disaster scenarios.

Surmann et al. [6] reviewed lessons from German rescue robotics deployments, emphasizing real-world testing and collaboration to improve disaster response readiness.

Huang et al. [7] explored FPGA-based AI for UAV and UGV search and rescue, achieving 90% survivor detection accuracy and 1.7–1.9× faster processing speeds.

Ocando et al. [8] developed a 2D SLAM and 3D mapping system using a single 2D LiDAR with ROS, enabling cost-effective and accurate disaster response mapping.

Murcia et al. [9] introduced a 3D scene reconstruction method using a 2D moving LiDAR. Their approach efficiently generated accurate 3D maps, validated through real-world experiments, offering a cost-effective solution for robotics and autonomous navigation.

Yan and Ma [10] developed a real-time obstacle avoidance algorithm using 2D LiDAR. Their method enabled autonomous systems to navigate dynamic and unstructured environments effectively, proving valuable for applications like search and rescue operations.

Yan et al. [11] proposed an online learning approach for 3D LiDAR-based human detection. By improving point cloud clustering and classification, their method achieved high detection accuracy and robustness, enhancing real-time human-robot interaction and safety.

Choi and Kim [12] combined LiDAR with a thermal infrared camera for autonomous vehicles. Their deep learning-based detection framework significantly improved object recognition in low-visibility conditions, enhancing navigation and safety in challenging environments.

**Objectives**

Following are the objectives of our project:

* To design and develop an unmanned ground vehicle (UGV) capable of navigating hazardous terrains using LIDAR.
* To enhance autonomous navigation by incorporating intelligent obstacle avoidance and optimized route planning for efficient movement in disaster zones.
* To leverage LIDAR technology to generate 3D maps, assisting rescue teams in disaster-stricken areas.
* To integrate thermal imaging and vision-based AI models to detect and locate survivors efficiently.

**Methodology**

1. **Research and Requirements Gathering**

The first step is to understand the challenges in disaster-response situations and identify the necessary technologies. Research AI, sensor technologies (like thermal, LIDAR, GPS), and their application in unmanned ground vehicles (UGVs). Gather information on the performance requirements for both hardware and software.

**2.** **Hardware Design and Integration**

Select the required sensors (thermal for human detection, LIDAR for mapping, and GPS for location tracking). Design the physical structure of the UGV, ensuring that the sensors can be integrated smoothly. This step ensures that the UGV can operate in difficult environments and collect the necessary data.

1. **Sensor Data Processing and Fusion**

Once the hardware is set up, process the data from the thermal, LIDAR, and GPS sensors. Thermal data is essential for detecting humans, while LIDAR data helps with mapping and obstacle detection. The data from multiple sensors is fused together to create a detailed and accurate 3D representation of the environment, allowing the vehicle to understand its surroundings.

**4.** **Machine Learning and Computer Vision Development**

Now that the sensor data is processed, develop AI models to interpret this data. For human detection, deep learning models like CNNs (for image recognition) and YOLO (for real-time object detection) will be trained using thermal and visual data. The machine learning models will help identify survivors, obstacles, and fire hazards, allowing the UGV to make decisions based on real-time input.

**5.** **Autonomous Navigation and Obstacle Avoidance**

Develop algorithms that allow the UGV to autonomously navigate the terrain. Using SLAM (Simultaneous Localization and Mapping), the UGV will create accurate maps of the environment and plan safe paths. Obstacle detection and avoidance strategies are critical to ensure that the UGV can navigate through unknown and hazardous environments without human intervention.

**6.** **Real-Time Dashboard Development**

Build a dashboard for the rescue teams to monitor the UGV’s status and environment. The dashboard will display sensor data, maps, and alerts (like fire detection or human presence) in real time. This ensures that rescue teams can make timely and informed decisions during operations.

**Project Outcomes**

### **Functional Prototype of UGV for Disaster Response**

### The primary objective is to develop a functional prototype of an Unmanned Ground Vehicle (UGV) equipped with advanced AI, LIDAR, and machine learning algorithms. This system will be capable of accurately navigating hazardous terrains, detecting fire hazards, and generating high-resolution 3D maps. The prototype will showcase the integration of intelligent obstacle avoidance, real-time hazard identification, and survivor detection functionalities.

### **User Experience Evaluation Report**

### A detailed evaluation report will summarize the results of testing the UGV in simulated disaster environments. This includes usability testing for autonomous navigation, accuracy in fire detection and mapping, and task completion efficiency. Feedback from rescue teams and experts will provide qualitative insights into system usability and effectiveness, offering valuable suggestions for further optimization and improvement.

**Individual Roles**

**1. Research and Requirements Gathering –** All members

Conduct research on disaster-response technologies, sensors, and AI applications for UGVs to define project requirements and address challenges.

**2. Machine Learning and Computer Vision –** Vaishnavi, Tanishq

Develop AI models for fire detection, human identification, and thermal imaging, and implement computer vision algorithms for real-time data processing.

**3. Hardware Design and Integration –** Mokshit, Tanishq

Select and integrate sensors (LIDAR, thermal cameras, GPS) and design the mechanical system of the UGV, ensuring compatibility and performance.

**4. Sensor Data Processing and Fusion –** Ishu, Udhav

Process data from multiple sensors (LIDAR, thermal, GPS) and integrate them for 3D mapping, obstacle detection, and situational awareness.

**5. Autonomous Navigation and Obstacle Avoidance –** Vaishnavi, Ishu

Develop algorithms for autonomous navigation, using SLAM and real-time data to ensure safe and efficient movement through difficult terrain.

**6. Real-Time Dashboard Development –** Mokshit, Udhav

Build a user-friendly dashboard for rescue teams to monitor UGV data, maps, and alerts in real-time.

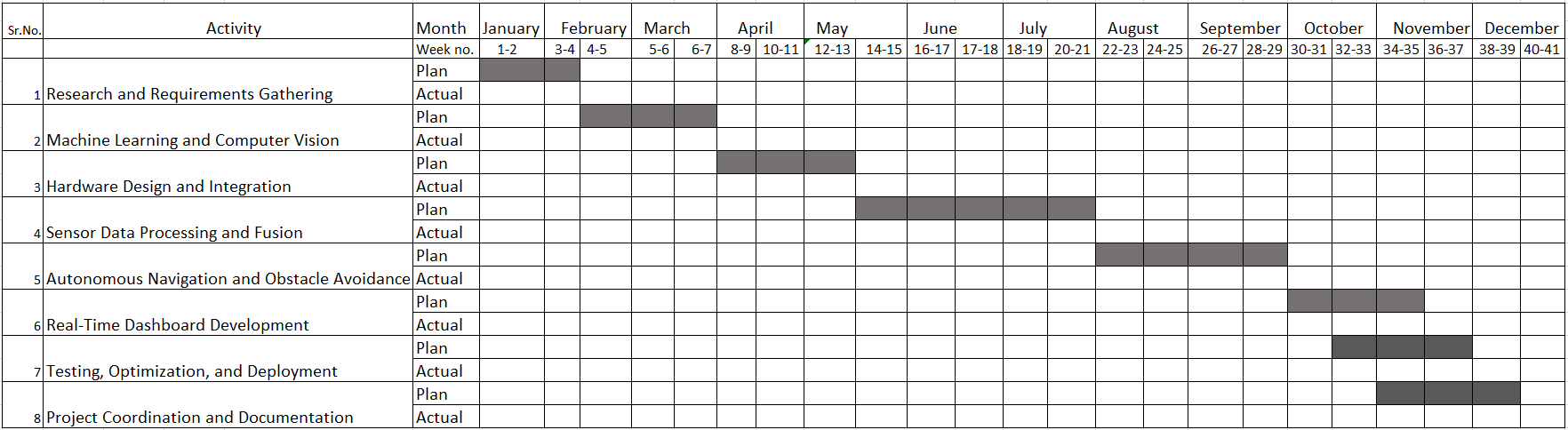
**7. Testing, Optimization, and Deployment –** Tanishq, Mokshit

Test the UGV in real-world environments, optimize performance, and handle deployment for disaster scenarios.

**8. Project Coordination and Documentation –** All members

Manage the project timeline, milestones, and documentation, ensuring clear communication and comprehensive reporting.

**Work Plan**



**Course Subjects**

1. Machine Learning (UML501)
2. Software Engineering (UCS503)
3. Deep Learning (UCS761)
4. Computer Vision & IOT (UCS672)
5. Measurement Science & Techniques (UES034)
6. Artificial Intelligence (UCS521)
7. Cloud Computing (UCS531)

**References**

[1] Liu, K., Zhou, X., & Chen, B. M. (2022, June). An enhanced lidar inertial localization and mapping system for unmanned ground vehicles. In 2022 IEEE 17th International Conference on Control & Automation (ICCA) (pp. 587-592). IEEE.

[2]Singh, B., Kumar, P., & Kaur, N. (2024, July). YDM-SLAM: YOLOv8-Powered Dynamic Mapping of Environment Using ORB-SLAM3. In 2024 International Conference on Data Science and Network Security (ICDSNS) (pp. 01-07). IEEE.

[3] Zade, S., Tidke, V., Gawande, S., Dhule, C., Agrawal, R., & Morris, N. C. (2023, October). Real-Time Survivor Detection in UAV Thermal Imagery Based on Deep Learning. In 2023 IEEE International Conference on Blockchain and Distributed Systems Security (ICBDS*)* (pp. 1-6). IEEE.

[4] Hasan, M. W., Shanto, S., Nayeema, J., Rahman, R., Helaly, T., Rahman, Z., & Mehedi, S. T. (2024). An Explainable AI-Based Modified YOLOv8 Model for Efficient Fire Detection. Mathematics, 12(19), 1-21

[5] Surmann, H., Daun, K., Schnaubelt, M., von Stryk, O., Patchou, M., Böcker, S., ... & Kruijff‐Korbayová, I. (2024). Lessons from robot‐assisted disaster response deployments by the German Rescue Robotics Center task force. Journal of Field Robotics, 41(3), 782-797.

[6] Li, S., & Zhu, C. (2024, October). Improved RRT\*-Smart Algorithm for UGV Path Planning in Emergency Rescue Scenarios. In 2024 7th International Conference on Robotics, Control and Automation Engineering (RCAE) (pp. 212-218). IEEE.

[7] Huang, C. H., Chen, Y. C., Hsu, C. Y., Yang, J. Y., & Chang, C. H. (2024). FPGA-based UAV and UGV for search and rescue applications: A case study. Computers and Electrical Engineering, 119, 109491.

[8] Ocando, M. G., Certad, N., Alvarado, S., & Terrones, Á. (2017, November). Autonomous 2D SLAM and 3D mapping of an environment using a single 2D LIDAR and ROS. In 2017 Latin American robotics symposium (LARS) and 2017 Brazilian symposium on robotics (SBR) (pp. 1-6). IEEE.

[9] Murcia, H. F., Monroy, M. F., & Mora, L. F. (2018). 3D scene reconstruction based on a 2D moving LiDAR. In *Applied Informatics: First International Conference, ICAI 2018, Bogotá, Colombia, November 1-3, 2018, Proceedings 1* (pp. 295-308). Springer International Publishing.

[10] Yan, K., & Ma, B. (2020). Obstacle Avoidance Based on 2D-Lidar in Unknown Environment. In *Proceedings of 2019 Chinese Intelligent Systems Conference: Volume I 15th* (pp. 609-618). Springer Singapore.

[11] Yan, Z., Duckett, T., & Bellotto, N. (2020). Online learning for 3D LiDAR-based human detection: experimental analysis of point cloud clustering and classification methods. *Autonomous Robots*, *44*(2), 147-164.

[12] Choi, J. D., & Kim, M. Y. (2023). A sensor fusion system with thermal infrared camera and LiDAR for autonomous vehicles and deep learning-based object detection. *ICT Express*, *9*(2), 222-227.