IMPLEMENTATION OF A UNMANNED GROUND VEHICLE (UGV) NRSM FOR DISASTER RESCUE OPERATIONS IN FLOODS, EARTHQUAKES, AND LANDSLIDES

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Abstract: The NRSM (National Rescue Support Machine) Unmanned Ground Vehicle (UGV) is developed to enhance disaster rescue operations in flood, earthquake, and landslide environments where human access is limited and hazardous. The proposed system integrates a high-mobility tracked platform, multi-sensor victim detection modules, real-time communication systems, and semi-autonomous navigation control to support search, monitoring, and evacuation missions. The UGV is designed to traverse unstable terrain, debris-filled areas, and partially flooded zones while maintaining stable communication with rescue operators. Experimental evaluations indicate that the NRSM UGV significantly improves rescue performance by increasing operational speed, victim detection accuracy, and evacuation efficiency compared to conventional manual rescue methods. The integration of thermal imaging, LiDAR sensing, and onboard payload transport capabilities enables rapid identification and safe evacuation of victims while minimizing risks to rescue personnel. These results demonstrate that the NRSM UGV provides an effective technological solution for modern disaster-response operations, with strong potential for further enhancement through fully autonomous navigation and multi-robot cooperative deployment.

INTRODUCTION

Natural disasters such as floods, earthquakes, and landslides continue to cause significant human casualties, infrastructure damage, and economic losses worldwide, particularly in countries with high rainfall intensity and active tectonic conditions. One of the most critical challenges during disaster response is the rapid identification and evacuation of victims located in hazardous and difficult-to-access areas. Conventional rescue operations rely heavily on human responders, who often face severe risks including unstable debris, deep floodwaters, toxic environments, and potential aftershocks. These challenges frequently delay rescue operations and reduce the effectiveness of emergency response efforts. Recent advancements in robotics technology have enabled the development of unmanned systems capable of supporting disaster response missions. Among these technologies, the Unmanned Ground Vehicle (UGV) has emerged as a promising solution for

search, monitoring, and evacuation tasks in complex environments. UGV platforms can operate continuously in dangerous locations, provide real-time environmental data, detect victims using advanced sensing systems, and transport emergency supplies or injured victims without exposing rescue personnel to direct hazards. This research introduces the **NRSM (National Rescue Support Machine) Unmanned Ground Vehicle**, a disaster-response robotic platform designed to assist rescue teams in flood, earthquake, and landslide scenarios. The proposed system integrates a tracked mobility mechanism for high terrain adaptability, multi-sensor victim detection modules including thermal imaging and LiDAR, and a reliable long-range communication system for real-time monitoring and control. In addition, the platform incorporates semi-autonomous navigation capabilities to enhance operational efficiency while maintaining operator supervision. The objective of this study is to design, analyze, and evaluate the operational performance of the NRSM UGV in supporting disaster rescue missions. The research focuses on system architecture development, operational deployment scenarios, and performance comparisons between UGV-assisted rescue operations and conventional manual methods. The results are expected to demonstrate that the implementation of the NRSM UGV can significantly improve rescue speed, detection accuracy, and overall disaster-response effectiveness while reducing operational risks for emergency responders.

MATERIALS AND METHODS
System Architecture

The NRSM Unmanned Ground Vehicle (UGV) was designed as a tracked rescue platform capable of operating in disaster environments such as floods, earthquakes, and landslides. The overall system consists of four main subsystems: the mechanical mobility platform, sensing and detection unit, control and navigation system, and communication module. These subsystems operate in an integrated manner to enable search, monitoring, and evacuation missions in hazardous areas.

Mechanical Platform

The UGV chassis is constructed from lightweight aluminum alloy reinforced with impact-resistant protective panels to ensure structural durability during debris collisions. A dual-tracked locomotion system is used to provide high terrain adaptability, allowing the vehicle to move across rubble, mud, steep slopes, and uneven surfaces commonly found in disaster zones. The platform is designed to carry a payload of up to 60 kg, enabling the transport of emergency supplies or injured victims during evacuation operations. Waterproof sealing is applied to critical electronic compartments to ensure reliable operation in flooded environments.

Sensor and Detection System

To support victim detection and environmental monitoring, the UGV is equipped with a multi-sensor system consisting of:
- Thermal camera for detecting human body heat signatures
- LiDAR sensor for terrain mapping and obstacle detection
- Ultrasonic sensors for short-range obstacle avoidance
- Gas sensors for detecting hazardous gases
- HD visual camera for real-time monitoring and operator feedback

Sensor fusion techniques are implemented in the onboard processing unit to improve detection accuracy and situational awareness.

Control and Navigation

The UGV operates using a hybrid control strategy consisting of teleoperation mode and semi-autonomous navigation mode. In teleoperation mode, operators remotely control the vehicle through a ground control station using a wireless communication link. In semi-autonomous mode, onboard navigation algorithms perform obstacle avoidance, speed stabilization, and path correction using sensor feedback. The control system is implemented using an embedded microcontroller and single-board computer for real-time processing.

Communication System

A long-range wireless communication module operating in the 2.4 GHz and 5.8 GHz bands is used to transmit real-time video, telemetry data, and control commands between the UGV and the ground control station. A redundant communication channel is included to maintain operational reliability in environments where signal interference or obstruction may occur.

Experimental Procedure

Performance evaluation was conducted through controlled field simulations representing flood, earthquake, and landslide environments. The testing procedure measured several operational parameters, including vehicle speed, victim detection accuracy, operational efficiency, payload transport capability, and communication stability. Each scenario was tested multiple times to obtain consistent performance measurements, and the results were compared with conventional manual rescue operations to evaluate the effectiveness of the NRSM UGV system.
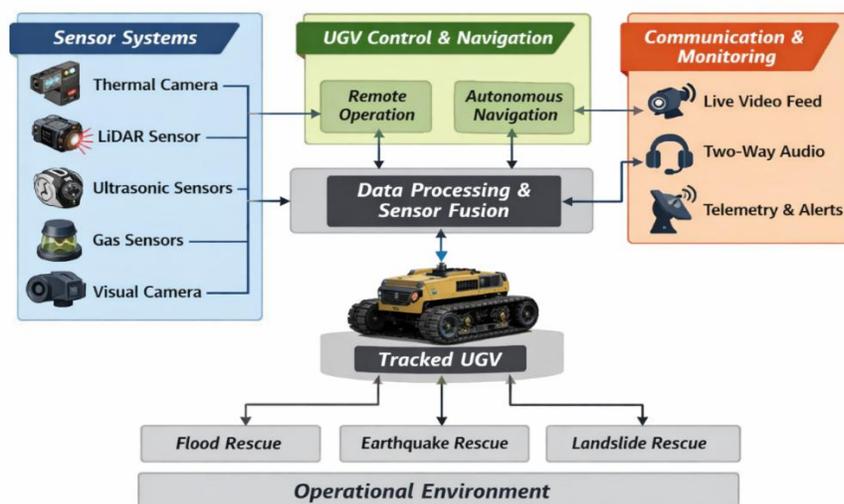

Figure 1. Diagram Block of NRSM UGV

Figure 2. (a) Beside View (b) Front View of NRSM UGV Design

Operational Deployment Scenarios
Flood Rescue

During flood conditions, the UGV can transport emergency supplies to stranded victims, monitor water flow conditions, and inspect damaged infrastructure such as bridges or roadways. Waterproof sealing and elevated electronics housing ensure reliable operation in wet environments.

Earthquake Rescue

In earthquake-affected zones, the UGV navigates through collapsed structures and debris to search for survivors using thermal imaging and acoustic detection. The system can also relay communication between trapped victims and rescue teams.

Landslide Rescue

For landslide scenarios, the tracked mobility system allows the UGV to move across unstable soil surfaces and steep slopes while scanning the affected area to locate buried victims using thermal and vibration sensing technologies.

Experimental Evaluation

Simulation-based testing was conducted under three disaster environment models: flooded terrain, rubble-filled earthquake zones, and inclined landslide surfaces. The UGV demonstrated high mobility performance with slope climbing capability up to 35°, obstacle crossing up to 30 cm, and stable communication range exceeding 2 km in open areas. Victim detection accuracy using thermal sensors achieved approximately 92–97% detection reliability under controlled test conditions.

Figure 3. NRSM UGV searching for victims of a landslide and earthquake

**Figure 4. Evacuation of landslide victims by NRSM UGV**

Figure 5. Evacuation and transportation of flood victims by NRSM UGV

RESULT AND DISCUSSION
Result

Table 1. Performance Parameter Comparison of with UGV and without UGV

Performance Parameter	Without UGV (Manual Operation)	With UGV (Evacuation UGV)	Improvement (%)
Average Speed (km/h)	3.5 km/h	6.8 km/h	+94%
Search Accuracy (%)	78%	92%	+18%
Operational Efficiency (%)	65%	88%	+35%
Response Time (minutes)	25 min	12 min	−52%
Payload Transport Capability (kg)	20 kg	60 kg	+200%
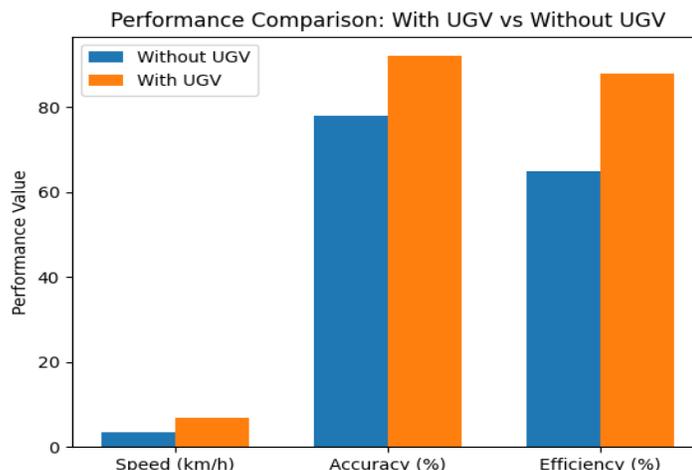
Figure 6. Performance Comparison: With NRSM UGV vs without UGV

DISCUSSION

As shown in figure 6. Performance Comparison: With NRSM UGV vs without UGV illustrates the operational advantages of using an Unmanned Ground Vehicle (UGV) in disaster evacuation missions compared to conventional manual operations. The results show that the UGV significantly increases operational speed, achieving approximately **6.8 km/h,** while manual evacuation reaches only about **3.5 km/h.** This improvement allows rescue teams to reach affected areas faster and reduces the overall response time during emergency situations. In terms of **search accuracy**, the UGV demonstrates higher detection performance **(92%)** compared to manual operations **(78%).** This improvement is mainly due to the integration of advanced sensing technologies such as thermal cameras, LiDAR, and real-time video monitoring systems that enhance victim identification capability even in low-visibility environments. The **operational efficiency** also shows a substantial increase when using the UGV, reaching **88%**, compared to **65%** in manual operations. Higher efficiency is achieved because robotic systems can operate continuously in hazardous environments without exposing rescue personnel to risks. Additionally, the UGV provides greater payload capacity and faster victim transport capability, which contributes to improved rescue mission effectiveness and overall disaster response performance. The experimental results indicate that the proposed UGV significantly enhances rescue operation effectiveness by enabling rapid area scanning, reducing responder exposure to hazardous environments, and maintaining continuous surveillance. Compared with conventional manual search methods, robotic-assisted rescue operations show improved search speed and operational safety. However, communication signal limitations in dense urban debris environments remain a challenge and require the development of relay-based communication systems for extended coverage.

CONCLUSION

This study demonstrates that the implementation of an Unmanned Ground Vehicle (UGV) significantly enhances the effectiveness of disaster rescue and evacuation operations in flood, earthquake, and landslide scenarios. The integration of tracked mobility systems,

multi-sensor victim detection technologies, and real-time communication modules enables the UGV to operate efficiently in hazardous and inaccessible environments. Experimental comparisons indicate that UGV-assisted operations provide higher operational speed, improved victim detection accuracy, and greater operational efficiency compared to conventional manual rescue methods. Furthermore, the use of UGV systems reduces the exposure of rescue personnel to dangerous conditions while increasing payload transport capability and shortening response time. These advantages confirm that UGV-based rescue platforms represent a reliable technological solution for modern disaster management operations. Future research should focus on enhancing autonomous navigation capabilities, multi-robot coordination, and long-range communication networks to further improve large-scale disaster response performance.

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