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Application of mobile robots in agriculture, healthcare, and disaster management

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ABSTRACT

Mobile robots have become increasingly relevant to applications in which repetitive tasks, difficult working conditions, or hazardous environments limit the effectiveness of conventional human-operated activities. Their application in agriculture, healthcare, and disaster management demonstrates how autonomous and remotely operated platforms can support productivity, service delivery, and human safety. However, each field presents distinct technical and operational challenges, including environmental uncertainty, interaction with people, limited communication, and requirements for reliable decision-making. This review examines the development and application of mobile robots in these three domains using research published up to 2015, with particular attention to their functions, technological contributions, limitations, and future development requirements.

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1. INTRODUCTION

Mobile robotics has developed from a specialized engineering research area into a technology with practical applications across several sectors. Advances in sensing, embedded computing, navigation, and control have enabled robots to perform tasks in environments that are difficult, repetitive, or potentially dangerous for human operators. Agriculture, healthcare, and disaster management are particularly important examples because each involves operational demands that cannot always be addressed efficiently through conventional automation. Despite their different objectives, these sectors share a common research problem: how to develop mobile robotic systems that can operate reliably while adapting to uncertain environments and human requirements.

In agriculture, mobile robots are expected to improve field monitoring, precision operations, and crop management while reducing dependence on repetitive manual work. In healthcare, mobile platforms can support hospital logistics, remote communication, and assistance for patients or medical personnel. Disaster management presents a different motivation because robots can enter hazardous locations to collect information and support rescue teams without immediately exposing human responders to danger. These applications demonstrate that the value of mobile robotics depends not only on movement capability but also on the robot's ability to perform useful tasks safely and consistently.

This review examines the principal applications of mobile robots in these three domains and identifies their technological requirements and limitations. The discussion is organized around agricultural operations, healthcare services, and disaster response, followed by a comparative analysis of their common challenges. The review focuses exclusively on publications available up to 31 December 2015. Its purpose is to establish a traceable understanding of the research problems, practical contributions, and unresolved issues that shaped mobile robotics during this period.

2. MOBILE ROBOTS IN AGRICULTURE

Agriculture provides an important application area for mobile robots because many farming operations require repetitive movement across large and sometimes unstructured environments. Conventional

agricultural machinery can perform several automated operations, but many systems still depend on human operators for navigation, supervision, and decision-making. Mobile robots offer the possibility of integrating environmental sensing, autonomous guidance, and task-specific equipment into a single operational platform. Auat Cheein and Carelli [1] describe agricultural robotic service units as a means of supporting precision agriculture through autonomous vehicles capable of collecting environmental information and executing agricultural tasks.

Agricultural mobile robots can be applied to field monitoring, weed detection, spraying, soil assessment, and harvesting. Field-monitoring robots collect information about crop conditions and environmental variations, helping farmers make more targeted management decisions. Weed-control robots combine navigation, plant detection, and precision treatment to reduce unnecessary chemical application and improve the selectivity of weed management. Slaughter *et al.* [2] identify guidance, weed detection and identification, precision in-row control, and mapping as important technologies for developing autonomous weed-control systems.

Harvesting represents a particularly demanding application because the robot must identify suitable crops, locate individual fruits, approach them without damaging surrounding plants, and execute a precise picking action. These operations require the integration of machine vision, robotic manipulation, localization, and motion planning. Bac *et al.* [3] reviewed harvesting robots for high-value crops and identified limitations in localization, harvesting success, cycle time, and product damage. Their findings indicate that the technical challenge is not simply constructing a robot that can pick fruit, but developing a complete system capable of achieving consistent performance under real production conditions.

Despite these opportunities, agricultural environments introduce several challenges that distinguish field robots from robots operating in factories. Uneven terrain, changing illumination, dust, vegetation growth, and weather conditions can reduce the reliability of sensors and navigation systems. Crop structures may also vary between fields and seasons, making it difficult to apply a single perception model or mechanical configuration universally. Consequently, agricultural robots require adaptable sensing, robust localization, suitable mobility, and task-specific manipulation systems.

3. MOBILE ROBOTS IN HEALTHCARE

Healthcare environments offer a different set of opportunities for mobile robotics because hospitals require continuous transportation, communication, and assistance services. Medical personnel frequently perform routine activities involving the movement of supplies, equipment, documents, and other materials between departments. Mobile robots can support these activities by transporting items through hospital corridors and reducing the time spent on repetitive logistics tasks. Rossetti *et al.* [4] investigated robotic courier systems in hospital distribution services through simulation, demonstrating the relevance of evaluating their operational costs and delivery performance before implementation.

Another important application is mobile robotic telepresence, which enables a remotely located person to interact with people and surroundings through a mobile robotic platform. Such systems generally combine a mobile base with cameras, microphones, displays, speakers, and a remote-control interface. Kristoffersson *et al.* [5] reviewed mobile robotic telepresence systems and identified healthcare environments and independent living for older people among their potential application areas. These systems can support remote communication, consultation, and social interaction when physical presence is difficult or impractical.

Mobile robots may also support rehabilitation and patient assistance, although these applications require more careful interaction with people than conventional transportation tasks. A rehabilitation platform must respond appropriately to patient movement, physical limitations, and therapeutic objectives. Robots intended to assist patients must also be designed around usability, comfort, reliability, and appropriate human supervision. In healthcare, therefore, technical performance alone is insufficient because the system must also meet clinical expectations and respect patient needs.

The implementation of mobile robots in hospitals remains challenging because healthcare facilities are dynamic and shared environments. Robots must navigate corridors occupied by patients, visitors, beds, and medical staff while avoiding collisions and maintaining predictable movement. Hospital integration may also require coordination with elevators, access-control systems, communication networks, and existing logistics procedures. Privacy, safety, hygiene, and acceptance by medical personnel are additional considerations that must be addressed before widespread deployment.

4. MOBILE ROBOTS IN DISASTER MANAGEMENT

Disaster management is one of the most demanding applications of mobile robotics because response operations frequently take place in dangerous and unpredictable environments. Earthquakes, building collapses, industrial accidents, fires, and nuclear incidents can create conditions in which human

access is restricted or unsafe. Mobile robots can provide remote observation, environmental assessment, and limited physical intervention while keeping responders at a safer distance. Murphy [6] documented the use of rescue robots during the World Trade Center response and discussed how mobility, sensing, control, communication, and power affected their field performance.

Search-and-rescue robots are commonly designed to move through rubble, confined spaces, unstable surfaces, or partially damaged structures. Tracked platforms are particularly useful when conventional wheeled mobility is insufficient, while compact robots can access narrow openings and restricted spaces. Their sensors may include cameras, thermal imaging devices, microphones, gas detectors, and other instruments for identifying environmental conditions or locating potential survivors. The collected information can help rescue teams assess the situation and determine where human intervention is most urgently required.

The Fukushima Daiichi nuclear accident demonstrated the importance of mobile robots in environments where radiation and structural hazards make direct human inspection dangerous. Nagatani *et al.* [7] reported the deployment of mobile rescue robots for surveillance missions inside damaged nuclear power plant buildings. Their work highlighted practical requirements involving hardware reliability, communication, radiation tolerance, and additional sensing equipment. The experience also showed that a robot designed for ordinary research or industrial operation may require substantial modification before it can perform reliably in a disaster environment.

However, disaster-response robots face limitations that are less common in controlled environments. Rubble, smoke, water, debris, and damaged infrastructure can restrict movement and interfere with sensing or communication. Wireless links may become unreliable inside buildings, while limited battery capacity can restrict mission duration and operational range. Murphy [8] also emphasized the importance of human-robot interaction in rescue operations, where effective communication and coordination between responders and robotic systems are essential. These challenges indicate that disaster robots should be designed as components of a broader response system rather than as independent replacements for rescue personnel.

5. COMPARATIVE ANALYSIS OF APPLICATIONS

Although agriculture, healthcare, and disaster management have different operational objectives, their mobile robots share several underlying technological requirements. Each application depends on a suitable mobile platform, environmental sensing, localization, navigation, control, and an effective interface with human operators. However, the relative importance of these components varies according to the operating environment and the consequences of system failure. Table 1 summarizes the principal applications, expected benefits, and major challenges across the three domains.

Table 1. Comparative overview of mobile robot applications

Application domain	Typical tasks	Main benefits	Major challenges
Agriculture	Monitoring, weed control, spraying, harvesting	Precision operations, reduced repetitive labor, targeted resource use	Uneven terrain, crop variability, perception accuracy, weather
Healthcare	Material delivery, telepresence, rehabilitation support	Reduced routine workload, remote interaction, improved service logistics	Human safety, privacy, hygiene, hospital integration
Disaster management	Search and rescue, inspection, environmental assessment	Reduced responder exposure, remote information gathering	Unstable terrain, communication loss, limited endurance, hazardous conditions

Table 1 illustrates that the same basic robotic capabilities serve different operational purposes. Agricultural robots prioritize field coverage, crop recognition, and precision task execution, whereas healthcare robots must navigate safely around people and integrate with established service procedures. Disaster robots place greater emphasis on mobility in damaged environments, robust communication, and remote sensing under hazardous conditions. These differences suggest that mobile robot development should be guided by application-specific requirements rather than by a single universal platform design.

A further comparison concerns the level of autonomy required in each application. Agricultural robots may operate autonomously over predefined field routes while receiving task instructions or supervision from an operator. Healthcare robots often require a combination of autonomous navigation and

human oversight because their operation directly affects patients and medical staff. Disaster robots may rely more heavily on teleoperation or shared autonomy because unpredictable terrain and incomplete environmental information can make fully autonomous decision-making difficult.

6. RESEARCH CHALLENGES AND FUTURE DEVELOPMENT

The reviewed literature indicates that reliability remains a central challenge across all three application domains. Agricultural robots must maintain performance despite changing crop conditions and outdoor disturbances, while healthcare robots must operate safely in environments with frequent human movement. Disaster robots must tolerate extreme environmental conditions and continue functioning when communication or infrastructure is degraded. These requirements make robust sensing, localization, navigation, and fault handling important research priorities.

Human-robot interaction is another common issue that influences the practical acceptance of mobile robotic systems. Operators must understand the robot's status, intended actions, limitations, and emergency behavior. In healthcare and disaster management, communication is particularly important because robots work directly with people who may depend on their information or assistance. Future systems should therefore provide intuitive interfaces, understandable feedback, and appropriate mechanisms for human intervention.

Another research priority is the development of integrated platforms that combine mobility with application-specific tools. Agricultural robots require effective combinations of navigation and crop-treatment or harvesting equipment, while healthcare platforms may need modular payloads and communication devices. Disaster robots require adaptable sensor packages and mechanical designs capable of handling different types of terrain and inspection tasks. System-level testing under realistic operating conditions is essential because the successful integration of individual components does not necessarily guarantee reliable field performance.

7. CONCLUSION

Mobile robots provide valuable opportunities to improve agricultural operations, healthcare services, and disaster-response activities. In agriculture, they support precision monitoring, weed control, spraying, and harvesting, although environmental variability and task complexity remain significant obstacles. In healthcare, mobile platforms can improve logistics and remote communication, but their deployment requires careful attention to safety, privacy, usability, and integration with clinical workflows. In disaster management, robots can reduce human exposure to hazardous environments by providing remote inspection and search capabilities, although mobility, communication, and endurance remain major constraints.

The comparative analysis demonstrates that successful mobile robot development requires more than autonomous movement. Reliable operation depends on the integration of appropriate hardware, sensing, localization, control, task-specific functionality, and human supervision. Each application domain must therefore adopt a design strategy that reflects its environmental conditions, operational priorities, and safety requirements. Continued research into robust autonomy, adaptable platforms, and effective human-robot collaboration is essential for translating promising robotic technologies into dependable real-world systems.

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