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Wildfire Emergency Response and Evacuation Framework Using Drones: Phase I

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Introduction

Wildfires in California present a significant and growing threat to lives, infrastructure, and ecosystems, highlighting the urgent need for advanced emergency response strategies. Traditional wildfire management methods often fall short due to delayed detection, limited resource allocation, and inefficient evacuation processes. This research proposes an innovative autonomous drone-based emergency response and evacuation framework that integrates advanced sensors, machine learning (ML), and optimization algorithms to significantly enhance wildfire response efficiency. The proposed drone network is equipped with innovative technologies including infrared (IR) cameras, LiDAR, and visible spectrum imaging to predict wildfires, optimize evacuation routes in real-time, and facilitate search and rescue (SAR) operations. This comprehensive framework uses artificial intelligence, specifically the Dynamic Wildfire Response Algorithm (DWRA), to adapt to changing wildfire conditions, ensuring effective evacuation, rapid victim detection, and precise allocation of emergency resources, ensuring help gets quickly to where it is most needed.

Study Methods

This study develops and tests an autonomous drone-based system for wildfire detection, evacuation planning, and search and rescue operations. The drone network features cutting edge technology such as advanced infrared (IR) cameras, visible spectrum imaging, LiDAR sensors, and onboard computing capabilities powered by NVIDIA Jetson AGX Orin processors. Machine learning algorithms analyze environmental data such as temperature, wind speed, and vegetation conditions to predict fire outbreaks and simulate wildfire spread. Real-time evacuation routes are computed using heuristic pathfinding algorithms including A star, Genetic Algorithms, and Ant Colony Optimization, which enable the system to dynamically adapt to evolving conditions. Additionally, drones equipped with AI-based thermal imaging and radar systems can identify victims in low-visibility conditions, sending information about their precise locations to emergency teams for quick response. Preliminary tests were conducted through field experiments to assess system accuracy, responsiveness, and coordination efficiency.

Findings

This research and the Dynamic Wildfire Response Algorithm (DWRA) demonstrated a number of key findings, including:

- Rapid Fire Detection: The drone system successfully detected wildfire ignition within 30 seconds, significantly quicker than traditional observation methods, with a detection accuracy of 97.2%.
- Effective Evacuation Optimization: Dynamic evacuation routes generated by the system improved escape efficiency by 28% compared to static evacuation strategies. Integration of heuristic algorithms and real-time data also further reduced evacuation times and enhanced safety.
- Advanced Victim Detection: The search and rescue component achieved a high accuracy rate of 95.4% in detecting individuals under dense smoke and limited visibility, which could significantly reduce rescue response times.
- Real-Time Coordination: Drones maintained robust, seamless multi-drone mesh networking, ensuring reliable communication and continuous data sharing even in infrastructure compromised areas.

Policy/Practice Recommendations

Based on the findings, this research and the framework it developed have the potential to improve emergency response and save ecosystems, infrastructure, and lives. The researchers recommend the following:

- Adoption of Autonomous Drone Systems: Emergency management agencies should integrate drone-based technologies into wildfire detection, monitoring, and evacuation operations to enhance rapid response capabilities and reduce casualty rates.
- Investment in AI-Enhanced Emergency Infrastructure: Policymakers and government entities must allocate funding toward advanced AI-driven systems, supporting their deployment for effective real-time wildfire management and resource allocation.
- Enhanced Training Programs: Comprehensive training initiatives for emergency personnel on drone system operations and AI-based emergency response methodologies could optimize system implementation and maximize operational effectiveness.
- Cross-Sector Collaboration: Strengthening partnerships among research institutions, emergency response agencies, technology providers, and policymakers is essential to facilitate widespread adoption and continuous advancement of AI-driven wildfire response systems.
- Public Awareness Campaigns: Educating communities on the capabilities and benefits of drone based emergency response systems can foster greater public cooperation during evacuation procedures and enhance overall community resilience.
- By combining cutting-edge technology with real-time adaptability, this research lays the foundation for a next-generation wildfire response system that is faster, smarter, and better equipped to meet the growing challenges of a warming world.

About the Author

Dr. Hovannes Kulhandjian is a tenured full Professor in the Department of Electrical and Computer Engineering at California State University, Fresno. His current research interests are in applied machine learning, wireless communications, and networking with applications to unmanned aerial vehicles, autonomous vehicles, and Intelligent Transpiration Systems (ITS).

To Learn More

For more details about the study, download the full report at transweb.sjsu.edu/research/2446

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