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A Comprehensive Survey of Artificial Intelligence and Machine Learning Approaches across Distinct Phases of Wildland Fire Management

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Abstract : Wildland fires, also known as forest fires or wildfires, are exhibiting an alarming surge in frequency in recent times, further adding to its perennial global concern. Forest fires often lead to devastating consequences ranging from loss of healthy forest foliage and wildlife to substantial economic losses and the tragic loss of human lives. Despite the existence of substantial literature on the detection of active forest fires, numerous potential research avenues in forest fire management, such as preventative measures and ancillary effects of forest fires, remain largely underexplored. This paper undertakes a systematic review of these underexplored areas in forest fire research, meticulously categorizing them into distinct phases, namely pre-fire, during-fire, and post-fire stages. The pre-fire phase encompasses the assessment of fire risk, analysis of fuel properties, and other activities aimed at preventing or reducing the risk of forest fires. The during-fire phase includes activities aimed at reducing the impact of active forest fires, such as the detection and localization of active fires, optimization of wildfire suppression methods, and prediction of the behavior of active fires. The post-fire phase involves analyzing the impact of forest fires on various aspects, such as the extent of damage in forest areas, post-fire regeneration of forests, impact on wildlife, economic losses, and health impacts from byproducts produced during burning. A comprehensive understanding of the three stages is imperative for effective forest fire management and mitigation of the impact of forest fires on both ecological systems and human well-being. Artificial intelligence and machine learning (AI/ML) methods have garnered much attention in the cyber-physical systems domain in recent times leading to their adoption in decision-making in diverse applications including disaster management. This paper explores the current state of AI/ML applications for managing the activities in the aforementioned phases of forest fire. While conventional machine learning and deep learning methods have been extensively explored for the prevention, detection, and management of forest fires, a systematic classification of these methods into distinct AI research domains is conspicuously absent. This paper gives a comprehensive overview of the state of forest fire research across more recent and prominent AI/ML disciplines, including big data, classical machine learning, computer vision, explainable AI, generative AI, natural language processing, optimization algorithms, and time series forecasting. By providing a detailed overview of the potential areas of research and identifying the diverse ways AI/ML can be employed in forest fire research, this paper aims to serve as a roadmap for future investigations in this domain.

Keywords : artificial intelligence, computer vision, deep learning, during-fire activities, forest fire management, machine learning, pre-fire activities, post-fire activities
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