

Advanced LiDAR Technology for Early Wildfire Detection and Monitoring

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Abstract: This study emphasizes the importance of early wildfire detection for safeguarding lives, properties, and public safety. Utilizing a developed scanning LiDAR system, the research focuses on early detection and source identification of wildfires. The system enables real-time monitoring of smoke and fine dust in diverse environments, providing accurate detection capabilities. The results demonstrate the effectiveness of LiDAR technology in early smoke detection due to wildfires, presenting potential to mitigate damages and enhance public safety.

1. Introduction

The detection and early suppression of wildfires occurring in various regions worldwide are crucial for safeguarding the lives and properties of citizens, as well as for preserving economic and public safety. According to the Korea Forest Service, from 2016 to August 2121, a total of 3,151 wildfires occurred, resulting in the loss of 9,666 ha. Specifically, wildfires in Gyeongbuk and Gangwon provinces in 2022 alone led to the destruction of 20,523 ha of land. Such incidents highlight the significant losses wildfires can inflict within a short period, emphasizing the paramount importance of early suppression measures. Therefore, enhancing the monitoring level of early wildfire detection methods is urgently needed to minimize wildfire-related damages.

2. The Limitations of Wildfire Monitoring Technology

Recent advancements in image and video processing technologies have led to the early detection of wildfires, increasing their applicability in monitoring large-scale forest areas. However, due to the limitations of manual detection methods, these technologies are susceptible to measurement interference and interference from fog and high concentrations

of fine dust, which frequently occur in mountainous regions, leading to false alarms and missed alerts [1]. In South Korea, CCTV cameras are primarily utilized for wildfire monitoring, with plans to incorporate thermal cameras and intelligent image processing capabilities. However, depending on operational environments, there is a possibility of reduced detection range and accuracy. Although attempts have been made to automatically detect fires using AI image recognition, the accuracy remains low, and detection is limited to short distances. Furthermore, adverse weather conditions such as reduced visibility due to fine dust and fog can impair image processing performance, while strong winds may result in rapid fire spread before detection. Even with infrared and thermal imaging surveillance systems, while they may provide information on fire direction through heat or smoke detection, accurately estimating the exact source of the fire is challenging. Satellite remote sensing technology used for wildfire detection, such as FIRMS (Fire Information for Resource Management System), offers wide observation coverage. FIRMS provides wildfire occurrence data within three hours of satellite observation using MODIS (Moderate Resolution Imaging Spectroradiometer) and VIIRS (Visible Infrared Imaging Radiometer Suite) with a

spatial resolution of 1 km [2-3]. However, satellite observation is susceptible to cloud cover and weather conditions and has limitations in real-time monitoring and spatial-temporal resolution [4-6]. Utilizing drones or UAVs equipped with cameras or thermal cameras for wildfire monitoring aims to reduce false alarms from traditional CCTV systems. However, these methods require preparation time and are limited by communication distance, weather conditions, and battery life, resulting in restricted flight times. Additionally, simultaneous wide-area monitoring of multiple regions poses challenges. Therefore, drones or UAVs have limitations in real-time continuous observation or simultaneous observation of mountainous regions. In contrast, LiDAR-based wildfire monitoring has gained attention as an active advanced remote sensing surveillance method capable of distinguishing fire particles by measuring the amount of light backscattered by smoke particles and identifying particle types with multiple wavelengths, offering potential solutions to overcome these challenges.

3. Wildfire Monitoring Scanning LiDAR Technology

Recently, a scanning LiDAR system was developed utilizing two wavelengths (532 nm and 1064 nm) and capable of horizontal scanning with an angular resolution within 20°, enabling 360° observation within 30 minutes. Additionally, utilizing the backscatter coefficients (β) obtained at these wavelengths, our analysis technique can estimate the mass concentrations of PM₁₀ and PM_{2.5}, allowing for early wildfire detection and source identification in broad areas while simultaneously analyzing concentration levels. This technology enables real-time continuous measurements regardless of day or night conditions, and leveraging multi-wavelength analysis and polarization extinction can further enhance the accuracy of wildfire smoke detection by analyzing the characteristics of particles in the atmosphere.

4. Results and conclusions

Utilizing a scanning LiDAR system, we conducted continuous monitoring of smoke detection and fine dust observation caused by

rural incineration. The system was installed on the rooftop of the public sewage treatment facility in Gimje-si, Jeollabuk-do, from January 28, 2021, to March 13, 2021. With the exception of special circumstances, continuous monitoring was conducted for 24 hours. As a result, we detected 12 smoke detection signals and confirmed 8 instances of smoke detection due to illegal incineration. Figure 1 visualizes the changes in smoke detection and fine dust concentration, confirming the potential for early detection of smoke caused by wildfires in the future.

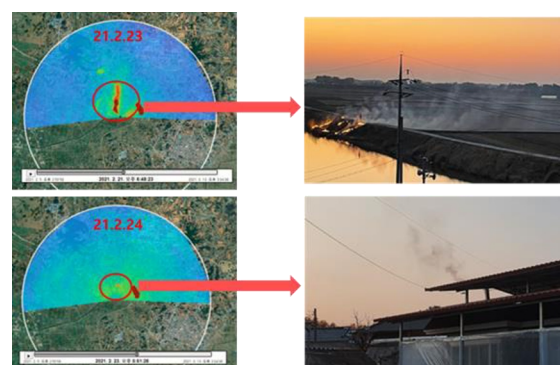


Figure 1. Smoke Detection and Fine Dust Measurement Using Scanning LiDAR in Rural Areas

5. Acknowledgments

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6. References

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