Forest Fire Research
&
Wildland Fire Safety

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Forest-fire detection by means of lidar

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Keywords: forest fire, remote sensing, lidar

Lidar is a promising tool for forest-fire monitoring because, due to its very high sensitivity and spatial resolution, this active detection technique enables efficient location of small smoke plumes that originate from forest fires in the early stages of development during both day and night and over a considerable range. Earlier experiments carried out by the authors testify that small fires with a burning rate of about 0.02 kg/s can be promptly detected from a distance of 6.5 km. However, considerable effort is still required to create effective, reliable, and simple methods for ground-based forest fire surveillance.

The present work partially addresses the problems arising from the high cost and complexity of common lidar equipment by experimentally investigating the possibility of using a simple single-wavelength direct-detection lidar to locate forest fires. First the fundamentals of smoke sensing using lidar are briefly discussed and SNR is related to the parameters of the lidar equipment, smoke plume, and atmospheric conditions. This relation allows theoretical predictions of the SNR for ideal observation conditions to be made, when the probing laser beam irradiates the center of a plume with constant shape. Then the results of experiments, designed to demonstrate the possibility of forest fire detection by lidar in a mountain region, even when the smoke plume is observed under strong wind against a steep hillside, are reported. It is shown that a medium-spatial-resolution lidar can reliably differentiate the signal resulting from a small smoke plume from large signals due to ground reflections. Another important characteristic of a lidar surveillance system is the promptness of the fire alarm. The experiments have demonstrated the possibility of detecting smoke plumes as early as 40 seconds after the fire starting. It is also shown how forest-fire location can be performed by an azimuth-angle sweep, allowing the position, dimensions and even internal structure of the smoke plume to be estimated. Examples of location of a smoke plume whose origin is out of line of sight and detection in unfavorable visibility conditions are also demonstrated.

Feasibility of the lidar technique for forest-fire surveillance is closely linked with opportunities to perform automated monitoring. In this connection, several methods of recognition of the smoke signatures in lidar signal based on neural-network technique are discussed. Finally, relatively simple but efficient neural-network structure based on a committee machine composed of three perceptrons is discussed. Being trained according to a specially developed error-backpropagation algorithm, the committee machine demonstrated 22 false alarms and 27 misdetections out of \( \sim 1.7 \times 10^4 \) patterns containing in 231 complete lidar signals, of which 122 had smoke signatures.