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Critical Nature of Prompt Wildfire Detection along Power Lines and a System for Providing Same

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Introduction

Wildfires ignited by powerline faults average approximately ten times greater in area than wildfires from all sources. As power line related wildfires are commonly associated with high wind events, prompt detection and reporting of these fires become critical to prevent them from turning rapidly into wildfires.

The system presented here was designed for deployment along power lines to provide prompt and early wildfire detection. The system focuses on detection of specific radiance in the mid-IR for maximum signal-to-noise ratio. A special IR sensor was developed to minimize the effect of atmospheric attenuation to maximize the range of fire detection. The system provides a continuous monitoring and wildfire detection radius of 300m, is capable of detecting wildfires as small as 1 m^2 and can generally report events within 2 minutes of detection. While originally designed for deployment along power lines, the system can be deployed to provide wildfire detection along any meandering right-of-way, border, or perimeter.

Wildfires and Power Lines

Electric power lines are a well-documented source of wildfire ignitions. In one study, for the 50-year period from 1960-2009, those wildfires in California started by power lines, grew to 10 times the size in acres burned than wildfires started by other causes (Mitchell, 2013). The connection between power lines and larger wildfires is succinctly stated by CalFire and the California Public Utilities Commission (CPUC): “The same weather conditions that contribute to power line faults also lead and contribute to the rapid spread of wildfire. High wind is the most critical of these weather factors and is commonly accompanied by high temperatures, low fuel moistures, and low humidity” (Porter & Richwine, 2020). It is understandable that they further state, “Electrical power presents a specific hazard that results in mutual concern from electric utilities and local, state and federal fire protection agencies” (ibid).

Requirements for Wildfire Detection Along Power Lines

The unique risks associated with power line rights-of-way call for defensive fire detection methods that can sense and report on a wildfire almost immediately after ignition. Specifically:

- An ability to detect very small fires at the point of ignition. Ideally, fires as small as 1 m^2 should be detectable immediately along the right-of-way as this will most likely be the location of ignition.
- An ability to detect fires of this size at any time of day or night.
- An ability to quickly report on the presence of the fire. As wind is often associated with power line fires, reporting of a fire ignition within a few minutes is highly desirable. This calls for a system which operates autonomously, reducing delays in detection due to human interpretation.
- An ability to capture images for visual confirmation and evidence collection.
- The ability to employ continuous learning from previously collected data to avoid false alarms and their potential for alarm fatigue, whereby otherwise valid alarms are ignored.

Such detection will maximize the available response time ensuring emergency response personnel arrive to the smallest possible fire. The author's company has developed a wildfire detection system called FIREBird that meets these requirements. While ideally suited for deployment along electric utility power lines, the system is suitable for deployment along other high-risk boundaries such as electrical substation perimeters, roadways, and wildland urban interfaces. It is also notable that 90% of all wildfires in the USA occur within ½ mile (0.8km) of a road (Peterson, 2007).

A Wildfire Specific Thermal Sensor

Fire can be detected during both day and night times from its characteristic IR radiance. When using IR radiance, it is necessary to detect the characteristic signal peaks associated with wildfire to avoid interference from warm or hot surrounding objects. Furthermore, it is important to minimize any atmospheric attenuation of the IR radiance allow for detection of the smallest possible fires from as far of a distance as possible.

Hyperspectral imaging techniques are usually employed using spectrometers for detailed analysis of the IR spectrum. However, while extremely sensitive to IR photon detection, these devices are difficult to justify for widespread application due to cost and complexity.

Instead, the FIREBird device uses a focal plane array (FPA) IR sensor where the pixels on the sensor array absorb incident heat flux from IR radiation to generate a voltage signal. The patent-pending sensor employs a custom, narrow bandpass anti-reflective (AR) coated lens designed to maximize transmittance of the near-IR peaks characteristic of wildfire radiance. The pixel shape was optimized to maximize the signal strength.

The new sensor can detect near-IR peaks which are subject to minimal atmospheric attenuation, thereby maximizing the range of fire detection compared to commercial, off-the-shelf CMOS sensors. The new optics offer greatly reduced levels of noise from nearby hot objects.

Eight such IR sensors are deployed across a hemispheric dome in fixed positions, providing continuous 360-degree wildfire detection without need for the mechanical rotation or scanning required of a single sensing device. This reduces detection time.

Overlapping Visible Light Cameras

Fire detection technologies using a single sensor or device can be prone to errors in fire detection which may cause false alarms. In addition to the IR cameras, the FIREBird device also employs six visible cameras, arranged to provide similar 360-degree coverage.

Autonomous Capabilities

Key to fast fire detection also depends on autonomous operation. Each FIREBird devices contains significant computational power to allow for all data and image processing, as well as fire detection and confirmation tasks, to be performed locally on the device. This avoids time delays in transmitting large amounts of data for external processing.

Each device contains built-in cellular communications, and satellite communications can also be included to provide back-up communications.

Completing the device's self-sufficiency is the ability to power the device from solar panels and the use of a battery capable of providing power for multiple days.

Fire Detection Method

Output from each of the IR detectors is first processed by a fire -peak detection algorithm to indicate a possible fire. Once detected, independent verification of fire detection or non-detection is achieved by passing the IR sensor output through a neural network (NN) trained to detect wildfires and reject nuisance heat sources.

If the IR-based NN confirms presence of afire, a set of images from the optical cameras is then captured and processed through a separate optical image specific NN algorithm. Both NNs are capable of continuous learning and re-training to provide site specific NN weighting matrixes designed to minimize false detections.

Agreement of the three algorithms; the characteristic-peak detection algorithm, IR NN, and optical camera NN, will result in a fire alarm.

Deployment

The FIREBird devices are intended to be installed along any high fire-risk boundary or right-of-way, such as an electric utility power line. Regular placement along the right of way provides for continuous wildfire detection and monitoring. The FIREBird's wildfire sensing pattern may be idealized as a 300 m radius circle with the device at the center (Figure 1). Due to the circular nature of the sensing pattern, FIREBird units should be placed close enough to ensure the patterns overlap to avoid areas of diminished detection.

For example, with a 300 m sensing radius, to ensure “a” is at least 150 m, “s” must equal 520 m (17% overlap). Using this as an example, three FIREBird units would be deployed along each km of monitored right-of-way, or four units per mile.

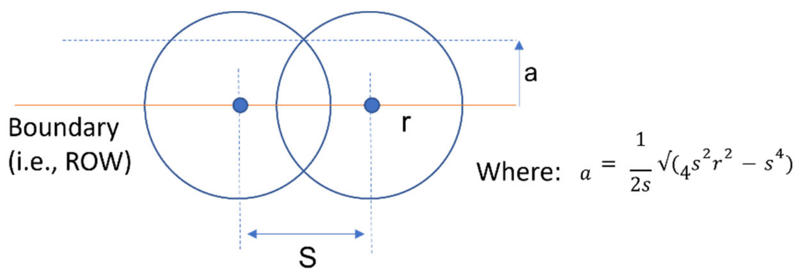

Figure 1: Suggested Overlap of FIREBird Device Sensing Pattern

Testing

Development of the FIREBird device began in 2019 with live fire testing commencing in May 2020 in conjunction with the Rancho Cucamonga (California) Fire District’s All Risk Training Center. See Figure 2. As development progressed, testing was eventually conducted in conjunction with various prescribed burn events. Validated FIREBird device fire size and detection distance is shown in Figure 3. In all cases, fire alarms were received on tester’s smart devices in 2 minutes or less.

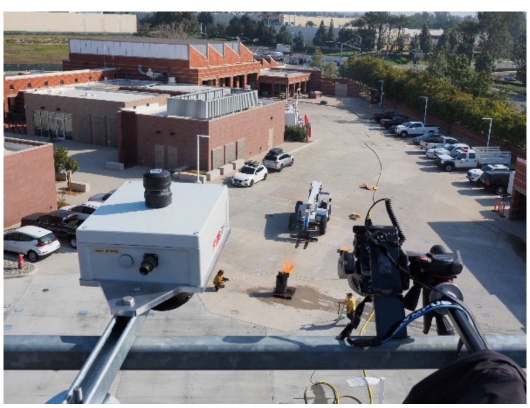

Figure 2: Early controlled FIREBird testing.

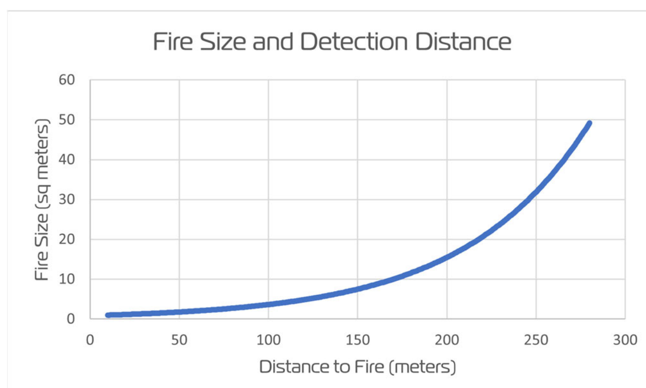

Figure 3: FIREBird Device Fire Detection Range vs Size

Summary

A device to promptly detect small fires along high-fire risk boundaries almost immediately upon ignition has been successfully developed. Using a variety of sensors and with processing performed locally on the device, the resulting system can operate around the clock without monitoring and therefore requires no dedicated staff to scrutinize and interpret the results. Wildfires are generally reported within 2 minutes. Wildfires can be detected out to 300 m distant. Wildfire as small as 1 m^2 can be detected.

With independent communications, power source, and use of cloud-based storage and notification, there is no requirement for the system to depend upon – or even to interface - with a user's existing IT or communications infrastructure. This can help reduce the cost and time associated with implementation.

References

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