An algorithm for fast and reliable fire detection

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Abstract

The purpose of detecting fires early is to provide an alarm when there is an environment which is deemed to be a threat to people or a building. The current generation of fire detection systems is designed to respond to smoke, heat, gaseous emission or electromagnetic radiation generated during smoldering and flaming combustion. Smoke is sensed either by light scattering or changes in conductive properties of the air, heat by thermocouples and thermistors, the electromagnetic spectrum by photodiodes, and gas concentrations by chemical cells. While there is much additional work in progress to use solid-state and electrochemical sensors for oxygen, hydrogen, water vapor, carbon dioxide, chlorine, hydrogen sulfide, the full gamut of fire detection is possible utilizing currently available sensor technology. It has been shown that the best combination for early detection has been shown to be the complement of ionization, photoelectric, carbon monoxide and temperature. This paper will demonstrate that low level sensing can achieve the goal of producing early detection using these signals. The example we use is a neural network trained with a model of fire growth and smoke spread. This allows us to reduce the time to detection as well as reduce the error rate for both nuisance alarms as well as missing fires.

Reliable fire detection is essential to fire protection in all constructed facilities, first for the safe evacuation of occupants and second as a means to initiate manual suppression to for control and extinguishment of unwanted fires.

Most commercial and industrial buildings have fire detection systems that supply limited information from detectors to fire alarm panels. The information available today, and likely in the future, can be used to improve the fire service effectiveness and improve safety of the fire fighting effort as well as reduce the loss of life and cost to the public. In order to accomplish these goals, we need to improve the reliability of detection systems and reduce the time to alarm for real fires.

High reliability detection is based on the supposition that it is possible to utilize a sufficient number of sensors to ascertain unequivocally that there is a growing threat either to people or to a building and provide an estimation of the seriousness of the threat.

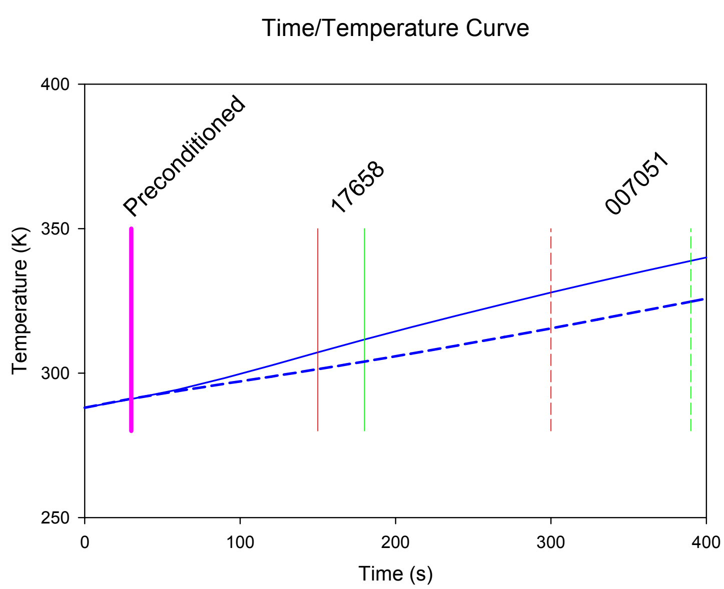
The current generation of fire detection systems[1] is designed to respond to smoke, heat, gaseous emission or electromagnetic radiation generated during smoldering and flaming combustion. Smoke is sensed either by light scattering or changes in conductive properties of the air, heat by thermocouples and thermistors, the electromagnetic spectrum by photodiodes and photovoltaic cells, and gas concentrations by chemical cells[2]. There is much additional work in progress to use solid-state and electrochemical sensors for oxygen, hydrogen, water vapor, carbon dioxide, chlorine and hydrogen sulfide. The use of these detectors, what signals they must (and should not) respond to is mandated by various acceptance tests from Underwriters Laboratories Inc[3], and FM Global Corporation[4].

An important facet of the present work is utilization of sensors which are currently in use in fire detection systems. While the alarms are based on specific criteria, there is additional information available in modern systems. The information from the sensors themselves is analog data, measuring temperature, obscuration, species density, heat flux and other characteristics of the environment. What is needed is a means to use this information directly to provide earlier warning, and more specific information before and after alarm using these sensor suites.

There are three algorithmic approaches to the detection problem: set point and rate of rise (or a combination), principal component analysis, and neural networks. In all cases, the intent is to signal the presence of a fire or other threat, while not responding to signals which occur in a natural, or non-threatening, environment. The most useful of the algorithms studied is the curve matching concept embodied in neural network methods.

We will review the state-of-the-art in all three detection strategies and then show how to train a neural network to reduce both false negatives (missed fires) and false positives (nuisance alarms), while decreasing the time to detection. In training such algorithms, it is important to use a sufficiently large set of training and testing samples so that the algorithm is robust. We would expect a single experiment to provide very early detection for that single response curve. However, as the number of training sets is increased, incorporating variations in geometry and insult, the time to reliable detection increases. As the number of sensors used increases, we expect the detection time to decrease. The trade-off is in the necessity for using large (more than 10,000) sample sets. With a judicious use of modeling and experimental testing, this should not be a burdensome exercise. We have demonstrated the training of a neural network to show that it is possible, including very early detection. Although we find a 2% error rate with the present training regimen, this is still considerably better than current detection (30%) as well as methods proposed to date (10%).

An example of this work is shown by



The figure shows the time/temperature curves for two of the scenarios used for testing the neural network. The numbers are sequence numbers of the scenarios (in this case from 1 to 20768). The green bars show the results of current detection strategies (set point and rate of rise). The red markers are the time for detection by the neural network, and the "preconditioned" marker shows the reduction in time after training with prior knowledge.

1. A Review of Measurements and Candidate Signatures for Early Fire Detection, W.L. Grosshandler, NIST Internal Report 5555 (1995).

2. The Use of Surface and Thin Film Science in the Development of Advanced Gas Sensors, S. Semancik and R. Cavicchi, Applied Surface Science *70/71*, 337 (1993).

3. Underwriters' Laboratories, 333 Pfingsten Road , Northbrook, IL 60062-2096 USA

4. Factory Mutual Global, 1301 Atwood Avenue, Johnston, Rhode Island 02919 USA