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A Review Paper on Fire Detection

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Abstract

Fire is a common disastrous phenomenon that causes a serious threat to life and property. In order to protect life and property, a good fire detection system is necessary. However, the major concern with existing fire detection system design is about false alarm problem. In the present review, a fire detection system with reduced false alarm rates are identified and still the best method is suggested. Based from current literature survey, a number of research results for reducing false alarms such as multisensor technique, the use of neural networks, and image processing are identified. This formed the basis for developing new fire detection techniques and would be useful for future fire protection.

Keywords: *Fire Detection, Smoke Sensors, Multisensor Data Fusion, Temperature Sensors*

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INTRODUCTION

Fire is the rapid oxidation of a material in the exothermic chemical process of combustion, releasing heat, light, and various reaction products. It is the most damaging disasters in modern society. How to prevent people's lives and society's wealth from harm caused by fire has become a major issue currently [1]. Fires that occur in wild land (forests, etc.) could also affect habited areas.

These areas are widely known as Urban–Rural-Interface (URI), i.e., zones, where forests and rural lands interface with homes, other buildings and infrastructures [2]. Fire may occur at the residential level, industries, during transportation (e.g., buses, trains, airplanes, etc.), forests causing treat to wildlife because of some fire accidents. To overcome such situation, a fast and effective detection of fire is necessary. To avoid uncontrollable wide spreading of fires, it is necessary to detect fires in an early stage and prevent its propagation [3].

Fire releases heat, accompanied by flame, burning sound and generates new materials such as smoke and so on in the burning process [1]. Most of all fires emit smoke aerosols at some point during the combustion process. Therefore most conventional fire detectors are based on the detection of smoke by light scattering [4].

Fires in buildings, industries, forests, and vehicles produce hundreds to thousands of different gaseous components. The main target gases for fire detection are CO, CO_2, H_2, NO, NO_2 for most fire types. Open fires or flaming fire results in NO_2, CO_2 gases; smouldering fires results in CO, H_2 gases and nuisance includes alcohol, water vapour or solvent vapours More investigations are required to implement a most reliable fire detection system and understand the fire gas propagation behavior [5].

Most of the fire detection systems are based on smoke detectors. Smoke sensor provides rapid response time; it has high false-alarm rates [6]. Existing smoke detectors have never failed to indicate an actual fire but results in high false alarm rates. Some estimates are as high as 11:1 for the ratios of false to actual alarms. Their applications are also limited in a confined area as the smoke concentration may be diluted in a large monitoring area, which delays or even worst desensitizes the alarm triggering [7].

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FIRE DETECTION METHODS

Many techniques have been proposed for the early detection of fire with low false alarm rates. The present work is to identify the most reliable fire detection system. A fire sensor system based on the simultaneous detection of CO, CO_2, and smoke concentrations are demonstrated. The rates of increase of these three components are used in the fire alarm algorithm to determine the presence of a fire. The algorithm monitors the rate of increase of smoke level, and when this rate exceeds its threshold rate, the rates of increase of CO and CO_2 concentrations are checked. When either the rate of increase of CO or CO_2 concentration exceeds its threshold rate, a fire alarm is initiated. The fire detection system was found to perform better than a smoke detector operating alone. In cases where the smoke detector did not alarm, the algorithm was able to detect the fire. However, in cases where the smoke detector did alarm, the algorithm detected the fire in a much shorter time [4, 6]. But here some restrictions apply when using gas sensors. Among others, these are low cost, low power and long-term requirements. We identified advantages but also some challenges of gas detection technologies by testing colorimetric gas sensors, gas sensitive field effect transistors and metal oxide sensors. Most technologies are not completely selective to the target gas as there is not "the" fire with one specific mixture of combustion gases [4].

The most commonly used fire detector in the fire safety sector is the smoke detector even if they always have false alarms. Some estimates are as high as 11:1 for the ratios of false to actual alarms. Their applications are also limited in a confined area as the smoke concentration may be diluted in a large monitoring area, which delays or even worst desensitizes the alarm triggering. Flame detectors that use optical sensors working at specific spectral ranges to record the incoming electromagnetic emission at the selected wavelengths include infrared (IR), visible and ultraviolet (UV). Only UV- flame detectors work with wavelengths shorter than 400 nm. They detect flames at a high speed of 3–4 ms due to the UV high-energy radiation emitted by fires and explosion at the instant of their ignition. UV/IR detectors compare the threshold signal in two spectral ranges and their ratio to each other to confirm the reliability of the fire signal, minimizing false alarms. A ZigBee-based wireless sensor network node is used for the ultraviolet (UV) detection of flame. A wireless sensor network (WSN) with flame detectors as WSN nodes can alleviate this problem with no wiring network installation [7].

Fire detection using multisensory data requires measurements from infield sensors that are deployed in the area or out-field sensors which monitor the same area from a distance. In the Sensor and Computing Infrastructure for Environmental Risks (SCIER) system, temperature and humidity sensors (in-field) and vision sensors (out-of-field) are used. The last are based on a high-dynamic range contrast camera in which the contrast representation of a scene can be used to detect a smoke or a flame and generate a probability of a fire event. These two categories of sensors are combined in a two-level fusion scheme, thus improving the reliability of the system with respect to fire detection. The adoption of such a scheme has the advantage of early fire detection while reducing the false alarm rate [2]. Adaptive fusion algorithm for fire detection uses a smoke sensor, flame sensor, and temperature sensor to detect fire incident. In reality, the phenomenon of fire incident may have smoke, flame, and high temperature situations. However, these signals may happen simultaneously or sequentially. A fire-detection module is designed using an ionization smoke sensor (TG-135), temperature semiconductor sensor (AD590), and ultraviolet sensor (R2868). If a fire incident occurs, the security robot can find the fire source using the fire-detection module and transmit the detected message to the user via the Internet and a GSM modem [8].

A single-chip CMOS smoke and temperature sensor is used in an intelligent fire detector. Smoke sensor measures smoke density based on the light-scattering method. The temperature sensor is integrated with the smoke sensor not only to sense heat from a fire but also to compensate for the temperature dependency of the smoke sensor. The prototype chip is fabricated using a 0.35 m CMOS process and is placed inside the smoke

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detection chamber, while the thermistor for the temperature sensor is placed outside the chamber. It effectively cancels the influence of the temperature on the dark current and sensitivity. The test results show that the proposed fire detector provides 1% smoke detection accuracy over the range 4–25% and ±1°C temperature sensing accuracy over the range of 25–95°C. The power consumption of the prototype chip is 220 nW, excluding the infrared light-emitting diode (IR LED). Single-chip sensor could be applied to the intelligent fire detector that reduces false alarm rates and provides high reliability at the same time [9]. Fire is a nonstructural problem and difficult to be precisely described by mathematical model. So fire detection models based on fuzzy-neural network, which combines the advantages of fuzzy system and neural network, and makes fire signal processing, have self-learning and adaptive abilities. The model improves the intelligence of fire signal processing and has a stronger ability to adapt to the environment. It effectively solves the problems of mistake and failure in the fire alarm, and improves the sensibility of fire detection [10, 11].

There are many techniques which involves creation of robots for fire detection. A fire fighting robot uses a modular design concept to implement fire detection, path direction and extinguishing operations. The usual trend in the previous implementation is the use of smoke detectors and physical sensors for fire detection as well as depth manipulation. Generally most sensors have low range and are sensitive to environmental changes. Computer vision-based algorithm for fire detection directs the robot towards the detected fire, thereby overcoming the above limitations. Colour segmentation is used in initial detection. Correlation is used to extract the nonstatic property of fire. Temperature sensor and UV-TRON sensor are used to confirm the presence of fire along with depth mapping. Finally, a water sprinkler is used to extinguish the detected fire. They either use the static or dynamic characteristics of fire or incorporate both. The false fire detection rate can be reduced by application of correlation which extracts the nonstatic property of fire and X-ray film which reduces the effect of ambient sunlight. Fire detection algorithm costs an average of 20 ms per image which is close to reality [12].

With the rapid development of image and video processing, the fire detection technology based on video processing is becoming the focal point. It has high intuitive, speed and anti-jamming capability. Here fire detection is based on region growing. This method uses colour and motion information extracted from video sequences to detect fire. It works both indoors and outdoors. Moreover, it detects fire at the beginning of the burning process, enabling an early response than would be possible with a conventional fire detector. The method performs the region growing segmentation to identify colour pixels in the scene and then identify moving pixels based on the ratio of height and width of suspected fire region and correlation coefficient. This method gets low false alarm rate by eliminating the fire-like colours because it just needs a fire pixel as the seed pixel. In different environments, the level of fire and colour may vary. So, the technique has to be further improved for each specific environment such as forests, tunnels [13].The colour models can be extracted using a statistical analysis of samples extracted from different type of video sequences and images. The extracted models can be used in complete fire/smoke detection system which combines colour information with motion analysis. The model achieves up to 99.00% correct fire detection rate with a 4.50% false alarm rate [8, 14].

The main problem of fire detection is in the presence of obstacles that are nontransparent to visible or IR wavelengths. Exploiting the obstacle penetration capability of microwaves, a solution based on passive microwave radiometry can be used. Such a situation can be investigated by creating a model of the scene sensed by a microwave radiometer, accounting for the presence of both fire spot and wall-like obstacles. By reversing the model's equations, it is possible to directly relate the obstacle emissivity, reflectivity, and transmissivity to the antenna noise temperatures measured in several conditions. These temperatures have been sensed with a portable low-cost instrument. The selected

12.65 GHz operation frequency features good wall penetration capability to be balanced with a reasonable antenna size.

In particular, a 2 cm thick plasterboard wall, typically used for indoor building construction, shows a transmissivity equal to 0.86 and can easily be penetrated by a microwave radiometer in the X-band [15]. Most of the above discussed techniques result in high false rate alarms or false fire detection. Therefore, precise detection and location of fire is very important to overcome such limitations. To do this, the most reliable technique proposed here is multisensor data fusion with the adoption of the Fuzzy Set theory to deal with uncertainty, imprecision and incompleteness of the underlying data. The data can be collected from different sensors (gas sensors, smoke sensors, temperature, vision sensors and humidity) that are scattered at the supervising area. The data are obtained using wired or a wireless network. These data are fused together to arrive at the decision.

CONCLUSION

Most of the fire detection systems are based on smoke detectors, and gas sensors. They improve the detection performance with respect to time. But these detectors suffer from dust and hence false alarm rate is high. Image processing techniques for fire detection provides good result by extracting the dynamic and static characteristics of fire. But they result in false alarm, if the background colour is same as fire constituent colour. Microwaves are used to locate the fire in the presence of obstacles like wall (2 cm thickness) that are nontransparent to visible. Such systems fail to detect fire, if the thickness of the obstacle is more. To overcome from high false alarm rates and for precisely detecting and locating the fire, the most reliable technique proposed here is multisensor data fusion.

The data can be collected from different sensors (gas sensors, smoke sensors, temperature, vision sensors and humidity) and fused together to arrive at the decision. The data are obtained using wired or a wireless network of environmental sensors scattered at the supervising area and a vision sensor that monitors the same geographical area.

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