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Signal processing algorithms for fire localization using temperature sensor arrays

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Abstract

This paper proposes signal processing algorithms to resolve the problem of robust fire source localization under planar or circular wavefronts of hot gas conditions. The approach is based on the signal time delay estimates and replicas of a source signal at spatially distributed temperature sensor arrays. According to different planar and circular wavefronts, the far-field and near-field algorithm can be used, respectively, to identify the position of the fire source. On the one hand, experiments indicate that the far-field method provides acceptable errors for fire localization. On the other, by using a near-field algorithm, we can increase the probability of correct fire source localization compared to using only the far-field approach.

Keywords: Array signal processing; Source location; Fire detection

1. Introduction

Identification of the location of fire sources from the observations collected by sensor arrays is an important step that can be introduced into sensor array signal

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processing applications in automatic fire detection and extinguishing. Different solutions have been suggested to tackle the problem of fire localization [1,2], but these are impractical as they suffer from unrealistic hardware requirements. Recently work on fire localization with temperature sensor arrays has been proposed [3] which involves the far-field of the arrays and addresses the estimation of the angle parameters. It normally relies on the acquisition of time-delayed signals at spatially distributed sensors [4] remote from the source. The far-field assumption leads to linearly planar wavefronts at the arrays. However, the wavefronts of the heat of the fire are not generally linear in practice, there are circular wavefronts and vortices. In the near field, most of the temperature wavefronts are not linear and the errors may become large if we only use the far-field algorithm for fire localization.

In this paper, we propose a near field algorithm for fire localization. It uses the far-field method as the first step to calculate the parameters which are needed in the near-field algorithm. Then a method of calculating the direction angle and the distance radius for the fire source based on the near-field is proposed. The experiments indicate that the errors of the near-field method are reduced.

In any case, the following criteria must be approximately fulfilled:

- The ceiling should be horizontal and flat with a low thermal conductivity.
- The flow current velocity $\vec{v}$ of the hot gases should be constant under the ceiling in the early stage of fire.
- The fire is near floor level and not located directly adjacent to a wall.
- The walls are of a similar temperature.
- Other air currents, e.g. caused by a heating system, are neglected.

According to the above assumptions, a fire in a closed room will produce the hot gases. The hot gases rise up to the ceiling and then propagate along the ceiling towards the walls. In a plan view of this behavior, the propagation of the hot gases is modelled as closed rings. Each ring indicates a temperature wavefront of the same temperature.

The paper is organized as follows. In Section 2, a brief summary of the far-field algorithm is given. Section 3 discusses the new near-field algorithm. In Section 4, we present the performance of our approach based on experiments. Finally, a discussion of the results is provided and some conclusions are drawn.

2. Far-field algorithm

If we assume that the distance r between the fire and the sensor array is large compared to the sensor array geometry dimensions d ($r \gg d$) the wavefront can be modeled as quasi-planar, as shown in Fig. 1. The velocity vector $\vec{v}$ of this wavefront has its origin at the thermal source at (x_0, y_0). S_1–S_4 are four temperature sensors, and comprise the sensor array.

The sensors are located at the points (x_n, y_n), $n = 1, 2, 3, 4$. The square area of the array in the first measurements has a size of d^2 with $d = 10\,\text{cm}$.