

A METHOD AND APPARATUS FOR PREVENTING THE OCCURRENCE
OF FALSE RESPONSES IN OPTICAL DETECTION DEVICES

The present invention relates to a method and apparatus for preventing the occurrence of false responses in optical detection devices, which are sensitive to changes or fluctuations in optical radiation emitted from a source.

Examples of such optical detection devices are flame-detectors, smoke detectors and the like.

The response signal of such optical detection devices can be applied to provide a fire alarm signal or, for example, to supervise operation of burners, furnaces and the like.

Flame detectors in which radiation from the flames is sensed have been proposed, utilizing radiation derived from the flames in the visible light range, infra-red (I.R.) range, or ultraviolet (UV) range. Known flame detectors, to provide outputs representative of presence of a flame, and operating purely within the above referred to light ranges, frequently are not reliable, since signals are derived not only from radiation due to flames, but also caused by extraneous radiation, such as daylight, artificial light sources, radiant heaters providing I.R. radiation, and the like, or interruption of such extraneous radiations although no real flame - to be sensed - is present. It is therefore necessary to provide characteristic differences which distinguish flame radiation from extraneous disturbance radiation when evaluating the signals in order to prevent erroneous signals and malfunction.

In one flame detector, which has been proposed, the different spectral composition of radiation from flames

is used in order to distinguish between radiation from flames and disturbing or interfering radiation. Two photoelectric sensors with different spectral sensitivity are exposed to radiation from the flame; for example, one photoelectric sensor is sensitive to blue light, and one is sensitive to red light. The photo cells may be serially connected. At the junction point between the two photo cells, a d-c signal will occur which depends on the spectral composition or the colour of the light radiation to which the sensors are exposed. Such a flame detector, while functioning properly under most conditions may, however, react to interfering radiation which by chance has the same, or similar spectral composition as radiation from a flame.

It has also been proposed to distinguish between signals from flames and disturbing signals by utilizing the temporal variation of radiation from a flame. Flames do not radiate constantly, that is, with uniform intensity, but are subject to flicker, particularly within a certain frequency range. The signal from an appropriate sensor such as an I.R. sensor or a photo sensor is applied to a band pass filter which passes signals only in a limited frequency range which is characteristic for flame flicker. Such apparatus unfortunately also can be triggered by disturbing radiation of varying intensity, for example light reflected from water surfaces, sunlight interrupted by leaves and branches moving in the wind, or by fluorescent lights which are about to burn out and flicker off and on.

Thus, existing detectors are still responsible for false alarms; these are expensive, causing unnecessary shutdowns and lost production. In the case of flame detectors many false alarms arise from the tuned bandpass filter used to detect "flame flicker". Repetitive beam

- interrupts, vibration or periodic sources can trigger such a system, even though their signals are distinctly different from those of flames.

Thus, there is a need for a method and device which are able to discern important signals from otherwise confusing similar signals, thus leading to a reduction in misleading alarms.

The invention therefore provides a method for preventing the occurrence of false responses in optical detection devices, which are sensitive to changes or fluctuations in optical radiation emitted from a source comprising the steps of:

- a) receiving optical radiation emitted by a source;
- b) selecting a predetermined range of wavelengths;
- c) detecting changes in the received optical flux and deriving therefrom a signal having time series data (signal traces) at the detector output; characterized by the step of
- d) analyzing the detected signal for its chaotic (i.e. aperiodic) behaviour by establishing the associated fractal dimension of the signal and using the existence of this fractal property of the said time series data of the optical radiation emitted by the said source to discriminate against those sources of fluctuating optical radiation which are periodic or intermittent; and
- e) only providing a response at the output of the optical detection device in case of chaotic behaviour of the source.

The invention further provides an apparatus for preventing the occurrence of false responses in optical detection devices, which are sensitive to changes or fluctuations in optical radiation emitted from a source comprising means for receiving optical radiation emitted by a source; means for selecting a predetermined range of wavelengths; means for detecting changes in the received

optical flux and deriving therefrom a signal having time series data (signal traces) at the detector output; characterized by means for analyzing the detected signal for its chaotic (i.e. aperiodic) behaviour by establishing the associated fractal dimension of the signal and using the existence of this fractal property of the said time series data of the optical radiation emitted by the said source to discriminate against those sources of fluctuating optical radiation which are periodic or intermittent; and means for only providing a response at the output of the optical detection device in case of chaotic behaviour of the source.

Advantageously, the emitted and received optical radiation is in the infra-red (I.R.) range. The invention is based upon the following steps:

1. If chaotic, the trace will have a fractal dimension - the existence of a fractal dimension confirms it is chaotic;
2. It may be that the value of the fractal dimension is useful in further discriminating between different sources of chaotic optical radiation.

The invention is further based upon the fact that certain optical radiation e.g. flame flicker is chaotic, i.e. aperiodic. The chaotic behaviour of the flame can be objectively quantified by applying the concept of fractal dimension to the time series data from the detector output. Rotating or vibrating sources will be periodic, i.e. non-chaotic and will not have a fractal dimension, neither will beam interrupts.

The mathematics of fractals is a broad subject which has been developed in recent years.

A primary motivation in the development of fractals has been the desire to provide tools for a geometric, statistical description of highly contorted and roughened surfaces and curves.

The mathematics of fractals is known as such to those skilled in the art and will therefore not be described in detail.

Generally, it can be said that when measuring the length of a highly roughened perimeter, the answer is found to depend on the measurement scale and to tend to infinity as the measurement scale approaches zero.

To perform such a measurement, the roughened perimeter could be enscribed by a polygon of N sides of equal length ϵ .

Then the length is $N\epsilon$, a quantity which in practice is found to increase as ϵ is decreased.

The reason for this behaviour is that for any ϵ considered the perimeter is, on that scale, rough, and thus the polygon is never a complete representation of the surface or curve in question.

In addition it is found that when the measured lengths are plotted versus ϵ on a log-log scale a straight line results. Fractal character thus exhibits two distinctive features: (1) the measured length of a curve (or the area of a surface) depends on the measurement scale according (2) to a power law dependence, ϵ^{1-D} for curves (and ϵ^{2-D} for surfaces). D is called the fractal dimension and is noninteger for a fractal curve or surface, while for a smooth curve $D = 1$ and for a smooth surface $D = 2$.

According to the invention the key property of the detected signal is chaotic behaviour.

Establishing the fractal dimension is a simple way of establishing whether the signal is chaotic. The actual value obtained for the fractal dimension, while it may prove a useful quantity in itself, is not as significant as the existence of a fractal dimension which holds over a broad range of time intervals (analogous to the wide range of ϵ values for the case of the perimeter

previously discussed). Therefore, in particular, the invention is based upon the idea of using the fractal property of the time series data of the optical radiation e.g. the I.R. emitted by a flame to discriminate against those sources of fluctuating I.R. which though not flame generated, do satisfy the frequency test of existing flame detectors.

The invention will now be described in more detail by way of example by reference to the accompanying drawings, in which:

fig. 1 represents schematically the operational principles of known I.R. flame detectors;

fig. 2 represents flame flicker data which are used to apply the concept of fractal dimension according to the present invention; and

fig. 3 represents a graph derived from the data of fig. 2 from which according to the invention the fractal dimension of flicker can be obtained.

Referring to fig. 1, a narrowband optical bandpass filter 1 restricts the I.R. radiation from a source entering the detection device to a narrow range of wavelengths around 4.4 microns. These wavelengths are e.g. emitted by flames 3 or hot surfaces but are sufficiently strongly absorbed by the atmosphere for no contribution to be left in sunlight at the Earth's surface. Consequently, any such wavelengths entering the detector will have been produced locally - either in a flame or from a hot surface. The detector is effectively "solar blind".

The transmitted I.R. radiation is then detected by an I.R. detector 2. This is very sensitive and inherently suited to detecting changes in I.R. flux. The detector output is passed through an electrical bandpass filter 4 that restricts the transmitted signal to components in the range of 0.5 to 15 Hz. These frequencies are

characteristic of flickering flames.

If the detector senses a fluctuating I.R. signal in the frequency range 0.5 to 15 Hz then the detector signals an alarm A. False alarms can arise:

(i) when a hot object periodically enters or leaves the detector's field of view. For example, rotating machinery might periodically obscure or reveal a hot surface to the detector, or

(ii) when the detector's line-of-sight to a hot object is intermittently obscured, such as by a group of people walking past.

In either of the above cases, the resulting signal trace is markedly different from that generated by a flickering flame.

As already indicated in the foregoing, according to the invention the chaotic behaviour of the flame can be quantified by applying the concept of fractal dimension to the time series data from the detector output.

In fig. 2, three graphs (a), (b) and (c) have been shown, representing flame flicker data, obtained as time series data from the detector output.

The vertical axes represent relative intensity, whereas the horizontal axes represent time in seconds.

The trace length of a signal can be measured with progressively smaller step lengths (finer discrimination) by any means suitable for the purpose for recognizing chaotic behaviour and determining fractal dimension.

Although the fractal dimension of a trace can be measured in numerous ways, many of which are inherently suited to automatic implementation, an instructive way to consider the operation is shown in Fig. 2. Imagine stepping along the trace using means for measuring the trace length of a signal with progressively finer discrimination, e.g. a pair of suitable frequency dividers set to a particular step length. The measured

length of the trace is the number of steps times the step length; obviously for large step lengths much detailed structure is missed out. As the process is repeated with progressively smaller step lengths, ever smaller features of the trace can be followed and the total length measured increases.

For a chaotic trace, a plot of $\log$ (total measured length) against $\log$ (step length) will yield a straight line graph whose slope gives the fractal dimension. Fig. 3 shows such a result for a flickering flame.

The horizontal axis represents Log_{10} (step length) whereas the vertical axis represents Log_{10} (total measured length).

In fig. 3 the slope $\cong -.37$ and the fractal dimension of flicker $\cong 1.37$.

It will be appreciated by those skilled in the art that fractal dimensions of time series data are established and determined by suitable algorithms. Via a microprocessor in the detector head efficient algorithms can be implemented. E.g., a plug-in replacement head could be applied for simple retrofitting to existing systems. Alternatively, a control card could be used to handle the processing for several detector heads, interfacing them to the existing fire-detection system.

It will further be appreciated that the present invention is not restricted to flame detection or hot surface changes detection, but the fractal test algorithm of the invention could also be applied to detect phenomena such as smoke (where the signal fluctuations due to real smoke, are chaotic, whereas those from obscuration of the beam or beam interrupts, are not), gas or other dispersing constituents of a mixture for which the signals representing fluctuations in concentration need to be distinguished from more periodic or intermittent confusing signals.

Various modifications of the present invention will become apparent to those skilled in the art from the foregoing description. Such modifications are intended to fall within the scope of the appended claims.

C L A I M S

1. A method for preventing the occurrence of false responses in optical detection devices, which are sensitive to changes or fluctuations in optical radiation emitted from a source, comprising the steps of:

- a) receiving optical radiation emitted by a source;
- b) selecting a predetermined range of wavelengths;
- c) detecting changes in the received optical flux and deriving therefrom a signal having time series data (signal traces) at the detector output; characterized by the step of
- d) analyzing the detected signal for its chaotic (i.e. aperiodic) behaviour by establishing the associated fractal dimension of the signal and using the existence of this fractal property of the said time series data of the optical radiation emitted by the said source to discriminate against those sources of fluctuating optical radiation which are periodic or intermittent; and
- e) only providing a response at the output of the optical detection device in case of chaotic behaviour of the source.

2. The method as claimed in claim 1, characterized in that the fractal dimensions of the signal traces are measured.

3. The method as claimed in claim 2, characterized in that the fractal dimensions are measured by an algorithm.

4. The method as claimed in claim 3, characterized in that the trace length of a signal is measured with progressively finer discrimination.

5. The method as claimed in any one of claims 1-3, characterized in that the emitted and received optical radiation are in the infra-red (I.R.) range.





6. The method as claimed in claim 5, characterized in that the I.R. source is a flame and the I.R. sensitive detection device is a flame detector.

7. The method as claimed in any one of claims 1-6, characterized in that the optical detection device is a smoke detector, where the signal fluctuations due to real smoke, are chaotic, whereas those from obscuration of the beam or beam interrupts, are not.

8. The method as claimed in any one of claims 1-6, characterized in that the optical detection device, is a detector for gas or other dispersing constituents of a mixture for which the signals representing fluctuations in concentration need to be distinguished from more periodic or intermittent confusing signals.

9. An apparatus for preventing the occurrence of false responses in optical detection devices, which are sensitive to changes or fluctuations in optical radiation emitted from a source, comprising means for receiving optical radiation emitted by a source; means for selecting a predetermined range of wavelengths; means for detecting changes in the received optical flux and deriving therefrom a signal having time series data (signal traces) at the detector output; characterized by means for analyzing the detected signal for its chaotic (i.e. aperiodic) behaviour by establishing the associated fractal dimension of the signal and using this fractal property of the said time series data of the optical radiation emitted by the said source to discriminate against those sources of fluctuating optical radiation which are periodic or intermittent; and means for only providing a response at the output of the optical detection device in case of chaotic behaviour of the source.

10. The apparatus as claimed in claim 9, characterized by means for measuring the trace length of a signal with

progressively finer discrimination.

11. The apparatus as claimed in claim 10 or 11, characterized in that a microprocessor is incorporated within the detector head.

12. The apparatus as claimed in any one of claims 9-11, characterized in that the emitted and received optical radiation are in the infra-red (I.R.) range.

13. The apparatus as claimed in claim 12, characterized in that the I.R. source is a flame or hot surface and the I.R. sensitive detection device is a flame detector.

14. The apparatus as claimed in any one of claims 9-13, characterized in that the optical detection device is a smoke detector, where the signal fluctuations due to real smoke, are chaotic, whereas those from obscuration of the beam or beam interrupts, are not.

15. The apparatus as claimed in any one of claims 9-13, characterized in that the optical detection device is a detector for gas or other dispersing constituents of a mixture for which the signals representing fluctuations in concentration need to be distinguished from more periodic or intermittent confusing signals.



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