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Decision Algorithms in Fire Detection Systems

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Abstract: Analogue (and addressable) fire detection systems enables a new quality in improving sensitivity to real fires and reducing susceptibility to nuisance alarm sources. Different decision algorithms types were developed with intention to improve sensitivity and reduce false alarm occurrence. At the beginning, it was free alarm level adjustment based on preset level. Majority of multi-criteria decision work was based on multi-sensor (multi-signature) decision algorithms – using different type of sensors on the same location or, rather, using different aspects (level and rise) of one sensor measured value.

Our idea is to improve sensitivity and reduce false alarm occurrence by forming groups of sensors that work in similar conditions (same world side in the building, same or similar technology or working time). Original multi-criteria decision algorithms based on level, rise and difference of level and rise from group average are discussed in this paper.

Keywords: Decision algorithms, System architecture, Fire detection systems.

1 Introduction

The application of multi-criteria fire-detection technology primarily started with the introduction of addressable analog detectors. Advances in microprocessor electronics first allowed detectors to be more intelligently monitored and controlled by a supervisory control panel. In more recent years, further advancements in microprocessor electronics have allowed the development of intelligent detectors. In this case, data processing can occur in the detector itself, independent of the control panel.

The use of multi-criteria-based detection technology continues to offer the most promising means to achieve both improved sensitivity to real fires and reduced susceptibility to nuisance alarm sources [1, 6]. A multi-criteria detection system can be developed by properly processing the output from sensors that measure multiple signatures of a developing fire or by analyzing multiple aspects of a given sensor output (e.g., absolute value, rate of rise or fluctuation).

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All of the work in the area of multi-criteria fire detection has focused on processing data from different types of detectors from the same point on the object, so cold multiple sensors (i.e., multi-signature detection) [2-4, 6, 8, 9]. All of those sensors operate with adjustable, but still predefined alarm levels.

Much of this research has focused on the development of alarm algorithms using fuzzy logic and neural networks for event classification and discrimination between fire and nuisance sources [7, 10].

Our idea is to consider same type (or types) of sensors on the different locations on objects as a group.

Grouping sensors according some criteria (topological, working time or technology), calculating group average level and using it in alarm level calculating could give the new quality in fire detection.

2 Alarm Level Settings

Independently of the place of execution of algorithms (in the detector or in the control panel), free alarm setting level is enabled.

Changing of alarm level could be automated on the different bases such as: winter, summer, presence or absence of heating, part of a day and similar. Fig. 1 shows natural course of daily temperature changes in a non air-conditioned working room during winter and during summer period. By changing of alarm level for daily and annual level, in advance settled curve was followed. Thus, it is possible to alarm fire danger already at 10°C (in a cold winter night) but only at 50° C (in a hot summer afternoon), in the same room. It is clear that similar curves of changes may be settled for smoke concentration.

Decision about alarm condition is made in the detector itself or in the control panel in the same way as with classic detectors by comparing the measured value with the alarm level. By such an approach, sensitivity of the detector is increased, and increase of false alarms is avoided [5].

Further increase of the quality of the announced alarms can be reached by uniting of detectors on the eastern and western side of a building, by detaching of their curves for temperature changing and by comparison of the measured temperature with the temperatures of detectors from the group. Fig. 2 shows the decision algorithm about the fire alarm comparing the measured level of fire parameter with the average value of the reached levels of other detectors from the group.

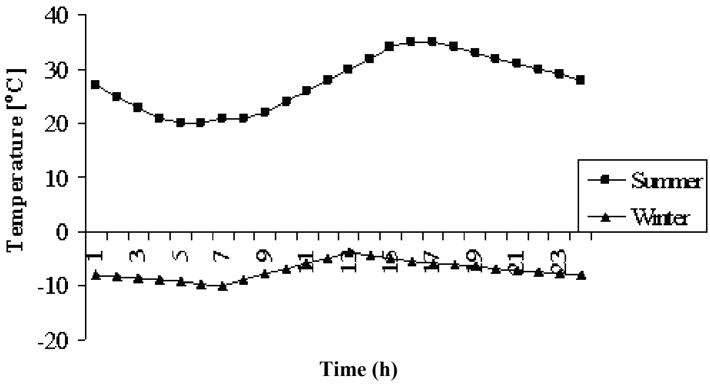

Fig. 1 – *Daily changes in temperature during summer and winter period in a not acclimatized and unheated room.*

(a)

if $E_i \geq E_{ial}$
    then if $E_i \geq E_g + \Delta$
        then $AL_i = 1$
    endif
endif

(b)

if $E_i \geq E_{ial}$
then $AL_i = 1$
    else if $E_i \geq E_g + \Delta$
then $AL_i = 1$
endif
endif

Fig. 2 – *Decision algorithm based on the reached level and average value of the group:* (a) *increased reliability*; (b) *increased sensitivity.*
E_i – *measured value on detector i*, E_{ial} – *alarm value for detector i,*
E_g – *average level of the group*,
Δ – *allowed difference from average value of the group.*

3 Gradient Introduction

Observation of analogue values of detectors enables us to follow the speed of increase of the observed fire parameters. With the classic detectors, there is a well-known type of thermo differential fire detectors. Now, it is possible, with the help of corresponding software, to treat each temperature sensor as both - top thermal and thermo differential. Besides, each smoke detector could be observed as a top and a differential detector. Now we can talk about the gradient (speed of changing) of the observed fire parameter. Fig.3 shows the decision algorithm on the base of the reached level and the gradient of the observed fire parameter. This type of algorithm could be executed in the detector itself as well as in the control panel and it gives more earlier information about the fire danger. If we make correct choice of alarm gradients, there will not appear an increased number of false alarms.

(a)	(b)

if $E_i \geq E_{ial}$
    then if $G_i \geq G_{ial}$
        then $AL_i = 1$
      endif
endif
	if $E_i \geq E_{ial}$
	    then $AL_i = 1$
	    else if $G_i \geq G_{ial}$
	        then $AL_i = 1$
	      endif
	endif

Fig. 3 – *Decision algorithm based on the reached level and gradient:*
(a) *increased reliability*; (b) *increased sensitivity.*
E_i – measured value on detector i, E_{ial} – alarm value for detector i, G_i –gradient on detector i, G_{ial} - alarm level for gradient for detector i.

4 Multicriteria Decision

Measuring of one fire parameter (example temperature) it is possible to recognize four different alarm conditions caused by:

Reaching of preset alarm level – ALL;

Reaching of preset gradient level – ALG;

Greater than allowed levels differ from average level of a group – ALLΔ;

Greater than allowed gradients differ from average gradient of a group – ALGΔ.

Maximal adaptability of alarm level to the conditions in observed room was reached by adapting alarm level during the year (because of yearly oscillations of the temperature) and during the day (because of daily oscillations of the temperature, people presence and technology).

Maximal adaptability of gradient alarm level to the natural gradient oscillations (caused by heating, cooling, people presence or technology) was reached by adapting gradient alarm level during the year and during the day.

Further decreasing of false alarm occurrence and increasing of sensitivity could be reached by appropriate grouping of detector on some reasonable base and by defining of allowed deviation from average level and gradient of the group.

Decision about fire alarm level could be made on the base of four parameters and choice of one of many decision algorithms. Four Boolean variables enable (theoretically) sixteen decision algorithms, but this number will be reduced on a few, in practice. **Table 1** shows all possible combinations of alarm variables on one detector and three of sixteen decision algorithms. Analogue values of level and gradient compared with pre defined alarm levels and average group levels and allowed differs gives values for four Boolean alarm variables (ALL, ALG, ALLΔ and ALGΔ), as shown on Figs. 2 and 3. Based on the values of four Boolean variables and using one of 16 possible algorithms we can make a decision about fire hazard as L – low, PA – pre alarm conditions, A – alarm. Some decimal value corresponds to any combination of Boolean variables ALL, ALG, ALLΔ and ALGΔ. Selecting one of possible algorithms (working regimes), in adequate row is fire hazard level.

Table 1
Alarm values and fire hazard.

N°	Alarm values				Algorithms					
	ALL	ALG	ALLΔ	ALGΔ	1	2	3	4		
0	0	0	0	0	L	L	L			
1	0	0	0	1	PA	L	L			
2	0	0	1	0	PA	L	L			
3	0	0	1	1	A	PA	PA			
4	0	1	0	0	PA	L	L			
5	0	1	0	1	A	A	PA			
6	0	1	1	0	A	PA	PA			
7	0	1	1	1	A	A	A			
8	1	0	0	0	A	L	L			
9	1	0	0	1	A	PA	PA			
10	1	0	1	0	A	A	PA			
11	1	0	1	1	A	A	A			
12	1	1	0	0	A	PA	PA			
13	1	1	0	1	A	A	A			
14	1	1	1	0	A	A	A			
15	1	1	1	1	A	A	A			

It is possible to make decision based on a couple of algorithms based on majority.

Systematically monitoring of false alarm and pre alarm and adjustment of alarm levels and allowed differs from group average of level and gradient requests organization of database about events in fire detection system and adequate programs for analyse and parameter correction.

Such algorithms are possible only in control panel, not in detector.

5 Supervision of Sensor Dirtiness

It is quite an expense for maintenance of the fire detection system. Also, for periodical checking of sensor dirtiness together with the additional unpleasantness that is obviously in connection with switching off of the certain informing sectors. Automatization of this process increases reliability of the whole system significantly by alarming of sensor dirtiness. Dirtiness level decision algorithm is shown in Fig. 4.

6 Conclusion

Number of variables used in decisions and the freedom of their assignment, undoubtedly brings new quality to the fire detection systems. Usage and maintenance by such a number of parameters represents also a potential source of errors. Further development of fire detection and information system will demand more attention to be paid to the so-called user's program-set of tools, which will enable the user more simple way of resourcefulness in abundance of possibilities.

Fuzzification of the observed fire parameters, by applying fuzzy logics and by forming of knowledge base, performances of the security system can be improved.

Addressable and analogue fire detection systems have opened many possibilities. Main directions and the way of using these possibilities were emphasized in this paper. Authors do not know fire alarm algorithms that use grouping sensors according some criteria (topological, working time or technology), calculating group average level and using it in alarm level calculating.

if $\Delta_{ig} \le \Delta_{iw} - C_1$;......................*daily difference min. and max. is different from weekly difference for* C_1
  then if $\Delta_{ig} \le \Delta_{im} - C_1$; ....*daily difference is different from monthly difference for* C_1
    then if $\Delta_{ig} \le \Delta_{im} - C_2$; ......*daily difference is different from monthly difference for* C_2
      then $SZ_i = 2$;................*dirtyness level* = 2
      else $SZ_i = 1$;.................*dirtiness level* = 1
    endif
endif
else $SZ_i = 0$;..*dirtiness level* = 0
endif

Fig. 4 – *Dirtiness level decision algorithm*:
Δ_{ig} – *daily difference on detector i*; Δ_{iw} – *weekly difference on detector i*;
Δ_{im} – *monthly difference on detector i*; C_1, C_2 – *constants*.

Original algorithms based on original idea were expressed in that paper.

If we succeeded to induce researches and planning engineers of some new thinking, and users to ask for explanations from their suppliers, we shall consider that the aim of this paper is reached.

7 Acknowledgement

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