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Editors: Kellie Beall, William Grosshandler and Heinz Luck

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NIST
National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

U. Oppelt
BOSCH Telecom GmbH, Ottobrunn, Germany

Measuring results of a combined optical, thermal and CO detector in real sites and classifying the signals

1 Introduction

One of the major problems of fire detectors is the number of deceptive alarms. Though the detectors themselves are not unreliable, they are sensitive to other aerosols and their large number in the field can lead to a significant amount of false actions of the fire brigades. It is fact, that deceptive signals, mainly caused by aerosols or dust, without any danger of fire, happen much more often than real fire situations. Various statistics prove, that fire brigade actions preponderate for other reasons than fire. The number of deceptive alarms depends on the application and the installation site, but there is also a human factor in not properly recognizing critical installation areas. The aim is, to find solutions for a better enhance disturbance behavior of today's detectors. For special applications like fire detection in airplanes or in coil processing plants, there are already sophisticated special solutions. But these solutions cannot be transferred easily to general purpose applications.

The range of applications for fire detectors can be broadened by using additional information from the signals provided by the fire accident. This additional information can be obtained from time analysis of the smoke density signal, from information on the installation site or from additional signals of other sensors. This paper reports on measurements with a new fire detector that comprises a light scattering detector, a temperature sensor and a CO-gas sensor.

2 Influence of variations of light scattering on the signals from a light scattering detector

Figure 1 shows the electrical signal of a light scattering detector over a time course of 9 hours in a normal environment without any signal processing or filtering.

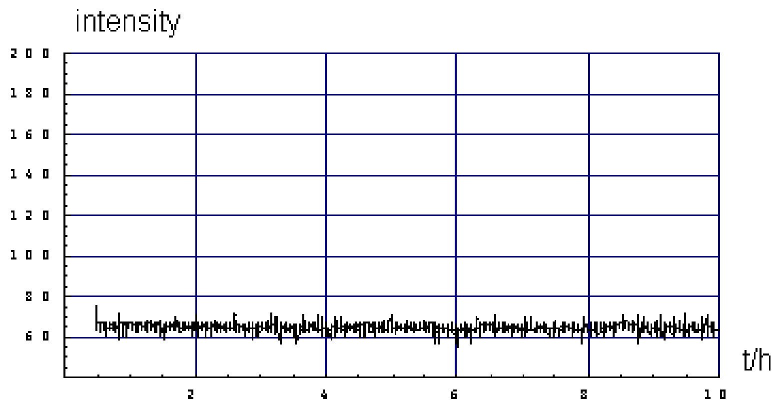


Fig. 1: Light scattering signal in normal environment

An analysis of the signal with a χ^2 –test shows, that a Gaussian distribution can be assumed for this sample. With an typical signal to noise ratio S/N=20 and sample rate of one second the threshold will be exceeded once in 2 x 10^{316} years. This dramatically changes with signals sampled from a susceptible environment. Fig. 2 shows for the signal taken in a smokers room as an example.

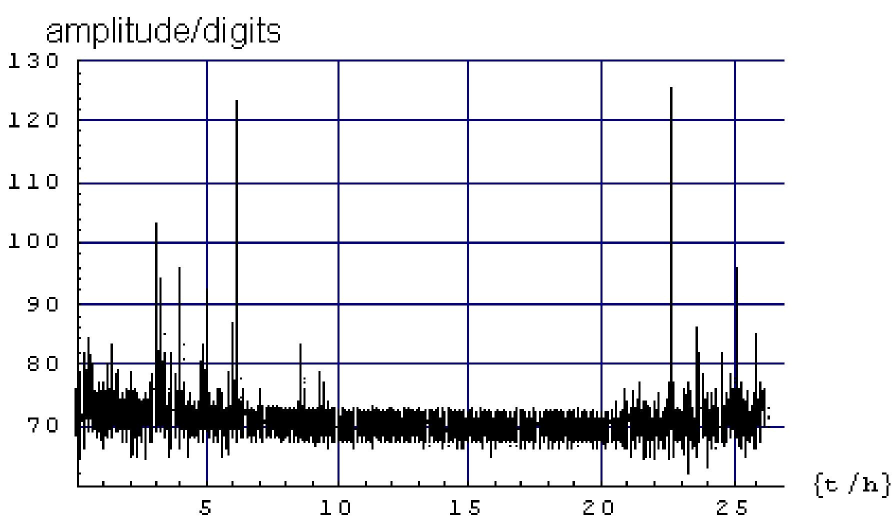


Fig. 2: Raw signal from a smokers room

Distinct signals peaks are recognizable in the distribution density diagram. The values around zero have been suppressed, to highlight the distribution of the disturbance signal.

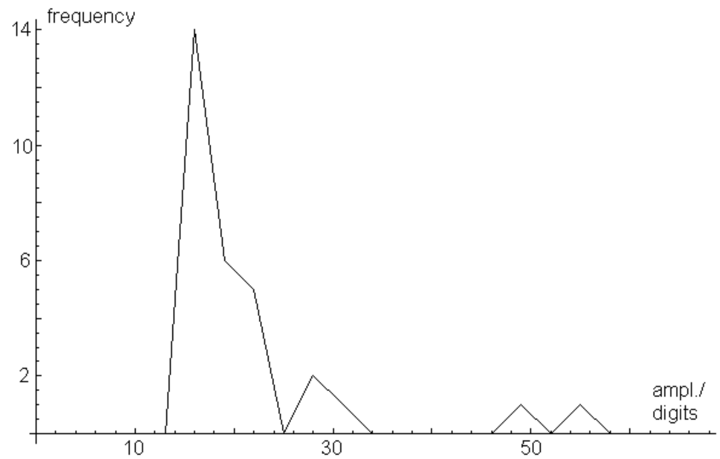


Fig. 3: Distribution density from signals of a smokers room

To estimate the probability of a deception alarm, the ditribution density was approximated with a logarithmic normal distribution density funtion.

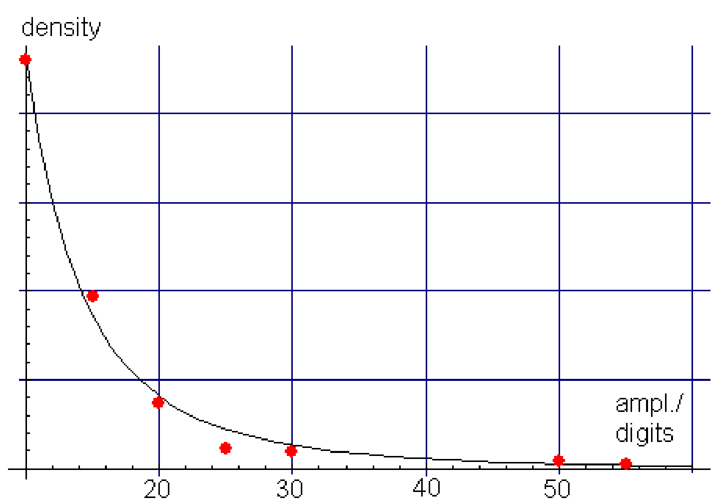


Fig. 4: Approximation of the measured distribution density with a logarithmic normal distribution density function

With this model one can estimate for a given alarm threshold, when a false alarm will occur.

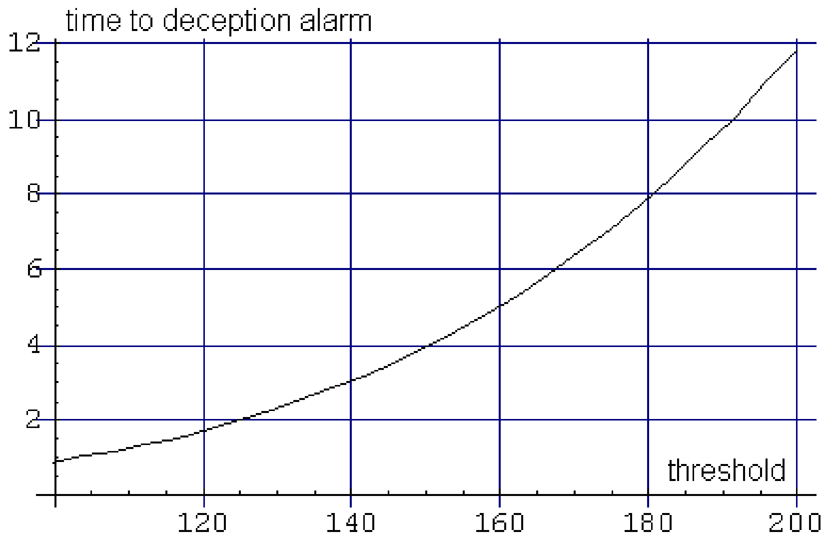


Fig. 5: Schematic rate of deception alarms depending of the alarm threshold

It can be seen, that the deception alarm rate decreases more than proportional. Doubling the threshold lowers the false alarm rate by a factor of 10. This consideration was done with raw signals, still without any aspects of signal analysis, and shows, what improvement can be expected using additional information to raise the threshold for the optical alarm signal. So the use of more than a single sensor is an attractive possibility for obtaining additional information. To get an impression about the usability of combined sensors in fire detection, a new detector comprising a light scattering chamber, a temperature sensor and a CO gas sensor was investigated with test fires of EN54 and some additional defined fires and artificial produced disturbances.

The CO sensor was an electrochemical cell. The properties of electrochemical cells have been significantly improved over the last few years. The life time of today's cells is specified with more than 5 years and the costs lie in a range now, making their use in fire detectors attractive. The selectivity is sufficient and the power consumption is low in contrast to metal oxid sensors, which need power to heat them. To analyze the new fire detector further, it has been analyzed under different environmental conditions for a longer time beside the pure fire tests.

3 Fire tests

The new detector was tested in a fire room with standard test fires. Table 1 shows the CO sensor values at the end of the fires defined by EN54. In case of a fire situation a significant concentration of CO is expected, at smoldering fires (TF 3) it is particularly high (Fig 6).

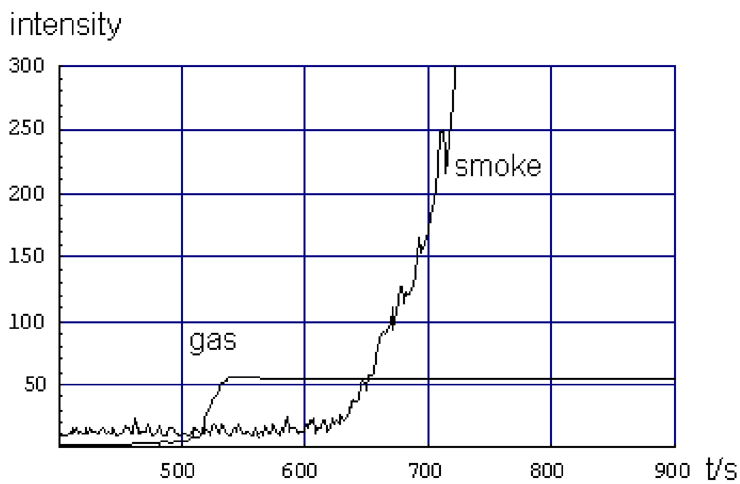


Fig. 6: CO and smoke signal of smoldering cotton fire (EN54)

One has to be aware that CO can also be measured at other occasions than a fire, e.g. in environments with cars with operating engine.

Test fire according EN54	CO-concentration at the end of fire in ppm
TF1 open wood fire	20 ... 35
TF2 smoldering wood fire	10 ... 47
TF3 glowing smoldering cotton fire	130
TF4 flaming plastics (polyurethane)	25
TF5 flaming liquid, n-heptan	14 ... 33
TF6 Aethanol	1,5 ... 10
TF7 Decalin	16 ... 27
cable fire	3 ... 6
paper bin fire	35

Table 1: CO-concentration at standard fires

Installations at real sites should reveal, therefore, which signals are to be expected, and whether the combination of the values of the scattering, temperature and CO concentration signals can give information about the origin of the sensor output.

4 Measuring arrangement

To analyze different applications for the new fire detector, it was exposed to various influences. In some situations the optical detector may react insensible, while the other sensors will be very reactive and vice versa. The list below shows some critical factors, to which a fire detector has to adapt in normal environments.

- cigarette smoke
- draught in entrance areas
- heater fans in industrial halls
- high humidity, dew
- fog
- all kind of dust (color, particle size)
- various climates and temperature cycling (operating < 0°C)
- fibers
- insects
- damp, smear films, solvents
- gasoline gases
- emanation in plasic manufacturing
- direct sunlight

For the selection of test sites as much different surroundings as possible were chosen. The results presented here include a smokers room, a welder room, a hall with open sides to the free air, a repair garage for cars and a normal industrial environment. Fig 7 shows the data acquisition system. The fire detectors were installed together with a customary fire panel. They sent all the actual sensor values on demand. The data were collected about every 5 minutes, depending from the number of detectors in the loop, and are temporarily stored in the fire panel. In case of an alarm or a pre alarm (75% threshold) the measurment ensemble was immediately transmitted, in order not to loose the values of the alarm situation. Furthermore the values of this special detector

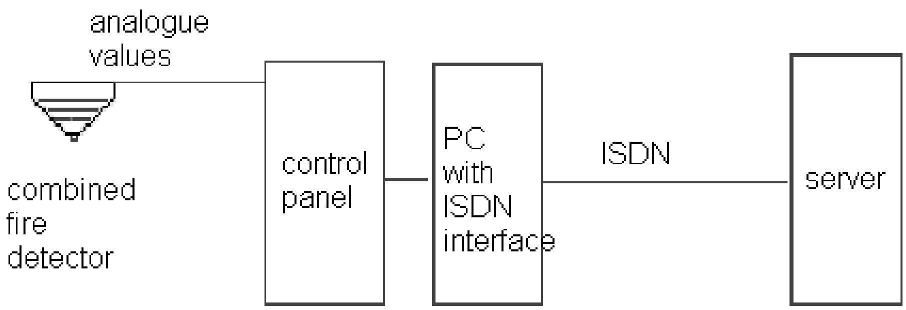


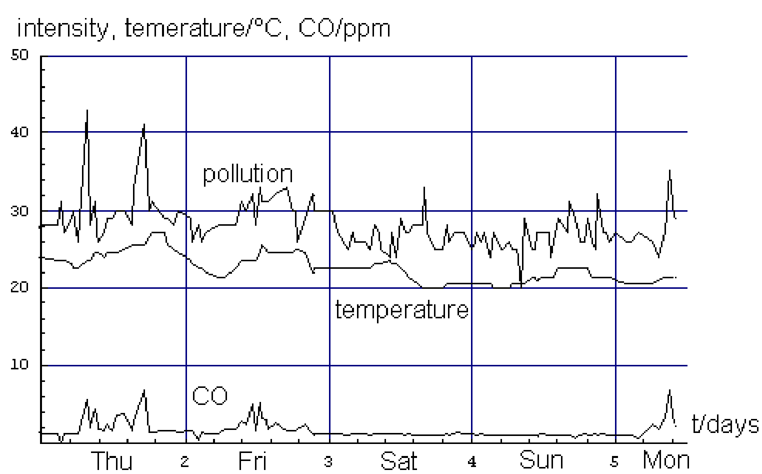
Fig. 7: recording of measuring values

in the loop were sampled with a higher sampling rate. Every hour, the stored values were transmitted to a personal computer, where the data were packed and saved in a sequential file on a mass storage. Once a day, these data were transmitted via an ISDN data link to a server at the development location for further data analyzis. For a detailed evaluation some data collection was also done in real time.

5 measuring values

The following figures show typical curves from the critical application areas with disturbace signals. A closer view at the data of the welding cabin shows, that the optical and CO signals are mainly short peaks. This could not only be seen in amplitude analysis but also in a time analysis. Specific experiments in the fire room show, that the emission of CO is less with electric welding than with autogenious welding.

Fig 8: Measurement curve in a smokers room for 4 days



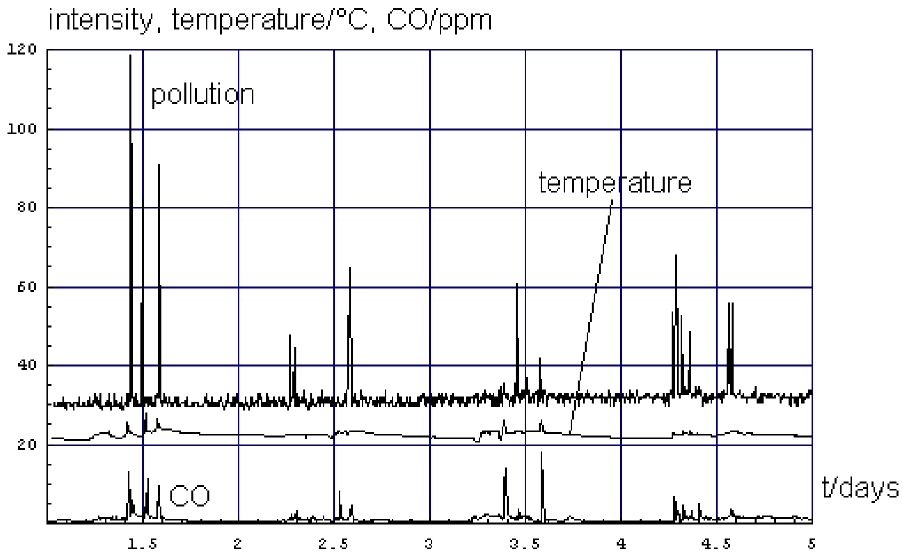


Fig. 9: measurements in a welding cabin

Contrary to welding, the cars driving in and out of a repair garage gave a significant CO signal. The values are higher than the values at the majority of the test fires. It is interesting, that the light scattering signal does not show significant amplitude values.

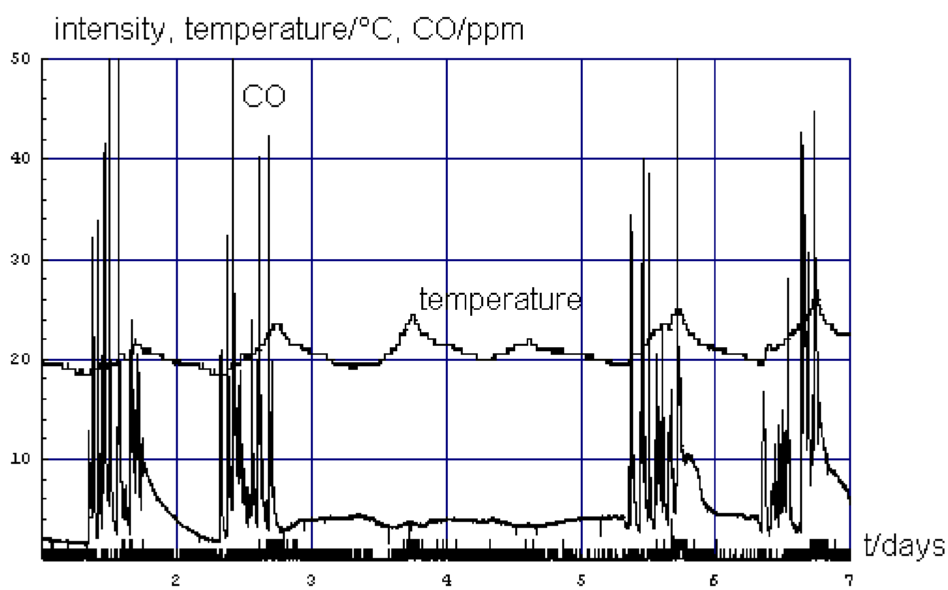


Fig. 10: signal curve in a garage

All shown disturbance values were especially chosen, because aerosol as well as CO occurs simultaneously even though in different amplitudes. However many disturbance effect only the optical part of the fire detector. For this belongs beside the general creeping dust accumulation, making the detector more unstable, all kind of dust and foggy substances corrupt the optical signals. An extreme example is an experiment with disco fog (Fig. 11). Similar to dust, there is no CO signal as well as there is no increase in temperature.

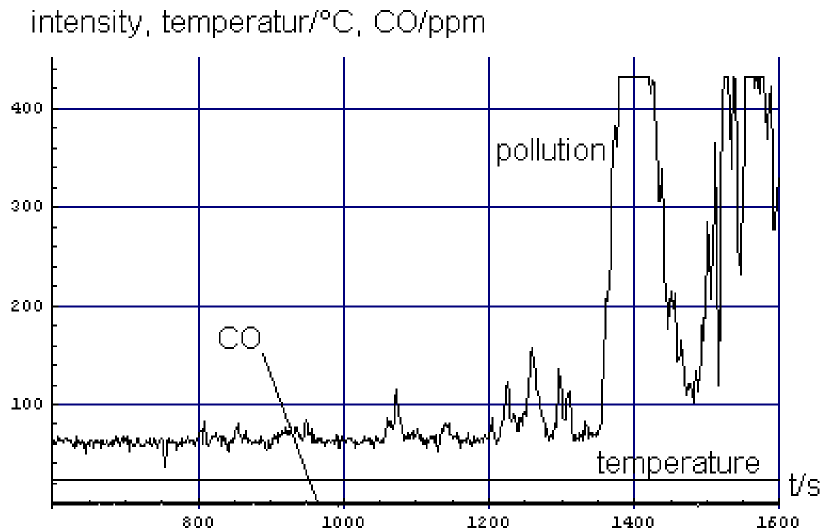


Fig. 11: experimental measuring with disco fog

6. Classification of the signals

The single signals of the detector have been divided into rough classes. The classes were named as “nothing”, “some”, “more”, “much”, “very much”. “Nothing” means, there is no signal which can be assigned to the event, “some” means a signal in accordance to the event, but it is to small to make a decision on this signal without a priori knowledge. “More” means a value near but not reaching the alarm threshold. “Much” stands for alarm and “very much” is a value far beyond the alarm. The presence of disturbance signals increase the risk of false alarms dependent on the probability of their occurrence. In table 2 it is seen, that at all test fires except the alcohol fire CO is generated in a measurable amount. Therefore it seems, that CO could be used for the validating a fire situation, but contrary it cannot be concluded that it is possible the CO signal alone for suppressing disturbance signals. With disturbance signals like cigarette smoke and welding CO concentrations are measured similar to some test fires. The combination of the light scattering signal and the CO signal is also not clear enough to make a distinction between fire and deception. The temperature and the optical signal cannot distinguish clearly between smoldering fires and disturbance signals caused by dust and aerosols. It is the nature of the deception signals caused by combustion processes have a similar behavior as caused by injuring fires.

event	scatter signal	temperature	CO signal	remarks
TF1	some	morer	more	
TF2	very much	nothing	much	
TF3	very much	nothing	very much	
TF4	much	some	more	
TF5	much	more	more	
TF6	nothing	very much	nothing	
TF7	very much	some	more	
dico fog	very much	nothing	nothing	
cigarette	some	nothing	more	CO conc. similar to TF1
welding autogenious	some	nothing/some	more	CO conc. to TF1
welding electro	much	nothing	some	
car garage	nothing	nothing	very much	high CO-values
diesel aggregate	some	nothing	very much	

Table 2: classifying of signals

Fig. 12 shows the recording of value triples. The large points show the values of the test fires, the smaller points represent the values of disturbance signals. In this three dimensional graph the disturbance signals could be separated from the fire signals, there is no overlap. Disturbance signals with a high amplitude in only one category could be suppressed with clever positioning a threshold area. The obtainable gain can be estimated from fig. 5 and is expected to be in one order of magnitude.

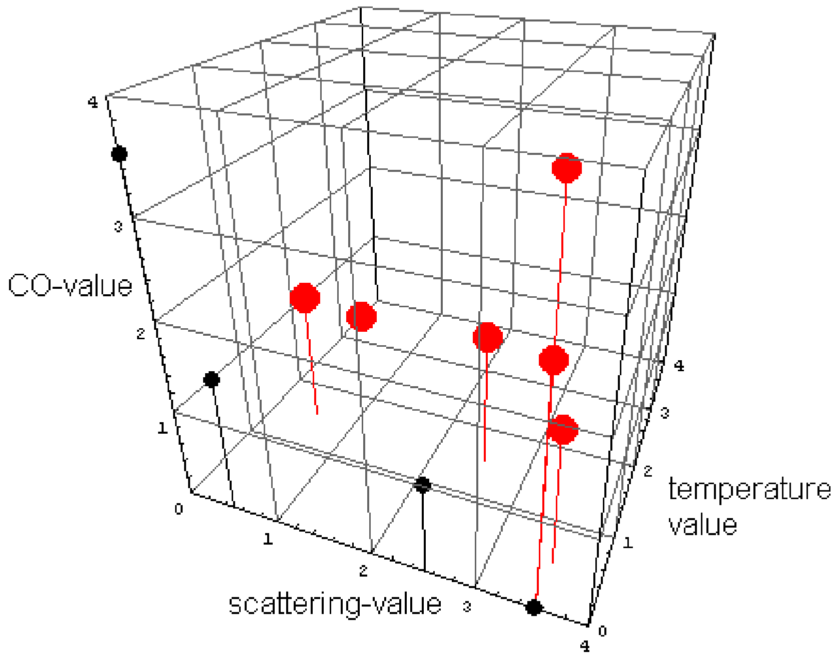


Fig. 12: Classifying of disturbance and fire signals (small points: disturbance signal, large points: signal from fire)

7 Conclusion

Measurement triple of new fire detector combining optical, temperature and CO sensors were be presented. Using all three signals in environments with disturbance signals caused by dust and aerosols a significant improvement of disturbance rejection can be expected. Deception signals caused by combustion processes resemble real fires with a high grade. Improved rejection of deception signals could be reached by selecting a threshold area between the different triple values of fire and non fire signals. Not mentioned in this report was the potential to validate signals by a time domain analysis. With the a priori knowledge about the application field, the detector combining optical, temperature and CO sensors promised a significant improvement in reliability in many disturbance areas.