Video-based fire detection with intelligent algorithms

White Paper - Bosch Building Technologies

Table of Contents

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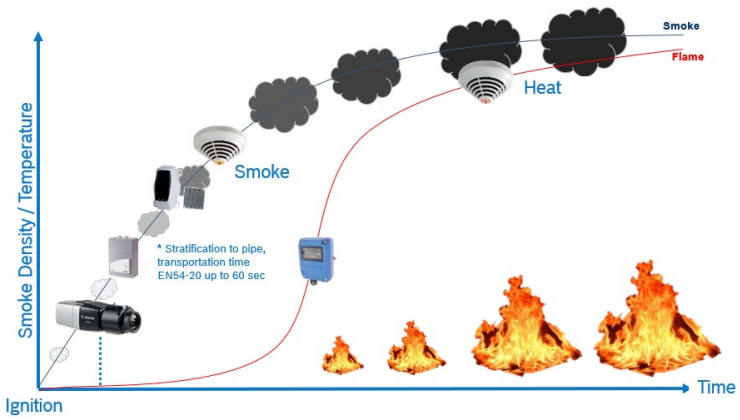
Executive summary

Common smoke and flame detection technologies are a reliable and a cost-efficient fire safety solution. However, they reach the limits of their efficacy in challenging environments. These include industrial sites, large, spacious buildings with high ceilings and sheltered outdoor constructions, often used for storage. In industrial applications, interference from disturbing factors, such as dust and humidity, can create false alarms or pollute the detector, while high ceilings often prevent early detection due to slow smoke migration towards the detectors, typically mounted on the ceiling. Video-based detection technologies, using intelligent video analytics and reliable detection at a fire's source, can be a solution in such cases due to their rapid, much earlier detection and subsequent alerts. More recent developments, with AI algorithms added to the cameras, have created an advanced level of fire detection which is not only more sensitive but also much more robust against false alarms. This offers not only a high level of reliability for safety and protection of entire premises, but also of business continuity.

Challenging environments and the limitations of typical fire detectors

Most of today's fire alarm systems use a variety of smoke detection technologies to detect fire. These include spot-type ionization and photoelectric detectors, aspirating smoke detectors and linear beam-type smoke detectors. In some applications, planners also use flame detectors or linear heat detectors for rapid flame detection. Vendors continuously improve all these detection technologies to provide broader coverage and a faster response to real fire sources while trying to eliminate false alarms as reliably as possible. In addition, improvements include feature development, and reducing the maintenance, testing and installation costs.



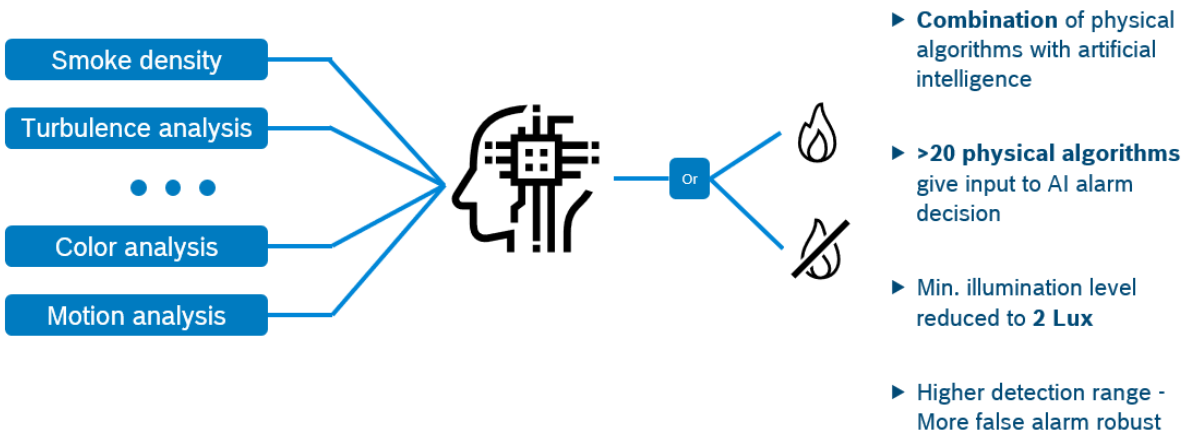
However, some fundamental issues will always limit the detectors' capabilities due to physical restrictions, especially when smoke needs to migrate to the detectors. This is even more the case in challenging environments with hazardous materials or a high fire load, like sawmills, power plants, warehouses or production facilities. Buildings with high ceilings and outdoor sheltered constructions, which are open to the elements and typically used to store large volumes of materials, equipment or machinery, also pose substantial challenges of installing reliable fire and smoke detection devices.

Using video technology for fire detection

When a fire breaks out, every second counts towards safety, protection of assets and premises, and business continuity. One of the main benefits of video-based fire detection is speed and reaction time. As a video camera can detect a fire as soon as the smoke enters its field of view, and thus does not require the smoke to migrate to the sensor, it triggers much faster than point-type, beam or aspiration smoke detectors. In demanding environments with high ceilings, video-based fire detection solutions can detect a fire at its source within seconds while other technologies will need minutes before the slow-rising smoke reaches them. Video-based fire detection can also cover larger areas and spaces than point-type detectors, making them a much more affordable solution for warehouses, hangars or large halls.

Operators in a monitoring center or local guards can verify the alert in the video image before triggering a fire alarm. In addition, they can precisely pinpoint the exact location of the fire, as well as involved commodities, potentially providing valuable time for firefighting.

Video-based fire detection solutions are installed with complex physical and AI algorithms which were pre-configured to analyze extensive video footage for any signs of smoke or flames. Neural networks, contrast-based and physical algorithms are all different technological options for analyzing the images from the video footage for any signs of smoke or flames, although newer video-based technologies are installed with advanced algorithms configured with artificial intelligence and IoT.



Neural networks use decision trees which are trained by labeled video footage. Depending on the training video footage captured, these algorithms learn what flames or smoke look like in the video image. Neural networks are therefore highly dependent on this video footage. This can be really effective when using the right footage – showing a wide variety of settings, scenarios, types of fire, and diverse degrees of illumination and movement – all labeled accordingly. If the footage has too little

variation in the types of fire and environments they show, the algorithms may encounter difficulties with anything different as these are unlabeled factors and parameters for which no decision tree has been set up. Too much, or too little training can risk either an undetected fire or frequent false alarms respectively. However, neural networks built up with the right footage and thorough training, covering all realistic eventualities, can be an effective approach for successful fire detection.

Contrast-based smoke detection algorithms check video images for growing gray areas and the loss of contrast to the background using the optical effects of smoke in the video image. They can only be used for smoke detection and are susceptible to illuminance changes. For detection performance to be effective, a very well-structured and high-contrast background is needed.

Physical algorithms use video images to detect fires by their behavior. Flames, for example, flicker and emit distinct colors. Smoke covers the background, as also detected by contrast-based algorithms, but also has special movement behavior due to thermal buoyancy. Due to their adaption to the fire's behavior, physical algorithms can minimize false alarms. Additional algorithms can also be developed and combined with the existing ones to minimize false alarms. At some point, however, all the options for adaption of physical algorithms are exhausted as dependencies are too complex to be understood and addressed completely. It then becomes clear that advanced technology, in the form of AI-driven algorithms, is needed for reliable detection and a significant reduction in false alarms.

In the future, it will be possible to understand the video content and its context, as well as the semantics using deep learning algorithms for computer vision. Currently, some of these algorithms are still in a research phase, including the development of specific hardware. But based on years of established physical algorithms for analyzing video footage, which have been used to build up effective neural networks, the limits of some current fire detection solutions can be highlighted and overcome. The gathered valuable experience and knowledge is the power for creating the next generation of highly reliable solutions.

A wide array of sensitivity settings, in combination with intelligent AI algorithms for generating subsequent responses for very specific scenarios, has the potential to cover any analytic gaps and thus extend the capabilities of all captured video footage. This makes video-based fire detection more customizable for its wide range of uses than ever before.

AVIOTEC: video-based fire detection from Bosch

While all common smoke and flame detection technologies work well and reliably in classical applications, they cannot guarantee satisfactory results in some challenging environments. Here, video-based technologies, such as AVIOTEC from Bosch, can be a viable alternative or complement to existing detectors.

Video surveillance technology and the development of intelligent algorithms for image analysis, as well as technologies for fire alarm systems, are among the core competencies of Bosch. This expertise has led to the development of specific algorithms that allow reliable fire detection within seconds and low false alarm scenarios at the same time. Specifically, algorithms provide the basis for continuous

ongoing development and a constantly increasing precision, while comparable technologies based on the input of images for visual alignment quickly reach their limits.

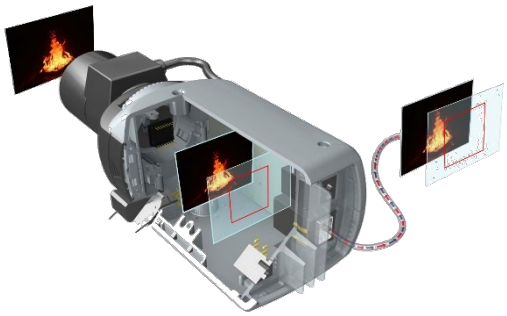
Detection based on physical smoke and flame models

Based on a unique and scientifically tested physical smoke model, AVIOTEC's algorithms directly detect smoke at the source, reliably distinguishing between smoke and moving objects. Detection occurs within seconds, but to avoid costly false alarms, the solution will add a customizable verification period before it issues an alarm. While most video-based solutions need a smoke opacity of 50-65%, AVIOTEC's patented algorithms will reliably detect smoke with an opacity of 40%, ensuring an even faster alarm notification. As AVIOTEC relies on the movement of smoke, it requires the fire in its initiating phase to be in the camera's field of view. It is not designed to detect ambient effects of smoke, like contrast decrease, which can easily be done with state-of-the art smoke detectors, but to speed up detection. Furthermore, the system issues a specific alarm in the case of developing ambient smoke.

As smoke detection uses a physical smoke model, a physical flame model based on flame color, flickering and shape underlies the detection of flames. Flame characteristics of different fires are well understood, and thus flame detection through intelligent video analysis is just as reliable as smoke detection.

Usually, video-based fire detection is more sensitive to false alarms than even the latest fire detectors. However, compared to other video-based fire detection systems, AVIOTEC is highly robust against such false alarms. This is backed up by intelligent video analysis within the camera that allows it to detect disturbance values, such as movement, reflections or changes in lighting conditions, and to offset such influences.

In various countries AVIOTEC has already received various awards for the product and the technology, reflecting the market recognition and esteem around this kind of robust solution.



The expertise that Bosch has acquired in fire detection and video surveillance, but also in intelligent video analytics and the design and manufacturing of video cameras, enables AVIOTEC to offer highly reliable smoke and flame detection, thus improving safety and business continuity for diverse industries. These features are all integrated directly into the cameras, making no further analytic equipment necessary. In addition, once installed, AVIOTEC IP starlight 8000 cameras with their Intelligent Video Analytics (IVA) can also be used for automated surveillance tasks. They are able to detect unusual movements, as well as blocked aisles or emergency exits, thus increasing safety and operational efficiency. In warehouses and in outdoor storage facilities, AVIOTEC doubles as efficient surveillance for the prevention of theft, vandalism and arson, which rank only second to electrical problems when it comes to the causes of warehouse fires. Fire alarms can be transmitted via relay or network, depending on what is needed.

AVIOTEC IP starlight 8000 cameras cover broad areas, need little maintenance and do not require individual power supplies. With connectivity such as Power over Ethernet (PoE), power and video signals use the same cable, also allowing the camera to benefit from the uninterruptable power

supplies (UPS) in the Ethernet switches. Thus, even entire solutions can come with a very affordable total cost of ownership.

AVIOTEC scales well from a single camera to a networked system of distributed cameras with a central console and management system. It can relay alarms to an existing fire alarm panel or transmit them via Ethernet to the monitoring center or a mobile device. Receiving HD quality video images in real time, gives firefighters a good understanding of the current situation on their approach, before they even arrive at the scene of a fire.

Why use AVIOTEC?

To summarize: While standard smoke and flame detection technologies work well in most environments, video-based detection with AVIOTEC offers a lot of advantages in challenging environments:

- Fast fire detection – minimizes damage and saves lives
- Fire detection at the source – responds quickly, even in inversion layers with hot air pockets and applications with air movement
- Intelligent algorithms – ensure high immunity against false alarms and precise detection
- Root cause analysis – videos can be analyzed to prevent future damages by the same matter
- PoE power supply – reduced installation costs - one cable for alarm, video and power transmission
- Parallel video surveillance and video analytics – minimizes equipment and saves costs
- Fire prevention coverage of a premises includes sheltered outdoor constructions

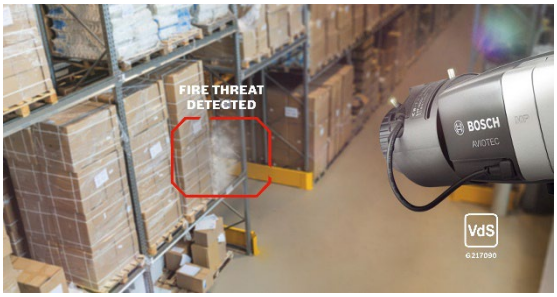
AVIOTEC IP starlight 8000: The first VdS approved VFD solution worldwide

When installing a fire alarm system or equipment in a premises, it is very important that it meets the highest quality standard and is installed correctly, so that it will achieve its function and will operate as expected. This is achieved by ensuring that the equipment and the installation meets the standards as laid down, for instance, in the appropriate EN54 Specification.

Therefore, standardization of video-based fire detection (VFD) is very important for this new technology. VFD is an Active Work Item in ISO, yet FM3232 and UL286 standards for VFD do already exist. Although VFD offers a lot of benefits, so far there is no EN54 standard available for this technology. To close this gap in the European certification, the VdS Schadenverhütung GmbH (VdS) has developed a sophisticated test procedure for video-based fire detection that incorporates the proven VdS guidelines 2203, "Requirements for fire protection software," as well as the "Requirements for testing flame detectors." More recently in 2019, a standard was developed and published for "Requirements for video camera equipment for visual fire monitoring" – VdS3847. The VdS is an independent, renowned institution for corporate safety and security that sets international guidelines through its synchronized set of rules. The VdS quality seal is an important investment criterion.

Based on this new VdS test procedure, the long-term functional safety and reliability under difficult environmental conditions, as well as operation-related mechanical influences were tested. The comprehensive tests covered not only the effectiveness and reliability of VFD products, but also included testing of the long-term functional consistency, confirmed by functional tests after sulphury dioxide corrosion. In addition, VFD has been tested under harsh environmental conditions, such as increased heat, cold, humidity and mechanical influences, usually occurring under operating conditions. The tests followed procedures and values as defined in EN54 standards. Tests and certification by VdS stand for a reliable and fast detection of test fires like TF2, TF4, TF6 and TF8.

In the past, VdS certifications of individual solutions have more than once been the starting point for formal standardization of smoke detection technologies. Aspirating smoke detectors, for example, became very popular after VdS had tested several solutions and issued a guideline for these detectors. This guideline then served as a quality mark and interim standard until the respective EN54 standard became valid. Similarly, linear heat detectors have long enjoyed high acceptance in the fire detection market before the formal standard was published in 2015.



AVIOTEC is the world's first video-based fire detection system which has received the approval of VdS Schadenverhütung GmbH (VdS) as an automatic video camera for visual fire monitoring with the number G217090. Given the VdS approval, AVIOTEC is a perfect option for environments and applications where no other EN54-compliant solution exists. For some applications, it even has the potential to enable insurance coverage that so far had to go uninsured. In other scenarios, AVIOTEC may effectively complement existing and certified fire alarm systems with regard to speed detection, increase of safety level and the integration of video surveillance.

Sophisticated solutions for challenging environments

Due to its innovative technology, AVIOTEC can greatly improve speed and accuracy of smoke and flame detection in a lot of different industries and environments, especially within large buildings with high ceilings:

- Industry – great fire risks and high values to protect with high ceilings, dust and humidity as the limiting factors for common detectors
- Logistics – warehouses with high fire risk and high fire loads combined with the need for additional video surveillance, plus usually long detection times due to high ceilings
- Energy/Utilities – often part of critical infrastructures with the need to avoid outages and disruption; very large buildings with high ceilings (turbine halls etc.)
- Transport – very high ceilings (airport hangars, train stations), polluting factors of dust, humidity and exhaust particles; need for video surveillance

- Culture – very careful handling of listed buildings with high property values, special architectural constructions with high ceilings and high fire risk
- Retail – special architectural constructions with high ceilings and high fire risk; video surveillance required
- Sawmills – harsh environments with extreme fire risk and highest possible fire load; there has been no solution so far
- Waste treatment - Facilities for managing waste and processing recyclable materials often comprise a perfect cocktail of kindling and conditions to spread a fire

Planning considerations

AVIOTEC has been designed for low-light conditions and will typically achieve very high detection accuracy of both smoke and flames with a present illumination of as little as 2 Lux for standard lighting and even 0 lux when using IR illuminators. This can even be directly within the application instead of at the sensor, which further optimizes detection.

In addition, in the software settings, two sliders, one for fire size and one for verification time, provide further accuracy. An optional masking can complement the alignment.

Conclusion

There are two different approaches to video-based fire detection. VFD can complement existing technologies with an EN-54 certification such as smoke detectors, greatly increasing speed and accuracy of fire detection with further possibilities for visualization and surveillance. Another approach can be to use video-based fire detection for applications where no other solution exists.

With its VdS approval, AVIOTEC stands for independently tested and documented detection accuracy, reliability and robustness against false alarms. This is even the case in challenging environments such as hazardous industrial settings, spacious buildings with high ceilings, and outdoor sheltered constructions, often used to store valuable business assets, for which no other reliable solution currently exists.

For more information: www.boschsecurity.com