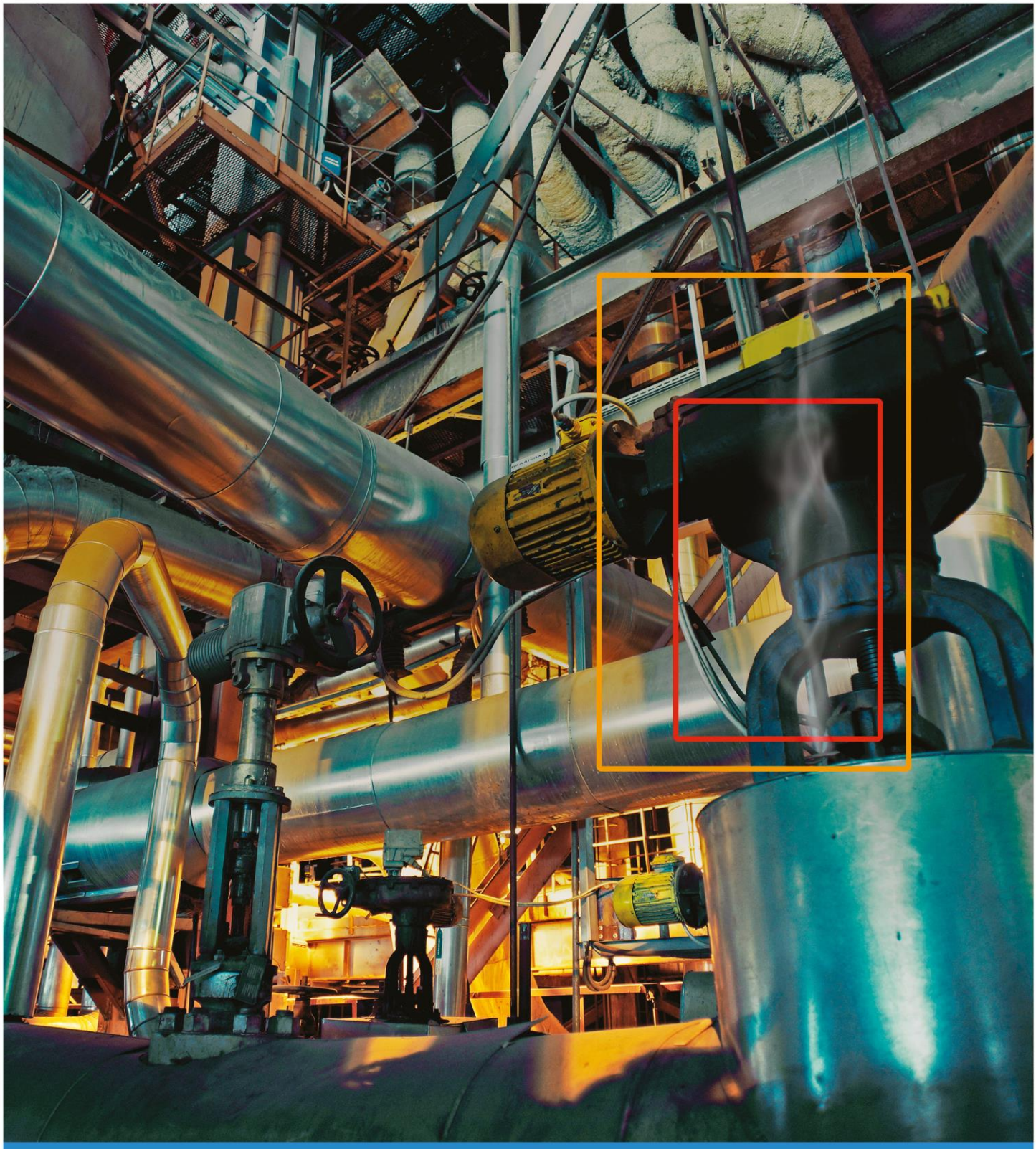

THE WHAT, WHY & HOW OF **VIDEO SMOKE DETECTION**

ARAANI
VISION ON SAFETY

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INTRODUCTION

With the advent of Video Smoke Detection (VSD) technology, the security and fire safety industry have discovered a new and efficient way to detect smoke and fire in its' very early stage. VSD is becoming increasingly popular in environments where there was no failsafe fire detection or smoke detection solution available.

High-impact or high-risk environments such as chemical plants, high indoor environments, and harsh environments involving chemicals, dust or humidity being present on a daily basis, all experience great difficulties in terms of smoke detection and fire detection using conventional linear, beam, or spot-type detectors. With VSD, those who depend on the fire detection and security industries finally have a solution, which accurately detects smoke and fire and at the same time reduces the number of unwanted alarms that affect the performance of an organization.

In this paper, Araani describes the different technology components of a Video Smoke Detection system, including the camera and the algorithm, as well as the overall system architecture.

Subsequently, we describe a number of environments where VSD is considered by Araani and its many global systems integrators to be the most effective solution available. In most locations, applicable standards are required to be adhered to in order to get your VSD system certified for use.

WHAT IS VIDEO SMOKE DETECTION (VSD)?

VSD makes use of CCTV security cameras and smart video analytics that are able to recognize initiating smoke and fire in the video image. VSD systems are becoming increasingly popular in critical environments, such as: chemical plants; waste storage bunkers or production facilities. These are locations typically where the impact and the risk of a fire can be very high. In such environments, conventional smoke detection technologies, including beam or point-type detectors, can be less effective, either because the detection is too slow, or because these systems generate too many false alarms. VSD employs 'Volume' type detection technology, which can view the whole target detection area or substantial parts of it and unlike 'point type detection' does not even have to be directly exposed to the products of combustion. VSD in some circumstances can be located outside the fire risk area viewing, subsequently into it making maintenance access much simpler.

Today, VSD is especially used in critical infrastructures in order to protect people, property and production processes. VSD technology can prevent serious fire incidents from happening and thus avoid high costs, more specifically:

- The cost of fire damage to infrastructure;
- The cost of human lives;
- The cost of production stops and evacuation during an alarm phase;
- The cost of emergency services;
- The cost of cleaning, and
- Image damage and the cost of bad reputation.

THE BENEFITS OF VIDEO SMOKE DETECTION

In environments where traditional detection technologies are less effective, VSD is a reliable, failsafe solution to protect people, property and production process.

It's fast

In fire safety, speed is crucial. VSD systems will detect initiating smoke much faster than conventional systems. VSD makes efficient use of CCTV, so it is able to see dangers from a very large distance. Therefore, unlike many other smoke detection technologies, video analytics do not need to make physical contact with smoke or dust. They immediately 'see' the danger when and where it originates.

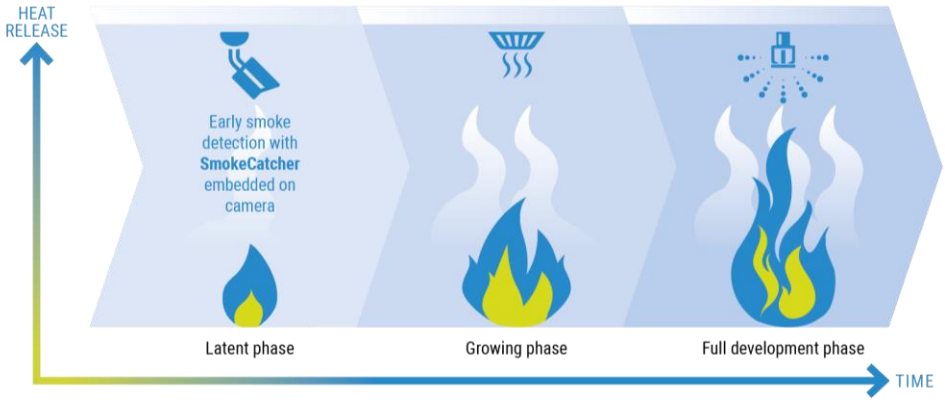


Figure 1 - VSD is faster than conventional smoke detection technologies

It's accurate

VSD is very accurate, thus the false alarm rate is comparatively extremely low. Unwanted alarms can be very costly. Just think of the time lost when a production line needs to be stopped or imagine the cost of an erroneously called emergency team. Business interruption losses are also not always covered by insurance policies.

VSD systems will efficiently analyze the video image to make a distinction between starting smoke and other irregularities, such as people walking in the field of view, animals, vehicles or objects.

It's visual

Control room operators can monitor the CCTV video images in real time, however automatic alarm activation is available at all times, even when the control room is unoccupied or the VSD monitors are not being viewed. Viewing the CCTV VSD real time video images allows operators to assess the nature and severity of the fire as well as the fire growth stage. Based on pre-incident recording, they can see whether people are present at the place of the incident and they can better assess the overall situation. This way, they can also make better use of their emergency resources. After the incident, the video footage can be used for risk analysis and prevention of future incidents as well as for insurance purposes.

VIDEO SMOKE DETECTION CAMERA REQUIREMENTS

VSD means that the video image from an analog or digital camera is processed to determine whether smoke or flame from a fire can be identified in the field of view. Smoke detection applications based on CCTV cameras make use of a surveillance network that is often already in place in public areas and within many companies.

Today's VSD systems rely on the resolution and accuracy of a standard network security camera in the visual spectrum, which needs to have a fixed field of view, with Pan-Tilt-Zoom (PTZ) cameras being unsuitable for this application.

Smoke detection cameras are especially used in environments at great height or where traditional smoke detectors are impractical. Cameras can detect smoke appearing from significant distances. Depending on the lens type, any reasonable distance can be monitored for smoke or fire.

Video Smoke Detection versus security monitoring

VSD cameras are configured and positioned in a way that is optimal for their use, that is, for smoke detection. This sounds self-explanatory; however, it is useful to highlight the differences between smoke detection and typical security monitoring applications.

CCTV security cameras need to capture human activity. Usually, the performance of a security camera is defined according to five observation categories, based on the relative size (%) that a person appears on a screen. With a CCTV system, users want to monitor/control, detect, observe, recognize or identify human activity. These observation criteria range from simply monitoring movements of people without actually recognizing them up to enabling the identity of an individual for evidentiary reasons.

Category	PAL	1080p	720p	WSVGA	SVGA	VGA	2CIF	CIF	QCIF
Identify	100	38	56	67	67	84	139	139	278
Recognize	50	19	28	34	34	42	70	70	139
Observe	25	10	14	17	17	21	35	35	70
Detect	10	4	6	7	7	9	14	14	28
Monitor	5	2	3	3	3	5	7	7	14

Table 1Equivalent percentage of screen height for different digital resolutions. Yellow boxes indicate that it is reasonable to achieve the appropriate camera view. Orange boxes indicate it may be unreasonable or difficult to achieve an appropriate camera view.[1]

[1] CCTV Operational Requirements Manual 2009, N. Cohen, J. Gattuso, K. MacLennan-Brown

These CCTV criteria translate into a range of camera requirements. Firstly, the field of view and camera direction of a CCTV camera are horizontal. This is necessary in order to fully capture the traits of the human face. Other specific CCTV-related characteristics help improve detection of human activity, including wide dynamic range, iris control to maintain the optimum light level, and other automatic image optimization techniques, such as backlight compensation.

VSD camera requirements

All of the above-mentioned features do not really apply or are of less importance for VSD cameras. Smoke detection cameras are set up and optimized for video analysis, not for image quality in itself.

Smoke and fire[2] are completely different phenomena compared to human activity, which also results in specific VSD camera requirements. First of all, the field of view and camera direction for smoke detection cameras are different. The field of view of VSD cameras is optimized to capture initiating smoke in the earliest possible stage. Image quality enhancements are not relevant for this application. Most smoke detection cameras however do need to be able to cope with low-light conditions.

Maintenance

VSD systems don't need a lot of maintenance. As with any CCTV camera system, it is important to keep the lens and optical windows clean and the camera position fixed and unobstructed. In case the view gets obstructed or the lens is too dirty, most camera systems have built-in alarm mechanisms that warn operators when the camera performance is insufficient. An important advantage of VSD systems compared with typical point type and multi-point aspirated systems is that in many situations the VSD CCTV camera can be located outside the fire risk area. This is very important, as the CCTV cameras may be located in areas of easy access not requiring the disruptive use of costly height access equipment to carry out servicing of the VSD system cameras.

[2] The term 'fire' used in this paper refers to 'flaming' combustion, where 'smoke' refers to non-flaming combustion.

THE VIDEO SMOKE DETECTION ALGORITHM

Carefully developed software algorithms deployed on the camera scan the environment and continuously analyze it in real time to accurately locate the smoke or fire incident. VSD algorithms use different techniques to identify the flame and smoke characteristics and can be based on changes in brightness, contrast, edge content, motion, dynamic frequencies, and pattern and color matching.

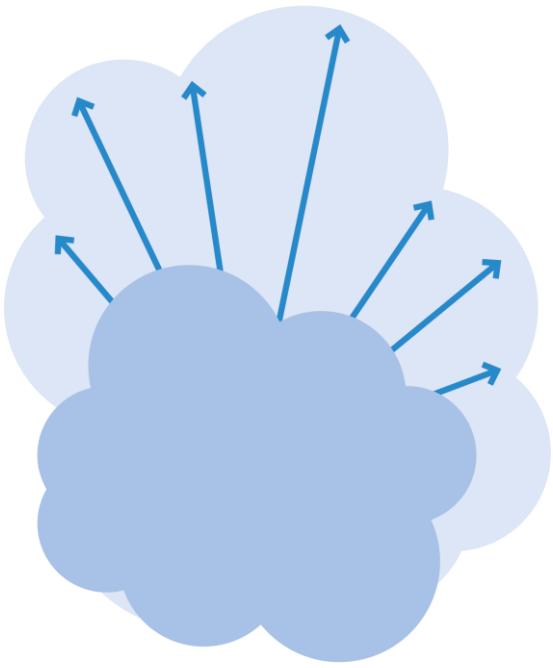
Two of the most important VSD techniques are moving object detection with edge analysis and wavelet-based energy analysis.

Video Smoke Detection: Moving object detection with edge analysis

A large number of VSD suppliers rely on the following methodology:

- Find “a moving object”
- Analyze the edge
- Evaluate the growth

As a first step, object detection aims at locating and segmenting interesting objects in a video image. Then, the objects can be tracked from frame to frame, and the tracks can be analyzed to recognize object behavior, e.g. growth.

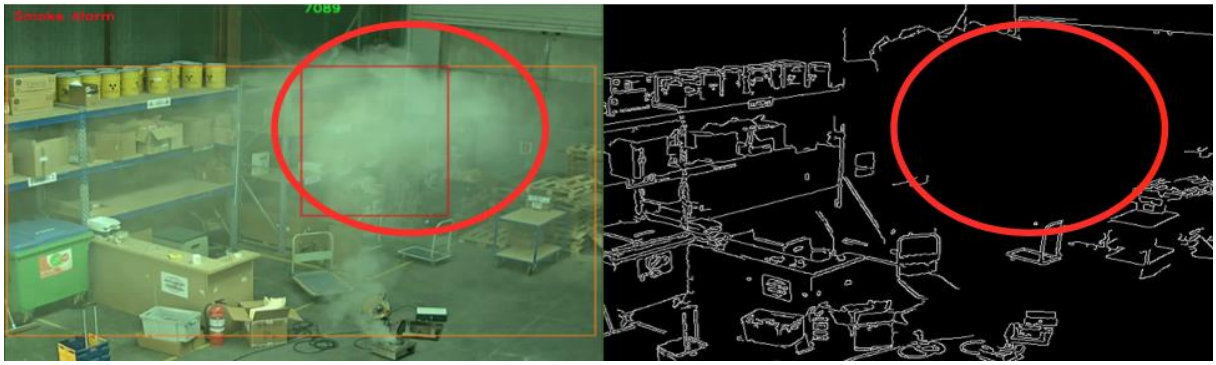


Video Smoke Detection based on these principles is extremely fast. However, this approach can also generate substantial false alarms with non-smoke-related events, such as people, vehicles or animals walking in the field of view. VSD systems based on these types of algorithms are also less effective in detecting ‘thin smoke’. Moving object detection also relies on finding the source of the smoke, which is not always visible in the camera’s field of view.

Video Smoke Detection: Wavelet-based energy analysis

Smoke causes obscuration, which is visually expressed in a loss of contrast. In other words, smoke makes an image grayer and less colorful. Brightness of a video image is also a form of energy, such that a brighter image will have higher energy than a darker one. By using wavelet transform analysis, the area of decreased high frequency energy can be identified as smoke.

VSD systems working by this principle can detect smoke independent of the source and generate no false alarms for other movements than smoke. The challenge with the set-up of such systems is to make sure that the scene has a minimum of basic contrast.



Video Fire Detection: Moving object detection

Video Fire Detection is a totally different process compared with Video Smoke Detection, as both techniques are assessing different physical phenomena. Most Video Fire Detection algorithms are based on moving object detection to capture the fire, and combine this with frequency analysis of the flames inside and at the edge of the fire. This frequency can range from 0.5 to 20 Hz. Video Fire Detection also relies on RGB color information to detect the fire, with a focus on red, elements of green, but not blue.

Video Fire Detection is extremely sensitive and fast. However, it is subject to unwanted alarms on red and orange colors coming from flashing beacons, welding stations or reflections from flashing lights. Video Fire Detection as a means of initiating a fire alarm situation also tends to be delayed compared to smoke detection, as smoke always precedes fire. This situation can have a significant impact on evacuation initiation in terms of fire life safety and on response to fires before they become significantly large, which impacts on both asset loss and business continuity.

SYSTEM ARCHITECTURE

In case a smoke or fire incident is detected, the VSD system will generate an alarm output and send it over to the fire control panel. A video detection system can also be connected to a video management system in order to provide control room operators with visual feedback on the incident.

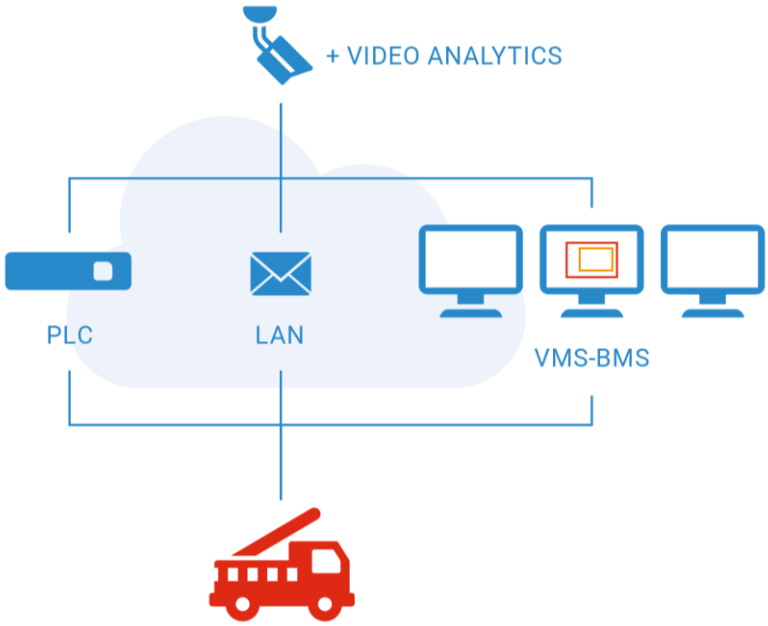


Figure 2: Simplified VSD alarm management process diagram

Alarms are generated as a result of software algorithms which continuously process the camera image for irregularities. This image processing can be integrated into two types of system architectures: distributed or edge-based.

Centralized processing

Traditionally, in a centralized processing architecture, high-quality video images are transmitted from the camera to a central server, where the video streams are processed and analytics are being performed. The transmission path for the video stream can be a coax cable for analog cameras, an Ethernet cable for IP-cameras, and video can be uploaded to a cloud service (where suitable available Cloud Services exist).

A suitable central server unit can send outputs to activate a fire control panel. Also, it is able to record pre-incident or post-incident video footage associated with the incident and can provide real-time visual feedback to an operator screen.

There are several drawbacks to the centralized approach. First of all, a lot of high-quality video needs to be transmitted to the server over a network. This can result in heavy network traffic. Due to the need for reliable and extensive cabling, the centralized processing approach has a high cost. Since it is part of a fire detection system, the transmission path is considered a point of failure, and cabling is typically subject to further constraints to meet the fire safety regulations, which makes the cabling very expensive. Furthermore, the central server that handles the video analytics is also considered to be a single point of failure. When broken down, it can immediately affect a large number of VSD cameras.

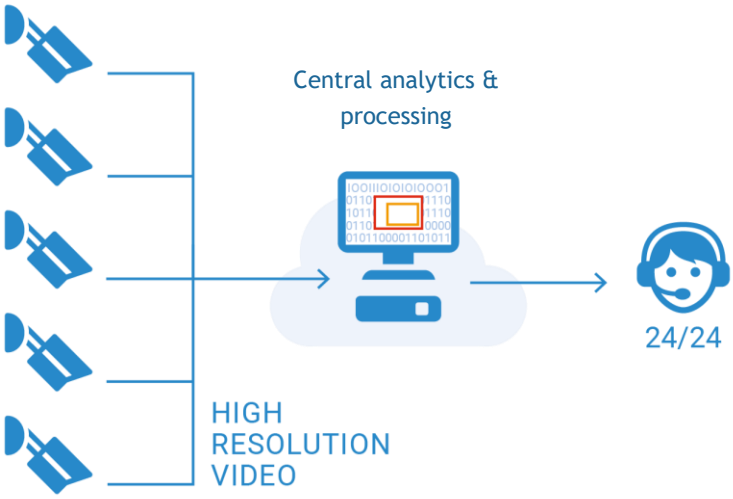


Figure 3: Simplified centralized processing architecture based VSD system

Image processing on the edge

In the edge-based approach, the analytics functionality is integrated on the smoke detection camera's CPU, at the edge of the network so to speak. This set-up has become increasingly popular, as the key driver of this evolution is increased processing power. Moving the intelligence to the camera in the past has been difficult due to the very limited processing power in cameras, leading to very limited capabilities or poorly performing analytics. Today however, evolving processor technology enables manufacturers to move their processors into their camera designs reducing cost and increasing performance.

The edge-based approach has a number of advantages. First of all, in an edge-based architecture, the point of failure is limited to the surface of one camera. Secondly, if the video analytics is running on the edge, the network traffic is heavily reduced. As long as there is no incident, it is not required to send high-quality video over the network. Video for the purpose of control room visualization and verification can be compressed and will require lower bandwidth. Finally, thanks to absence of extensive cabling, the installation cost is much lower. An IP-based architecture further allows companies to scale more easily without encountering high costs.

Edge-based camera devices can also be monitored remotely via the network and pre- and post-incident video can be archived and displayed in real-time.

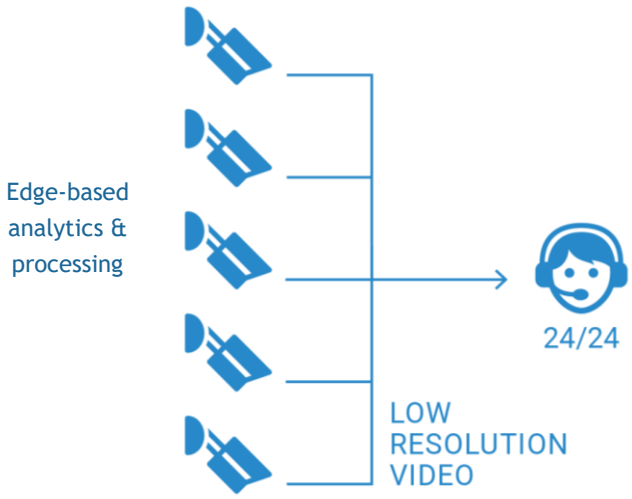


Figure 4: Simplified edge based architecture VSD system

WHEN TO USE VIDEO SMOKE DETECTION

A wide number of smoke detection technologies are available on the market. All of them have proven their value in non-critical environments. These are some of the most common ones:

- Point-type smoke detectors are housed in plastic enclosures. When smoke reaches this enclosure, smoke can be detected optically (photoelectric), by a physical process (ionization) or through a combination of both.
- An optical beam smoke detector uses a projected beam of light to detect smoke across large area. Optical beam smoke detectors work on the principle of light obscuration. Once a certain percentage of the transmitted light has been blocked by the smoke, a fire is signaled.
- Multi-point aspirating smoke detectors draw in air via a network of pipes. These air samples are then processed by a centralized, highly sensitive detection unit.
- Flame detectors (IR/UV) monitor the infrared spectral band for specific patterns given off by fire or hot gases.

The technologies described above are cost-effective and will perform very well in most environments like offices or indoor commercial spaces and in some critical environments. However, most of these technologies (except Flame detectors) require physical contact with the products of combustion. In some critical environments, this can impose serious restrictions on the performance of these detectors:

- False alarms: When aggressive chemicals, dust or vapor, present during normal operations, make physical contact with a detector, this can trigger an alarm.
- Slow detection:
    - It can take precious time until smoke reaches ceiling-mounted detectors. Since smoke cannot make physical contact with the detector (point, beam or aspiration detectors) in time, the detection will be too slow.
    - Smoke always comes before fire. Before a flame detector will be able to detect a fire, the fire will already be in an advanced state.
- High maintenance cost: Chemicals or dust will pollute conventional sensors and will cause them to degrade preliminarily. This will result in high costs:
    - High maintenance cost to keep the sensors clean
    - Replacement cost because of limited lifetime

- Limited use in extreme temperatures: In certain extreme temperature environments, conventional smoke detectors are just not an option.
    - Ovens / High-temperature environments: In contrast to conventional detectors, a camera can monitor high-temperature environments, while positioned outside of the environment, for example by looking in through a window.
    - Industrial freezers: In contrast to conventional detectors, a camera can be installed in an adapted housing to withstand the extreme temperatures.

VSD cameras can be installed within almost any environment: for all the challenging environments described above, one can find a camera housing adapted to this particular environment in which the VSD camera can be integrated. This varies from housings with integrated heating or cooling to overcome extreme temperatures, to protective housings for use in aggressive environments and where potentially flammable atmosphere exists, Explosion Protection (Ex) techniques (IECEx, ATEX or similar), protected housings for corrosive environments,….

This makes Video Smoke Detection a valuable addition to the current spectrum of smoke detection technologies that is specifically useful for environments where no adequate solution is available today:

- Harsh environments
- High-impact/high-risk facilities
- Indoor spaces with high ceilings

#1 VSD application in harsh environments

Where conventional smoke detectors generate too many unwanted alarms

Smoke detection systems that generate too many unwanted alarms are not only very annoying, they are also quite costly. In production facilities, alarms will require the production lines to be stopped. Unwanted alarms also lead to the unavailability of emergency teams in case of real fires. In some cases, users of these detection systems might decide to deactivate the detectors altogether, just to avoid the above-mentioned problems.

Figure 5: Image of waste recycling facility where VSD is a suitable early smoke detection method

In harsh environments, where chemicals, dust or vapor are present every day, conventional smoke detectors will generate a lot of unwanted alarms.

- Humidity: A high degree of humidity in the air can activate a conventional point or beam-type smoke detector. Humidity can be created by processes where steam is involved, but detectors can also be activated by very humid weather.
- Chemicals: Smoke detectors can be set off by strong chemicals like ammonia, paint fumes or volatile sprays.
- Dust: A conventional smoke detector will be triggered by dust in the same way as by smoke particles, which can set off the alarm. Dust is also one of the reasons why a conventional smoke detector will degrade very fast.

Because of its visual nature, video smoke detection will be able to analyze the above-mentioned phenomena in a more intelligent way through the use of smart video analytics. This will heavily reduce the number of unwanted alarms. That is why video-based smoke detection is an ideal technology for use in harsh environments, such as chemical plants, waste recycling plants, wood processing companies or in the oil and gas industry.

#2 VSD application in high-impact environments

When detection speed and visual feedback is crucial

In some environments, such as chemical plants, even a small fire can cause huge consequential damage. In these high-impact and high-risk environments, conventional smoke detectors would be useless, because these might only get activated when the damage is already done.

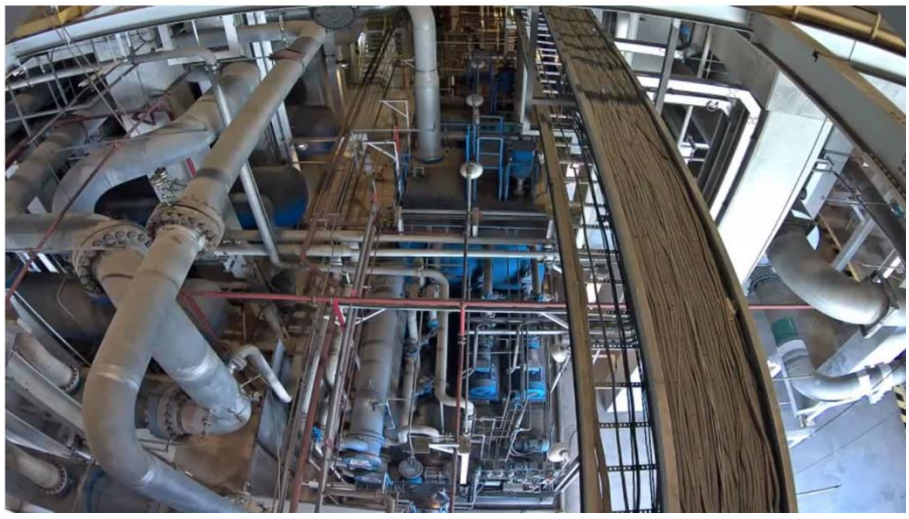


Figure 6: Image of chemical processing facility where VSD is a suitable early smoke detection method

Video smoke detection has a number of significant benefits that make it the ideal detection technology for high-impact and high-risk environments:

- The high detection speed of video smoke detection will dramatically reduce the impact and the risk of a fire outbreak.
- The accuracy of detection will bring down the false alarm rate to an extremely low level.
- The visual nature of VSD will allow control room operators to monitor any irregularity very meticulously. VSD almost rules out any uncertainty and enables operators to immediately see any irregularity and as a result make well-founded decisions in case of real and unwanted alarms.

#3 VSD application for great heights

Where conventional technologies will not detect or will detect too late.

Video smoke detection is ideal for use in tall buildings or large indoor spaces. In these environments, smoke might never reach a traditional smoke detector, because of a process called stratification, which stops the upward movement of smoke.

Figure 7: Image of high ceiling warehouse facility where VSD is a suitable early smoke detection method

The smoke stratification phenomenon

High or voluminous buildings of 10m+ have issues with the stratification of smoke whereby smoke will not rise high enough or quickly enough to reach ceiling mounted point or beam detectors. This is often the case for example in aircraft hangars, airport passenger terminals, factory production halls, retail areas, museums and many historical buildings.

In atrium halls or in large spaces where a sun-heated roof is poorly insulated, a layer of hot air may form under the ceiling. On the other hand, the more smoke rises, the more its temperature will decrease. So, when the smoke plume's average temperature is less than the upper hot air layer, this layer may prevent the smoke from actually reaching the ceiling.

Conventional point-type and beam-type detectors are typically not sensitive enough to provide early warning of smoke in large open spaces or tall buildings, because stratification sometimes prevents the smoke from making physical contact with the detectors in time. By the time smoke is detected in such installations, a fire might already be quite significant, whereas VSD would likely have detected smoke in such situations before flaming combustion occurs, so much earlier than applied point type detection methods.

In contrast, video smoke detection does not need to make physical contact with the smoke. The initiating smoke can be seen from a large distance, making early detection possible.

Figure 8: Image of stratification of a TF2 test during a summer day in a warehouse facility

PRACTICAL RECOMMENDATIONS FOR A VSD INSTALLATION

A VSD system will not operate flawlessly under just any condition. For the best VSD performance, a number of practical requirements need to be taken into account.

1. Sufficient light

For most Video Smoke Detection systems to work properly, dependent on the camera, a minimum of 10-15 lux of light should be present on a continuous basis, or at least during the time that the detection needs to be active. Some surveillance cameras can present a visually nice video stream at much lower light levels, but the camera settings (gain, exposure time, iris etc...) optimized for doing this impose a substantial amount of noise to the video stream and instabilities in intensity that make the video stream unsuitable for video detection in general, and video smoke detection in particular. So for optimal stable performance in all circumstances (day / night / sun / shadow / unstable lighting) it is better to provide a minimum light level in the environment.

2. A clear field of view

A VSD system can only provide good detection results for areas that can be seen by the camera. Obstacles in the field of view may limit the performance. Therefore, effective camera positioning is of utmost importance in a site design.
Since the functionality and layout of a facility space may vary in time, it is possible that the field of view of the VSD system may become blocked or sub-optimal for efficient detection. The lights might get broken or switched off, or other disturbances in the field of view can prevent the VSD from working properly.
Therefor a reliable VSD-system should have a self test and give a warning or a fault signal if it is unable to detect with optimal performance.

3. Light and weather conditions

VSD systems will perform best in indoor or roofed areas, since most disturbing environmental parameters (light, shadow, fog, rain, snow…) can be controlled.

However, it is necessary to ensure that the camera's field of view does not include areas with an uncontrollable light level (windows, outside doors, lights and lamps …).

In partially open areas, the camera position is critical. The camera should not be affected by direct sunlight shining into the lens or by reflections of the sun.

In outdoor environments, VSD is also an option, provided that the disturbing effects of uncontrollable light and weather conditions are compensated by additional intelligent algorithms. These algorithms need to be able to cope with various types of precipitation, including rain, snow or mist.

GETTING A SYSTEM APPROVED AND CERTIFIED

Certification based on third-party testing and evaluation will help users gain trust in the fact that VSD technology will perform under the toughest conditions. Although certification is still in development in some parts of the world, a growing number of installations have been approved for use by official inspection organizations around the world. Moreover, an increased interest of inspection organizations has accelerated the development of standardization.

System installation standards

Currently NFPA 72 recognizes the use of video smoke or flame detection systems. Per this code, the installation of these systems requires a performance based design.

In Europe, VSD can fit into the compatibility and connectability standard of fire safety system integrations EN 54-13:2016. The 2016 update of this installation standard is explicitly receptive to accept new technologies for which there is no EN-product standard yet.

AS/NZS and BS installation standards also refer to VSD and recently ISO started with the development of ISO TS7240-30, a technical installation standard for Video Fire Detectors.

Product Standards

In the US, certification has been established with the UL 268B and FM3232 standards. A new ISO technical specification ISO 7240-29 has been approved in 2017.

- The UL 268B standard builds on the existing UL 268 standard for smoke detectors for fire alarm systems and incorporates additional requirements for the evaluation of Video Smoke Detection systems. This standard excludes Video Flame Detection systems.
- The FM3232 standard applies to video image fire and smoke detectors and evaluates a wide range of parameters including detectable fuel sources, influence of false alarm sources within the viewing area, field of view, minimum and maximum detection range, volume and size of the smoke and fire signature required for detection.
- ISO/TS 7240-29 – Video fire detectors is approved in 2016 and released in 2017 as a technical specification. This is a preliminary version of a Technical Standard, giving the industry the time to build up experience with the technology to finalize the specification into a standard.

CONCLUSION

VSD has clearly outgrown its infancy. Today, it has become a mature and reliable way to protect people, property and processes in critical environments. VSD has a number of benefits that conventional technologies lack:

- It's fast: Because it's visual, VSD can spot initiating fires directly at the source, practically from any distance. This is a huge speed advantage for operators that need to make quick decisions. With VSD, there is no need to wait until the smoke has reached the ceiling.
- It's accurate: A detection system that generates too many unwanted alarms will become useless and ignored in the long run. Video Smoke Detection technology on the other hand can effectively filter out unwanted events that are typical of some harsh environments.
- It's visual: VSD technology gives the control room operator room for interpretation. Since it is so fast and since it allows for visual verification, VSD provides the operator with valuable time to make a well-founded decision.

Although certification for video smoke technology is still in development, a growing number of installations have been approved for use by official inspection organizations around the world. In addition, new VSD solutions and solution providers that are emerging on the market, prove that there truly is a need for dependable VSD technology. More and more fire safety professionals acknowledge that VSD fills a void in the marketplace, because it offers a way to secure high-risk and high-impact environments for which there was no solution up to now.

As for the further development of VSD technology, the future is looking bright. The processing power and performance of CCTV cameras is continuously improving, allowing for reliable integration of VSD systems in an edge-based architecture. The worldwide VSD install base is also growing, providing manufacturers with a growing amount of video test data that can be used to further develop and fine-tune their video analytics.

ABOUT ARAANI

Araani is a Belgian video analytics company and the developer of SmokeCatcher. Araani's mission is to guarantee business continuity and fire safety for companies that operate in critical and demanding environments.

Araani has its roots in companies that have pioneered the video analytics industry. The expertise and years of experience of Araani's founders have resulted in a rock-solid video analytics solution for your high-risk or high-impact environment.

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