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(54) FIRE DISCRIMINATION BY TEMPORAL PATTERN ANALYSIS

(57) A method of fire detection and a fire system are described. The method of fire detection comprises: detecting a possible fire event using one or more sensors (3, 4; 23, 24); generating a temporal log of the possible fire event based on data from the one or more sensors (3, 4; 23, 24); examining the temporal log to identify a source of the possible fire event; and determining an action to be taken based on the identified source of the possible fire event, wherein examining the temporal log comprises detecting a temporal signature in the temporal log using pattern recognition, the temporal signature being one of a plurality of temporal signatures corresponding to a plurality of known sources.

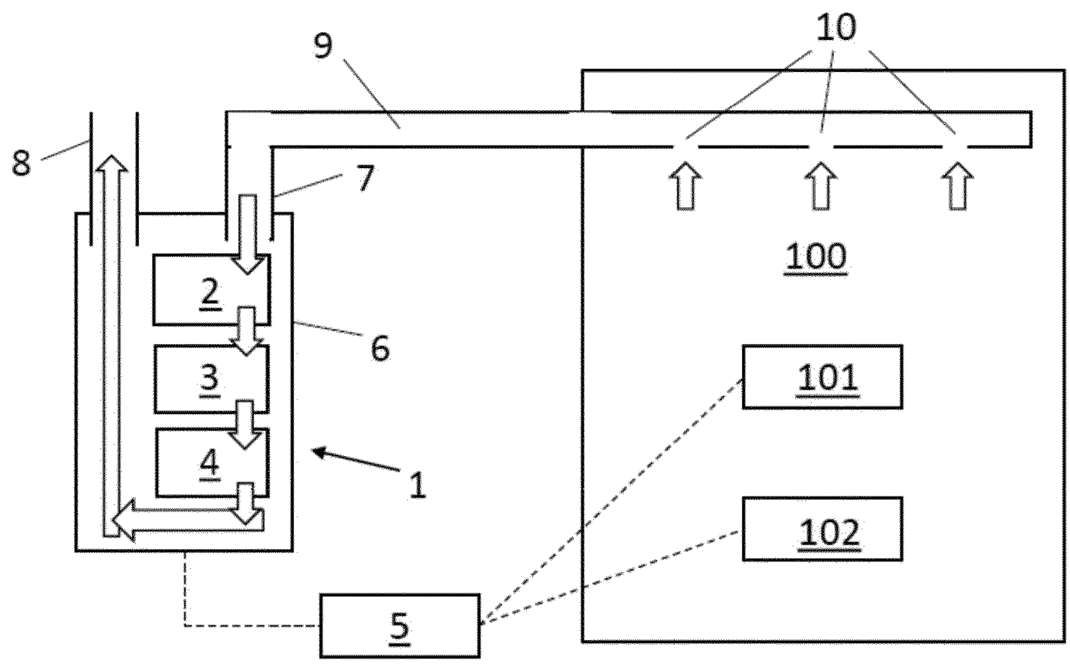

FIG. 1

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Description

Field

[0001] The present disclosure relates to the identification of a source of a possible fire event when performing fire detection, particularly by means of temporal pattern analysis.

Background

[0002] Fire detection systems are systems which detect fires within an environment monitored by the fire detection system. Appropriate action may then be taken in response to the detection of a fire within the monitored environment. Fire detection systems usually detect fires by detecting smoke, which is a common indicator of a fire within the monitored environment. However, fire detection systems are often not able to discriminate between sources of smoke within the environment they monitor, and consequently an alarm may be generated when smoke is detected from a source which does not require action, or is not of any significant danger to the monitored environment and any occupants within.

[0003] These sources may be regarded as nuisance sources, as they trigger an alarm or response from the fire detection system when no alarm or response is desired and/or required. Examples of nuisance sources may include cooking sources, including foodstuffs which when cooked or heated may produce smoke in a kitchen or otherwise, and other sources which may falsely trigger smoke detectors, such as cigarette smoke or steam.

[0004] As fire detection systems presently available on the market are not able to discriminate between sources of smoke from fires against which action should be taken and nuisance sources such as cooking sources, a user or operator may be alerted to a fire when no action is required. This may lead to some users disabling or disconnecting fire detection systems from the environments from which they monitor, which accordingly may endanger the residents or occupants of buildings which use these fire detection systems.

[0005] Additionally, new safety standards are being introduced in various territories which require fire detection systems to be able to discriminate between actual fire sources and nuisance sources, such as cooking. Such a certification standard is defined by UL 268, 7th Edition, UL Standard for Safety Smoke Detectors for Fire Alarm Systems.

[0006] Accordingly, it is an objective of at least the described embodiments of the present invention to provide a method of verifying detection of a fire event, and monitoring an environment for a fire event using the method of verifying detection of a fire event.

Summary

[0007] Viewed from a first aspect of the present invention, there is provided a method of fire detection. The method comprises detecting a possible fire event using one or more sensors: generating a temporal log corresponding to the possible fire event and based on data from one or more sensors; examining the temporal log to identify a source of the possible fire event; and determining an action to be taken based on the identified source of the possible fire event identified; wherein examining the temporal log comprises detecting a temporal signature in the temporal log using pattern recognition, the temporal signature being one of a plurality of temporal signatures corresponding to a plurality of known sources.

[0008] Different sources of fire events have unique, or classifiable, temporal signatures (i.e. temporal patterns) during combustion. Accordingly, it is possible to identify a source of a possible fire event based on a temporal log corresponding to the possible fire event detected. To achieve this, the method generates a temporal log, or temporal record, corresponding to the possible fire event and based on data from the one or more sensors. The temporal log comprises data from the one or more sensors captured within a timeframe that includes the detected possible fire event.

[0009] By identifying a source of the possible fire event, the method of the first aspect is capable of discriminating between non-fire (i.e. nuisance) sources which trigger the detection of a possible fire event but are false-positive detections; and between fire sources which trigger the detection of a possible fire event and are positive detections. Based on the identified source, and the discrimination between false-positive and positive detections, an action to be taken can be determined, For example, the detection of possible fire events identified to have been triggered by non-fire sources (e.g. cooking sources, airborne pollution, cigarette smoke and steam) preferably do not require a user to be alerted to the presence of such a source, or for immediate action to be taken based on the identification of such a source. Accordingly a volume of false alarms, or 'false-positive' detections may be reduced by further verifying detected fire events, according to the method of the first aspect.

[0010] Additionally, by being able to identify what the source of a possible fire event is, an action may be determined that appropriately mitigates the source of the fire event if it is a positive detection. For example, appropriate fire mitigation devices (e.g. water-based, foam-based, gas-based or powder-based suppression techniques and the like) may be engaged in response to the identified source.

[0011] The method of the first aspect comprises detecting the possible fire event using one or more sensors, and further identifies the source of the possible fire event based on data from the one or more sensors by generating and examining the temporal log. Accordingly the method of the first aspect is compatible with existing fire systems which comprise one or more sensors for detecting a fire event, and a controller which may be configured to execute the method of the first aspect.

[0012] A fire event will be understood to include any event triggered by a fire source, and hence includes where there may be combustion of a substance or composition. Such a fire event may justify the generation of an alert or activation of one or more mitigation devices. Whilst fires typically produce heat and smoke, they may not necessarily produce both in sufficient quantities to be able to be reliably detected. For example, smouldering fires may produce large amounts of smoke but not necessarily high temperatures. Other fires may be smokeless, or produce low quantities of smoke, yet produce high temperatures.

[0013] A possible fire event will be understood to include any fire event, but also to further include any event where there may be the production or presence of a substance or composition by a non-fire source which may comprise similar characteristics to those produced via combustion of a fire source. Accordingly it is advantageous to be able to discriminate between possible fire events triggered by fire sources and non-fire sources.

[0014] The temporal log indicates how a fire characteristic (e.g. how one or more of smoke concentration or temperature) evolves with respect to time prior to and/or after detection of the possible fire event. The temporal log may therefore also be referred to or regarded as a temporal record. The temporal log may be observed or obtained within a predetermined timeframe of the possible fire event, including at least a first period of time before and including the time at which the detection of the possible fire event occurred, and optionally further including a second period of time after detection of the possible fire event. Alternatively, the timeframe of the temporal log may be dynamic, for example the start of the first time period may be determined to start when a sensor reading exceeds a predetermined threshold. As the temporal log is generated based on data from the one or more sensors used to detect the possible fire event, no further sensors are required to obtain data suitable for generating the temporal log.

[0015] The temporal log can be generated based on a plurality of data points recorded using the one or more sensors, each data point including a value corresponding to a fire characteristic and including a timestamp. The plurality of data points can be simultaneously recorded as the one or more sensors are used to detect the possible fire event, and may be stored locally to a fire detection system comprising the one or more sensors and performing the method, or may be stored remotely on a server in communication with a fire detection system performing the method.

[0016] Additionally or alternatively, the method may comprise recording a plurality of data points obtained using the one or more sensors, for example if the timeframe includes a period of time after the fire event is initially detected.

[0017] As the plurality of data points are recorded during detection of the fire event, the plurality of data points may include data points recorded up to, and including, the time at which the fire event was detected. Accordingly the method may comprise selecting one or more of the plurality of data points occurring within a timeframe of the fire event, wherein only these one or more data points are used to generate the temporal log.

[0018] Examining the temporal log comprises the use of pattern recognition. Detecting a temporal signature in the temporal log generally comprises detecting a shape or pattern of the temporal log, and classifying the shape or pattern of the temporal log. The shape of the temporal signature may be classified as belonging to one of a plurality of known sources, and hence this known source may be identified as being the source of the possible fire event. The plurality of known sources will generally include both a plurality of known fire sources and a plurality of known non-fire sources.

[0019] The shape of the temporal log of the possible fire event may correspond (wholly or partially) to a shape of the temporal signature exhibited by one of the plurality of known sources during combustion. Such shapes can include complex shapes comprising one or more peaks and/or troughs or multiple gradients. Hence if the shape of the generated temporal log is found to correspond to the shape of that of one of the plurality of known sources then it is identified that this known source is the source of the possible fire event.

[0020] The temporal signature exhibited by a known source is how a fire characteristic (e.g. smoke concentration or temperature) may evolve in time, and accordingly may also be referred to as a temporal signal aspect, or a temporal pattern. As known sources may have distinguishable shapes to their temporal signature, identifying a source of the possible fire event by detecting a temporal signature in the temporal log corresponding to that of one of a plurality of known sources may provide a reliable method of discriminating between possible sources for a detected fire event.

[0021] As discussed above, the temporal log is examined using pattern recognition. Pattern recognition may comprise the use of a pattern recognition algorithm. Such pattern recognition algorithms may include, for example, recurrent neural networks or hidden Markov models. Such algorithms may be trained to discriminate between the shapes of temporal signatures belonging to a plurality of known sources, and accordingly the use of such algorithms provides a reliable way of identifying a source of a possible fire event based on its temporal log.

[0022] Whilst recurrent neural networks or hidden Markov models are the preferred pattern recognition algorithms, other pattern recognition algorithms that may be used include: non-recursive or recursive linear filters; finite state machines; dynamic programming; Bayesian belief networks; sequential belief networks; Markov models; convolutional neural networks; Boltzmann networks, including Boltzmann machines, restricted Boltzmann machines, conditional restricted Boltzmann machines or temporal restricted Boltzmann machines; time delay neural networks; long-short term memory recurrent neural networks; spiking neural networks; spatio-temporal inference networks; hierarchical temporal memory networks; and prediction-based temporal networks.

[0023] Such pattern recognition algorithms may be trained according to a plurality of known sources of interest. For example, if known non-fire (i.e. nuisance) sources are likely to be present in a factory (such as airborne pollution including nuisance particulates and/or pollutants), or in a building or other space where a possible fire event may be detected then only the temporal signatures of sub-set or specific group of the plurality of known sources may be used as inputs for, or fed into, the pattern recognition algorithm. This may improve the efficiency, or response time, of the pattern recognition algorithm.

[0024] If the identified source of the possible fire event is a fire source, the action to be taken may include a first action. If the identified source of the possible fire event is a non-fire source, the action to be taken may include a second, different action.

[0025] As discussed above, different fire sources generally require a different, immediate, action to be taken compared to the action to be taken when the source is identified as a non-fire source. Hence different actions are determined based on if the identified source if a fire source or a non-fire source.

[0026] The non-fire source may be any one of steam, a cooking source, airborne polution or cigarette smoke.

[0027] The method may comprise, after determining an action to be taken, taking the determined action.

[0028] The method may comprise generating an alarm signal based on the identified source, and may further comprise activating an audible indicator based on the identified source. The audible indicator may be configured to produce a sound when activated, and may further produce different sounds according to the identified source. It is preferable to execute these actions are executed in response to determining that the identified source is a fire source. Therefore, preferably, the first action may comprise generating the alarm signal, and may further comprise activating the audible indicator.

[0029] Additionally or alternatively, the method may also comprise engaging one or more fire mitigation devices based on the identified source. The one or more fire mitigation devices may be selectively engaged based on the identified fire source. It follows that generally fire sources require mitigation, and therefore more preferably the first action may include engaging the one or more fire mitigation devices based on the identified source. That is, the first action may further comprise executing one or more specific fire suppression techniques based on the identified fire source.

[0030] The one or more fire mitigation devices may include automatic fire extinguishers, such as those which deploy carbon dioxide or CFC foams, or water sprinkler systems. The one or more fire mitigation devices may also include any means configured to prevent the supply of any electrical mains or gas mains to a location of the possible fire event.

[0031] Accordingly, the first action may include one or more steps which may mitigate a fire event, or which may alert occupants of an environment being monitored for possible fire events, to the presence of a fire source.

[0032] By determining that the first action is to be taken based on the identified source being a fire source, occupants may be alerted to events only as necessary such that some users are less inclined to deactivate a fire detection system or the like in response to a volume of false-positive detections.

[0033] The action to be taken may not include the first action if the identified source of the possible fire event is a non-fire source. In this case, users will not be alerted or notified to the presence of a non-fire source, and/or mitigation devices will not be engaged when the identified source is a non-fire source.

[0034] The second action may comprise generating a notification signal, and may further comprise activating a device configured to display textual information. The second action may also comprise sending the notification signal to the device. The device may be a display panel or the like and accordingly will be part of the fire detection system, or a device external to the fire detection system, such as a mobile phone or smart device. The device may be a central monitoring station (CMS).

[0035] The notification signal may comprise data identifying the source of the possible fire event, such that a user or occupant may be informed of the identification of a non-fire source. The notification signal may be configured to not audibly alert a user or occupant to the detection of the possible fire event (e.g. via the device or the audible indicator).

[0036] Detecting the possible fire event may comprise determining that a sensor value from the one or more sensors exceeds a predetermined threshold. Such a determination may generally include: sensing a fire characteristic value (i.e. the sensor value) in a monitored environment using the one or more sensors; comparing the fire characteristic value to a respective predetermined threshold; and in response to the fire characteristic value exceeding the respective predetermined threshold, detecting the possible fire event.

[0037] It will be appreciated that when the sensor value does not exceed the predetermined threshold, then a possible fire event may not be detected.

[0038] The one or more sensors may comprise a smoke detector configured to determine a concentration of smoke in a sample of air from the monitored environment, and/or a temperature sensor configured to sense a temperature of the temperature in the monitored environment. The smoke detector and the temperature sensor may be located in a common housing as part of a common detection unit, or may be located in different housings as part of different detection units.

[0039] The temperature sensor may be any known type of temperature sensor that may monitor how a sensed temperature evolves in time and may include, for example, a thermistor, a thermocouple or an infrared sensor or detector. The temperature sensed by the temperature sensor may be used to detect the fire event, by determining if the sensed temperature exceeds a predetermined temperature threshold. The sensed temperature may include a direct (i.e. actual) sensed temperature of the monitored environment, or an indirect sensed temperature of the monitored environment (i.e. a temperature indicative of the direct temperature of the monitored environment).

[0040] The temperature threshold may be, for example, at least 50°C; at least 55°C; or at least 60°C. In some examples the temperature threshold may be at least 58°C.

[0041] The smoke detector may be any smoke detector suitable for monitoring how a concentration of smoke varies in time in a monitored environment. Preferably, the smoke detector is an optical smoke detector, and comprises a detection chamber into which the sample of air is passed, a laser and a photodiode; and determines a concentration of smoke in the sample of air by measuring a scattering of light emitted by the laser.

[0042] Alternatively, the smoke detector may be an obscuration-type smoke detect which determines a concentration of smoke in the sample of air by measuring an obscuration of the smoke in a detection chamber.

[0043] The concentration of smoke determined by the smoke detector may be used to detect the possible fire event, by determining when the determined smoke concentration exceeds a predetermined smoke concentration threshold.

[0044] The pattern recognition algorithm may be configured to provide a probability that the identified source of the possible fire event is one of a plurality of known sources. Accordingly, if the pattern recognition algorithm is unable to exactly identify, or identify within a predetermined confidence interval, what the source of the detected fire event is, the pattern recognition algorithm may still provide an indication of the source of the possible fire event.

[0045] If it is determined that a source of a possible fire event is most likely one of a plurality of known sources then this known source may be identified as being the source. If one of the plurality of known sources is determined to be the source of the detected fire event with a probability greater than a threshold probability then that known source may be identified as being the source of the possible fire event. The threshold probability may be a predetermined value set by an installer, or a value set during the learning stage of a pattern recognition algorithm and may be, at least in one example, at least 50%. If none of the plurality of known sources are determined as being the source of the possible fire event with a probability of at least 50%, then a known source having a probability greater than any known source and at least greater than any of: at least 35%; at least 40%; or at least 45%; may be identified as being the source of the possible fire event.

[0046] Where none of the plurality of known sources are identified as being the source of the possible fire event according to the above criteria, the source may be identified as being a non-fire/nuisance source.

[0047] If the source is identified as being a non-fire/nuisance source (including the situations where both the source is positively identified as being a non-fire source, and where the source of the possible fire event cannot be identified), the method may comprise determining if a sensor value from the one or more sensors exceeds a respective modified threshold. The respective modified threshold will be less sensitive to the sensor value. For example, a modified temperature threshold will be higher than the predetermined temperature threshold; and/or a modified smoke threshold will be higher than the predetermined smoke threshold.

[0048] If the method determines that the sensor value from the one or more sensors exceeds the respective modified threshold, the method may comprise determining that the first action is to be taken (i.e. the method identifies the source of the possible fire event as a non-specific fire source).

[0049] Accordingly possible fire events which may be triggered by non-fire sources, or possible fire events where the source cannot be identified, may still result in the first action being taken. This may still reduce a volume of false alarms or false-positive detections being detected, whilst providing an adequate level of fire detection/intervention to ensure the safety of a user or occupants at the location of the possible fire event.

[0050] In alternative embodiments, where none of the plurality of known sources are identified as being the source of the possible fire event according to the above criteria, the source may be identified as being a fire source.

[0051] If two or more sensors are provided, the method may comprise generating a temporal log based on data from only one of the sensors. Alternatively, the method may comprise generating two or more temporal logs based on data from the two or more sensors, respectively. Accordingly the method may further comprise examining each of the two or more temporal logs to identify one or more sources of the possible fire event; and determining if the possible fire event requires action based on the one or more identified sources of the possible fire event.

[0052] For example, multiple sources may be identified when multiple temporal logs are examined. If at least one of the multiple identified sources is a fire source, then it may be determined that the first action is to be taken.

[0053] It is possible to combine the step(s) of examining the temporal signature to identify a source of the possible fire event with further steps capable of discriminating between known sources of possible fire events. This may improve the discriminating ability of the method.

[0054] For example, the one or more sensors may comprise a multi-wavelength optical sensor used to detect the possible fire event. The multi-wavelength optical sensor generally comprises a detection chamber into which the sample of air is passed. In some arrangements, the multi-wavelength optical sensor comprises a laser configured to emit two or more wavelengths and a photodiode configured to detect two or more wavelengths. In other arrangements, the multi-wavelength optical sensor comprises two or more lasers configured to each emit a different wavelength and two or more photodiodes configured to each detect each different wavelength. The multi-wavelength smoke detector may determine a concentration of smoke in the sample of air by measuring a scattering of light emitted from the laser(s). A possible fire event may be detected based on the determined concentration of smoke.

[0055] Additionally, the multi-wavelength smoke detector may be configured to discriminate between a plurality of known sources based on a measurement of how each wavelength is scattered. Smoke produced by different sources of fire events may have a unique, or distinguishable, composition and hence may produce different amounts of scattering at different wavelengths. Accordingly it is possible to examine an amount of scattering at a plurality of wavelengths to identify a source of the possible fire event.

[0056] Hence, in addition to examining the temporal log to identify a first potential source of the possible fire event, the method may further comprise, wherein the one or more sensors comprises a multi-wavelength optical smoke detector, receiving scattering data from the multi-wavelength optical smoke detector; examining the scattering data to identify a second potential source of the possible fire event; and determining if the possible fire event requires action based on the first identified source and the second identified source of the possible fire event.

[0057] If at least one of the first and second identified sources of the possible fire event is identified to be a fire source, then the detected fire event may be verified as being a positive detection.

[0058] Alternatively, it may be required that both the first and second identified sources of the fire event must be identified to be a fire, for the detected fire event to be verified as being a positive detection. This may further reduce a volume of false-positive detections, which may result in false-positive alarms being generated.

[0059] By providing two discriminating steps in combination, the discriminating power of the method may be further improved.

[0060] The method may comprise using a fire system, the fire system comprising the one or more sensors. The fire system may be comprise aspirating detection system or a point detection system, the aspirating detection system or point detecting system including the one or more sensors.

[0061] Viewed from a second aspect of the present invention, there is provided a fire system for monitoring an environment. The fire system comprises: one or more sensors configured to monitor a respective fire characteristic in the monitored environment; and a controller in communication with the one or more sensors; wherein the controller is configured to: detect a possible fire event using the one or more sensors; generate a temporal log corresponding to the possible fire event and based on data from the one or more sensors; examine the temporal log to identify a source of the possible fire event; and determine an action to be taken based on the identified source of the possible fire event; wherein examining the temporal log comprises detecting a temporal signature in the temporal log using pattern recognition, the temporal signature being one of a plurality of temporal signatures corresponding to a plurality of known sources.

[0062] That is, the controller may be configured to perform the method of the first aspect. Hence the system of the second aspect may be configured to perform any one or more or all of the steps, including optional steps, and include any of or more or all of the features, including optional features, of the method described above. Thus the above description of the first aspect may be equally applicable to the system of the second aspect.

[0063] If the identified source of the possible fire event is a fire source, the controller may be configured to determine that a first action is to be taken. If the identified source of the possible fire event is a non-fire source, the controller may be configured to determine that a second action is to be taken.

[0064] The fire detection system may comprise an audible indicator in communication with the controller. The first action may comprise using the controller to generate an alarm signal, and may further comprise using the controller to activate the audible indicator.

[0065] The audible indicator may be configured to produce a sound when activated, and may be configured to produce different sounds based on the identified fire source.

[0066] The fire detection system may comprise one or mitigation devices in communication with the controller. The first action may comprise using the controller to engage at least one of the one or more fire mitigation devices. Which of the one or more fire mitigation devices is to be engaged may be selected based on the identified source.

[0067] The one or more fire mitigation devices may include automatic fire extinguishers, such as those which deploy carbon dioxide or CFC foams, or water sprinkler systems. The one or more fire mitigation devices may also include any means configured to prevent the supply of any electrical mains or gas mains to a location of the possible fire event.

[0068] The controller may be configured to determine that the action to be taken does not include the first action if the source of the possible fire event is a non-fire source.

[0069] The second action may comprise using the controller to generate a notification signal, and may further comprise using the controller to send the notification signal to a device configured to display textual information.

[0070] The notification signal may comprise data identifying the source of the possible fire event, such that a user or occupant may be informed of the identification of a non-fire source. The notification signal may be configured to not audibly alert a user or occupant to the detection of the possible fire event (e.g. via the device or the audible indicator).

[0071] The fire system may comprise the device, the device optionally being a display panel or the like. The device may be a central monitoring station (CMS). Alternatively, the device may be a mobile phone or smart device in communication with the fire system via one or more suitable communications protocols.

[0072] The fire system may comprise a point detection system. The point detection system may passively sample the air when monitoring the environment, and hence may be regarded as a passive detection system. That is, the point detection system may rely on the passive movement of air, including smoke and the predetermined gas within the monitored environment, to the gas sensor and the smoke detector.

[0073] Alternatively, the fire system may comprise an aspirating detection system. The one or more sensors may be located remotely from the monitored environment and may be located within a detection unit of the aspirating detection system. The aspirating detection system may comprise a pipe, wherein an opening of the pipe is exposed to the monitored environment. The pipe may also be in fluid communication with the smoke detector and the gas sensor. As such, the pipe may facilitate fluid communication between the smoke detector, the gas sensor and the monitored environment.

[0074] The aspirating detection system may comprise an aspirating device. The aspirating device may comprise a fan, blower, pump or the like configured to aspirate air from the monitored environment. The aspirating device may hence be configured to aspirate a sample of air from the monitored environment.

[0075] The sampling pipe may comprise an opening exposed to the monitored environment. The sampling pipe may facilitate fluid communication between the monitored environment and the smoke detector and the gas sensor. The sampling pipe may also be in fluid communication with the aspirating device, such that air is sampled from the monitored environment by aspirating air from the monitored environment using the sampling pipe.

[0076] The aspirating detection system may be regarded as an active detection system. That is, the aspirating detection system may actively sample the air of the monitored environment. Active detection may provide quicker detection times of sources of smoke (and hence possible fire events) within a monitored environment, as particulates and gases within the air are motivated to the smoke detector and the gas sensor rather than relying on random processes, such as the stochastic movement of air.

[0077] Aspirating detection systems may also provide more reliable detection means than passive detection systems, such as point detection systems. For example, smouldering fires may produce large amounts of dense smoke. As smouldering fires may not produce large amounts of heat, the smoke and other combustion products from the source of the smoke may not be motivated to a ceiling or sampling point and/or detector located above the point at which the smoke hangs in the air. However, the aspirating detection system may aspirate and/or motivate the low hanging smoke such that it does reach the smoke detector and the gas sensor, such that a source of smoke is reliably detected, and the source of the smoke may be identified.

[0078] Further, aspirating detection systems may monitor larger areas more reliably, as air is motivated to the smoke detector and gas sensor. That is, a time of travel between a fire and the various detectors within the aspirating detection system is reduced, such that fires may be reliably detected across vaster areas.

[0079] Viewed from a third aspect, there is provided a computer program product comprising computer readable instructions that, when executed, will cause a processor to perform a method comprising: detecting a possible fire event using data from one or more sensors: generating a temporal log corresponding to the possible fire event and based on data from one or more sensors; examining the temporal log to identify a source of the possible fire event; and determining an action to be taken based on the identified source of the possible fire event identified; wherein examining the temporal log comprises detecting a temporal signature in the temporal log using pattern recognition, the temporal signature being one of a plurality of temporal signatures corresponding to a plurality of known sources.

[0080] The computer program product of the third aspect may be a computer program product comprising computer readable instructions that, when executed, will cause a server to perform the method of the first aspect.

[0081] The computer program product of the third aspect may have one or more or all of the features (including optional features) of the method of the first aspect. Thus the above description of the method of the first aspect may be equally applicable to the computer program product of the third aspect.

[0082] The computer program product may be stored on a tangible, computer-readable medium.

Brief description of the drawings

[0083] Certain exemplary embodiments of the disclosure will now be described by way of example only and with reference to the accompanying drawings in which:

Figure 1 shows a schematic diagram of an aspirating detection system in flow communication with a monitored environment;

Figure 2 shows a schematic diagram of a point detector disposed in a monitored environment; and

Figures 3A-D illustrate how a monitored smoke concentration varies in time for a wood fire, a nuisance cooking source, a flaming polyurethane foam fire, and a paper fire, respectively.

Description of the preferred embodiment

[0084] Figure 1 shows a schematic diagram of an aspirating detection system 1 monitoring an environment 100. The fire detection system 1 includes a central detection unit 6 connected to a sampling pipe 9. The sampling pipe 9 is exposed to the monitored environment 100 via a plurality of sampling holes 10 in the sample pipe 9, such that the central detection unit 6 is in fluid communication with the monitored environment 100. The central detection 6 is in wired and/or wireless communication with a controller 5. The controller 5 is also in wired and/or wireless communication with an alarm system 101 and a fire mitigation device 102, both of which are present in the monitored environment 100.

[0085] The central detection unit 6 includes an inlet 7 which is connected to the sampling pipe 9. The central detection unit 6 also includes a temperature sensor 3, a smoke detector 4 and an outlet 8. Air is aspirated into the central detection unit 6 using an aspirator 2, which draws a sample of air from the monitored environment (100) through the sampling pipe 9 and into the central detection unit 6 via the inlet 7. The sampled air is passed, in series, through each of the temperature sensor 3 and the smoke detector 4. The sampled air is then exhausted from the central detection unit 6 via the outlet 8. The order of the aspirator 2, the temperature sensor 3 and the smoke detector 4 may be changed.

[0086] The flow of air through the central detection unit 6 is generally indicated by the arrows shown in Figure 1. Aspirated air is motivated into the central detection unit 6 due to the rotation of an impeller of the aspirator 2. The aspirated air is then passed to the temperature sensor 3 and the smoke detector 4, before being exhausted from the housing via the outlet 8. Whilst not illustrated in the present embodiment, not all of the air is necessarily passed through both the smoke detector 4 and/or the temperature sensor 3. The flow of air may be split such that different portions of the sampled air are passed to each of the smoke detector 4 and the temperature sensor 3. Optionally a bypass flow may be present, such that a portion of the sampled air is not passed through the smoke detector 4 and/or the temperature sensor 3, for example if the flow rate of the aspirator is greater than the flow rates that can be effectively processed by the smoke detector 4 and/or the temperature sensor 3.

[0087] Figure 2 shows a schematic diagram of a point detector 21 monitoring the environment 100. In contrast to the aspirating detection system 1 shown in figure 1, the point detector 21 is disposed in the monitored environment 100. The point detector 21 includes a temperature sensor 23, a smoke detector 24 and a controller 25, all located in or on a housing 26. The controller 25 is in wired and/or wireless communication with each of the temperature sensor 23 and the smoke detector 24. Additionally, the controller 25 is in wired and/or wireless communication with an alarm system 101 and a fire mitigation device 102, both of which are present in the monitored environment 100.

[0088] The point detector 21 passively samples air from the monitored environment 100. That is, the point detector 21 relies on air currents within the monitored environment 100 to carry air and/or particulate suspended in air to the point detector 21, for the smoke detector 24 to detect. In the illustrated embodiment, the temperature sensor 23 is an infrared sensor directly exposed to the monitored environment 100, and accordingly is less reliant on the motion of air currents within the monitored environment 100 to be able to sense a temperature. However, other types of temperature sensor 23 may alternatively be employed.

[0089] In each of the respective fire detection systems 1, 21 the smoke detector 4, 24 is configured to determine a concentration of smoke in a sample of air from the environment 100 which the fire detection system 1, 21 monitors.

[0090] The smoke detector 4, 24 in the illustrated embodiments is an optical smoke detector and comprises a detection chamber into which the sample of air is passed, a laser which is shone through the detection chamber, and a photodiode. If smoke is present in the detection chamber, the laser light will be scattered. The photodiode detects the scattered light such that an amount of scattered light can be measured. By measuring an amount of scattered light from the laser, a concentration of smoke present in the sample of air can be determined. In alternative embodiments, obscuration-based smoke detectors which are capable of sensing an obscuration, rather than determining a concentration of smoke present based on optical scattering, may still be used in accordance with the present invention.

[0091] The temperature sensor 3, 23 and the smoke detector 4, 24 of each of the fire detection systems 1, 21 described herein are used to continually to observe the monitored environment 100.

[0092] The temperature sensor 3, 23 is operated to sense a temperature of the monitored environment 100 via a sample of aspirated air as in figure 1. The smoke detector is operated to determine a concentration of smoke.

[0093] Using the controller 5, 25, the sensed temperature value is compared to a first temperature threshold. If the sensed temperature value exceeds the first temperature threshold then a possible fire event is detected. Simultaneously, the controller 5, 25 compares the determined concentration of smoke to a first concentration threshold. If the determined concentration of smoke exceeds the first concentration threshold then a possible fire event is detected.

[0094] In the present embodiment, only one of the first concentration threshold and the first temperature threshold needs to be exceeded by its respectively observed value for the fire detection system 1, 21 to detect a possible fire event. As will be appreciated, certain fire events may not necessarily produce high volumes of smoke but may exhibit high temperatures. Conversely, certain fire events may not necessarily exhibit high temperatures, but may produce high concentrations of smoke. Accordingly, being able to detect a fire event based on at least one of temperature and smoke concentration alone may improve the reliability of the fire detection system 1, 21. However, in other embodiments, multi-factor detection may be used, e.g. requiring both a temperature threshold and a smoke concentration threshold to be met.

[0095] Once a possible fire event is detected, as described above, the fire detection system 1, 21 identifies a source of the fire event before any further action is taken by the fire detection system 1, 21. Such an identification can be used to determine if the detection of a possible fire event is in fact a false-positive detection, in which case a user or occupant of the monitored environment 100 need not be notified as to the presence of a fire event. That is, the fire detection system 1, 21 validates if an actionable fire event has actually been detected.

[0096] During operation of the fire detection system 1, 21 data obtained using the temperature sensor 3, 23 and the smoke detector 4, 24 is recorded. This recorded data may be stored temporarily by the controller 5, 25 or may be sent to a remote server. Accordingly, from the recorded data a plurality of data points are obtained, each comprising a timestamp and a value corresponding to the sensed temperature or the detected concentration of smoke.

[0097] The data points recorded at and around the time at which the possible fire event is detected are used to generate a temporal log of the detected possible fire event. The generated temporal log records how the sensed temperature and/or the detected concentration of smoke varies with respect to time prior to and/or after detection of the possible fire event.

[0098] A temporal signature of an event defines a temporal shape that is generated by a particular source of heat and/or smoke. The controller 5, 25 examines the shape of the temporal log to identify one or more temporal signatures indicating the source of the possible fire event.

[0099] It will be appreciated that a temporal signature may be represented as a series or matrix of values, rather than a physical plotted chart or graph of the recorded data. However, for the purpose of illustrating the present embodiment figures 3A-D represent exemplary temporal signatures for various sources of fire events. As can be seen in figures 3A-D, various sources of detectable fire events have different temporal signatures or overall signal aspects.

[0100] In the present embodiment, the controller 5, 25 examines the temporal log of the sensor data to identify a temporal signature using a temporal pattern recognition algorithm such as a recurrent neural network or a hidden Markov model. Depending on the output of the pattern recognition algorithm, the controller 5, 25 identifies a source of the possible fire event based on a plurality of known events, including both fire events and non-fire events. Data collected from a plurality of each of such events will have been used to train the pattern recognition algorithm to identify the temporal signatures. Typically, at least 100 samples for each event will be used to train the pattern recognition algorithm to identify that event, although this value might change depending on the sampling rate and the depth of the algorithm.

[0101] Generally, temporal pattern recognition algorithms operate by detecting a shape in the temporal log corresponding to the temporal signature corresponding to a known event. Such shapes can include complex shapes, comprising one or more peaks and/or troughs or multiple gradients. This shape will then be classified as belonging to one of the plurality of known events, if this detected shape is found to correspond to the shape of a known event. If the shape is classified as being that of one of the known events it is likely that the detected possible fire event has occurred as a result of the same source. Hence the source of this known event will be identified as being the source of the possible fire event.

[0102] If the source of the identified event is one of, for example, steam, a cooking source, cigarette smoke or a known contaminant produced or present in the monitored environment 100, then the controller 5, 25 identifies the possible fire event as being a non-fire event that does not require action. The source is a 'nuisance' and a user or occupant of the monitored environment 100 does not need to be alerted. In other words, the detection of the possible fire event is a false-positive.

[0103] If the identified source is not a source that requires action, the controller will not generate an alarm. The user or occupant may still be notified of the detection but will be notified via a central monitoring station, or using an application on a mobile device, or using a screen or display (not shown) located in the monitored environment 100. The notification will comprise textual information relaying to the user or occupant what the identified source is, such that the user or occupant can take any action as required. However, by not alerting the user or occupant a volume of false alarms caused by nuisance alarms may ultimately be reduced.

[0104] If the identified source is any of, for example, a paper fire, a wood fire, a polyurethane fire or the like, then the controller 5, 25 identifies the possible fire event as being an actual fire event that requires action to be taken. That is, a user or occupant of the monitored environment (100) will need to be alerted to the fire event using the alarm system 101.

[0105] Depending on the identified source of the fire event, the fire mitigation device 102 may be engaged. Different fire suppression techniques, such as water-based, powder-based and gas-based fire suppression techniques, are differently effective against different fire sources. The controller 5, 25 may therefore determine a type of fire mitigation device 102 to engage based on the identified source of the fire event, and consequently engage an appropriate fire mitigation device 102 from a plurality of different fire mitigation devices 102.

[0106] In the event that the possible fire event cannot be identified the possible fire event may be treated as an actual fire event. That is to say, a user or occupant of the monitored environment (100) is alerted to the fire event using the alarm system 101 and/or the fire mitigation device 102 is engaged.

[0107] Optionally, a second, lower smoke threshold and/or a second, lower temperature threshold may be employed to identify a possible fire event. Where the lower thresholds are used, in the event that the possible fire event cannot be identified, the possible fire event may be treated as a non-fire event and no action may be taken until one of the higher thresholds is reached. This allows for early detection of an actual fire event using temporal pattern recognition, whilst still ensuring that action is taken in the event that an unidentifiable source generates a high level of smoke or heat.

[0108] Whilst in the preferred embodiment(s) the pattern recognition algorithm used is one of a recurrent neural network or a hidden Markov model, in various embodiments the pattern recognition algorithm may be any of the following: non-recursive or recursive linear filters; finite state machines; dynamic programming; Bayesian belief networks; sequential belief networks; Markov models; convolutional neural networks; Boltzmann networks, including Boltzmann machines, restricted Boltzmann machines, conditional restricted Boltzmann machines or temporal restricted Boltzmann machines; time delay neural networks; long-short term memory recurrent neural networks; spiking neural networks; spatio-temporal inference networks; hierarchical temporal memory networks; and prediction-based temporal networks.

Claims

1. A method of fire detection, comprising:

detecting a possible fire event using one or more sensors (3, 4; 23, 24);
generating a temporal log corresponding to the possible fire event and based on data from the one or more sensors (3, 4; 23, 24);
examining the temporal log to identify a source of the possible fire event; and
determining an action to be taken based on the identified source of the possible fire event;
wherein examining the temporal log comprises detecting a temporal signature in the temporal log using pattern recognition, the temporal signature being one of a plurality of temporal signatures corresponding to a plurality of known sources.

2. A method as claimed in claim 1,

wherein the action to be taken includes a first action if the identified source of the possible fire event is a fire source; and
wherein the action to be taken includes a second, different action if the identified source of the possible fire event is a non-fire source.

3. A method as claimed in claim 2, wherein the first action comprises generating an alarm signal, and optionally wherein the alarm signal comprises an audible indication.

4. A method as claimed in claim 2 or 3, wherein the first action comprises engaging one or more fire mitigation devices (102), optionally wherein the one or more fire mitigation devices (102) are selected based on the identified source.

5. A method as claimed in claim 2, 3 or 4, wherein the action to be taken does not include the first action if the identified source of the possible fire event is a non-fire source.

6. A method as claimed in any of claims 2 to 5, wherein the second action comprises at least one of:

generating a notification signal; and
activating a device configured to display textual information.

7. A method as claimed in any of claims 2 to 6, wherein the non-fire source is any of steam, a cooking source, airborne pollution or cigarette smoke.

8. A method as claimed in any preceding claim, wherein detecting the possible fire event comprises:

determining that a sensor value from the one or more sensors (3, 4; 23, 24) exceeds a respective predetermined threshold.

9. A method as claimed in any preceding claim, wherein the one or more sensors comprises at least one of:

a smoke detector (4; 24) configured to determine a concentration of smoke in a monitored environment (100); and
a temperature sensor (3; 23) configured to sense a temperature in the monitored environment (100).

10. A fire system for monitoring an environment (100), the fire system comprising:

one or more sensors (3, 4; 23, 24) configured to monitor a respective fire characteristic in the monitored environment (100); and
a controller (5; 25) in communication with the one or more sensors (3, 4; 23, 24), wherein the controller (5; 25) is configured to:

detect a possible fire event using the one or more sensors (3, 4; 23, 24);
generate a temporal log corresponding to the possible fire event and based on data from the one or more sensors (3, 4; 23, 24);
examine the temporal log to identify a source of the possible fire event; and
determine an action to be taken based on the identified source of the possible fire event;

wherein examining the temporal log comprises detecting a temporal signature in the temporal log using pattern recognition, the temporal signature being one of a plurality of temporal signatures corresponding to a plurality of known sources.

11. A fire system as claimed in claim 10,

wherein the action to be taken includes a first action if the identified source of the possible fire event is a fire source; and
wherein the action to be taken includes a second, different action if the identified source of the possible event is a non-fire source.

12. A fire system as claimed in claim 11, the fire system comprising an audible indicator (101) in communication with the controller (5; 25);
wherein the first action comprises activating the audible indicator (101).

13. A fire system as claimed in claim 11 or 12, the fire system comprising one or more fire mitigation devices (102) in communication with the controller (5; 25);
wherein the first action comprises activating at least one of the one or more fire mitigation devices (102), optionally wherein the at least one of the fire mitigation devices (102) is selected based on the identified source.

14. A fire system as claimed in any of claims 10 to 13, wherein the fire system comprises an aspirating fire detection system (1) including the one or more sensors (3, 4).

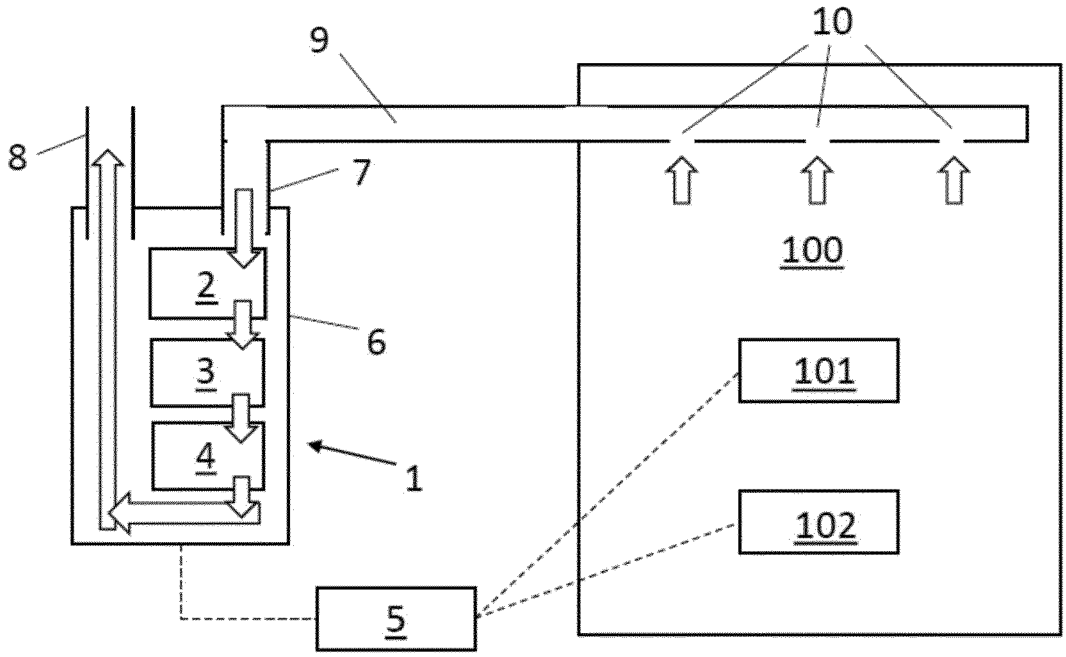

FIG. 1

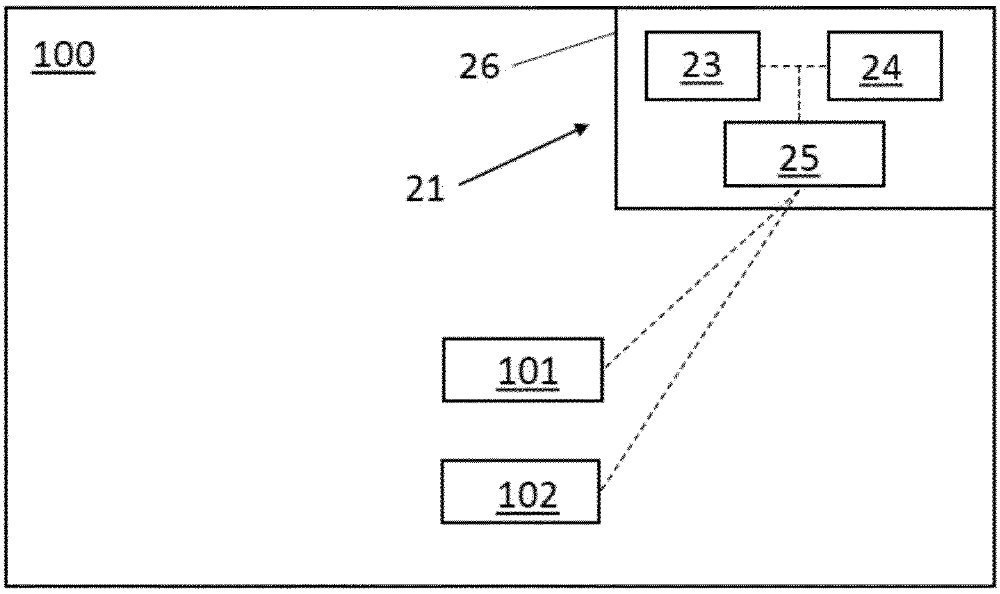

FIG. 2

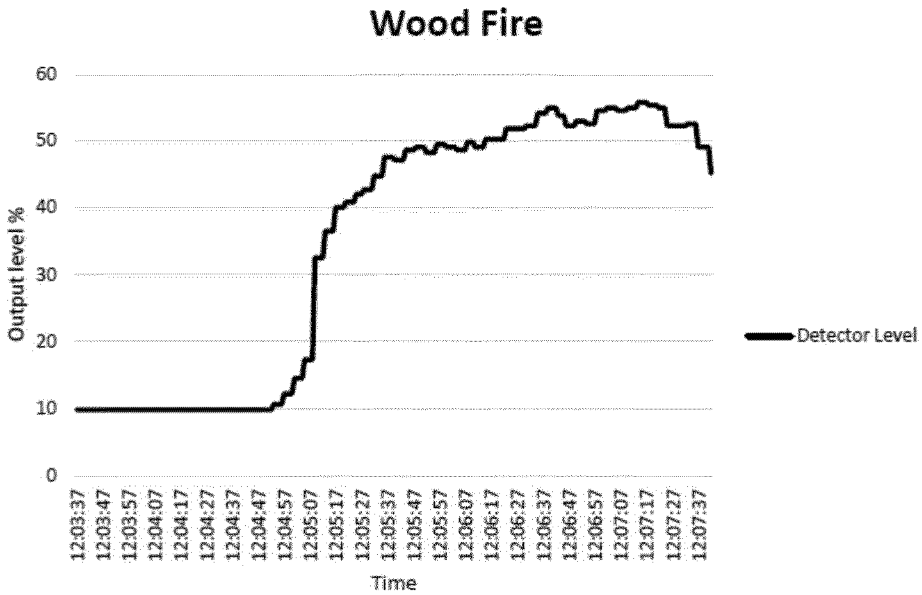
Wood Fire
60
50
40
30
20
10
0
Output level %
12:03:37
12:03:47
12:03:57
12:04:07
12:04:17
12:04:27
12:04:37
12:04:47
12:04:57
12:05:07
12:05:17
12:05:27
12:05:37
12:05:47
12:05:57
12:06:07
12:06:17
12:06:27
12:06:37
12:06:47
12:06:57
12:07:07
12:07:17
12:07:27
12:07:37
Time
Detector Level

FIG. 3A

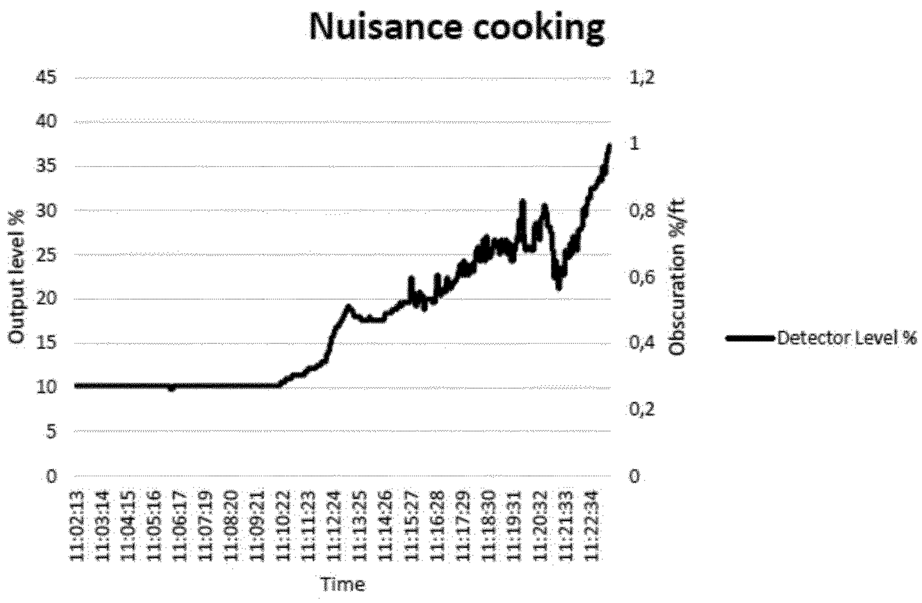
Nuisance cooking
45
40
35
30
25
20
15
10
5
0
Output level %
1,2
1
0,8
0,6
0,4
0,2
0
Obscuration %/ft
11:02:13
11:03:14
11:04:15
11:05:16
11:06:17
11:07:19
11:08:20
11:09:21
11:10:22
11:11:23
11:12:24
11:13:25
11:14:26
11:15:27
11:16:28
11:17:29
11:18:30
11:19:31
11:20:32
11:21:33
11:22:34
Time
Detector Level %

FIG. 3B

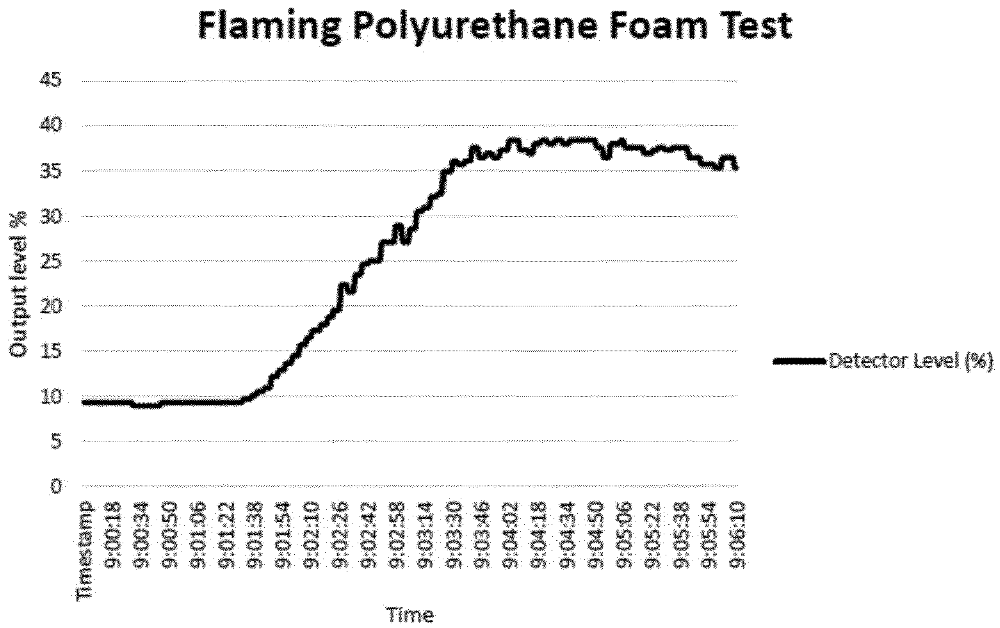
Flaming Polyurethane Foam Test
45
40
35
30
25
20
15
10
5
0
Output level %
Timestamp
9:00:18
9:00:34
9:00:50
9:01:06
9:01:22
9:01:38
9:01:54
9:02:10
9:02:26
9:02:42
9:02:58
9:03:14
9:03:30
9:03:46
9:04:02
9:04:18
9:04:34
9:04:50
9:05:06
9:05:22
9:05:38
9:05:54
9:06:10
Time
Detector Level (%)

FIG. 3C

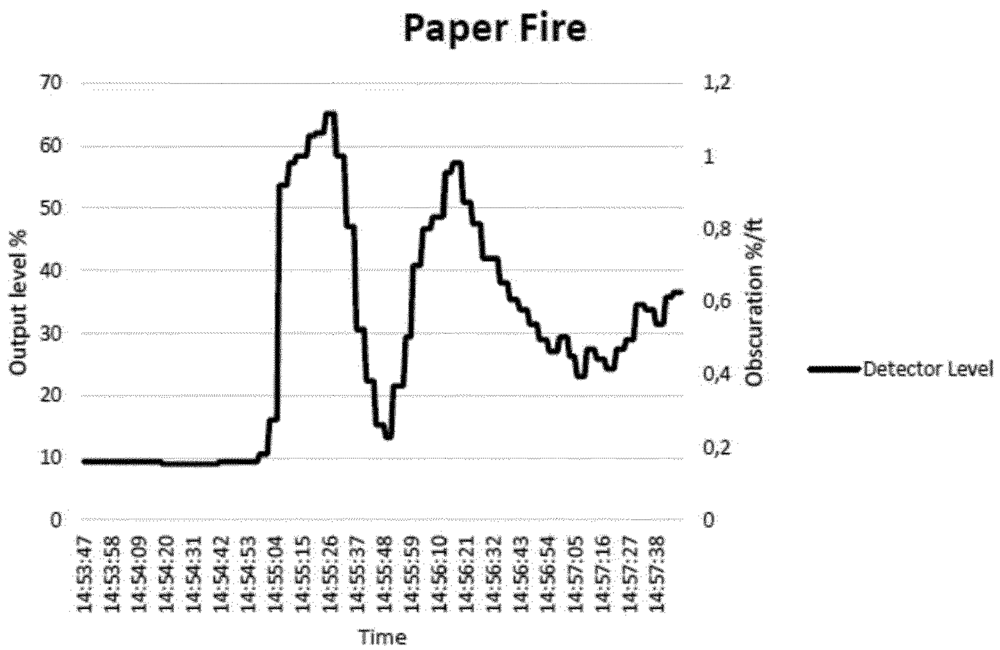
Paper Fire
70
60
50
40
30
20
10
0
Output level %
1,2
1
0,8
0,6
0,4
0,2
0
Obscuration %/ft
14:53:47
14:53:58
14:54:09
14:54:20
14:54:31
14:54:42
14:54:53
14:55:04
14:55:15
14:55:26
14:55:37
14:55:48
14:55:59
14:56:10
14:56:21
14:56:32
14:56:43
14:56:54
14:57:05
14:57:16
14:57:27
14:57:38
Time
Detector Level

FIG. 3D

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EUROPEAN SEARCH REPORT

Application Number
EP 21 38 2886

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	WO 2018/222905 A1 (GONZALES ERIC V [US]) 6 December 2018 (2018-12-06) * abstract; figures 1-13 * * page 4, line 1 - page 6, line 2 * * page 7 - page 9 * * page 25, line 5 - line 20 * * page 13, line 14 - line 17 * * page 14 - page 16 * * page 18, line 20 - page 19, line 18 * * page 22, line 11 - line 13 * * page 21, line 10 - line 11 * -----	1-3,5, 7-12 4,6,13, 14	INV. G08B17/103 G08B17/10 G08B29/18
Y	CN 110 102 001 B (BEIJING YATAIAN EQUIPMENT MOUNTING CO LTD) 9 April 2021 (2021-04-09) * paragraph [0041] - paragraph [0044] * -----	4,6,13, 14	
			TECHNICAL FIELDS SEARCHED (IPC)
			G08B

2

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	17 March 2022	Bilard, Stéphane

CATEGORY OF CITED DOCUMENTS

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17-03-2022

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