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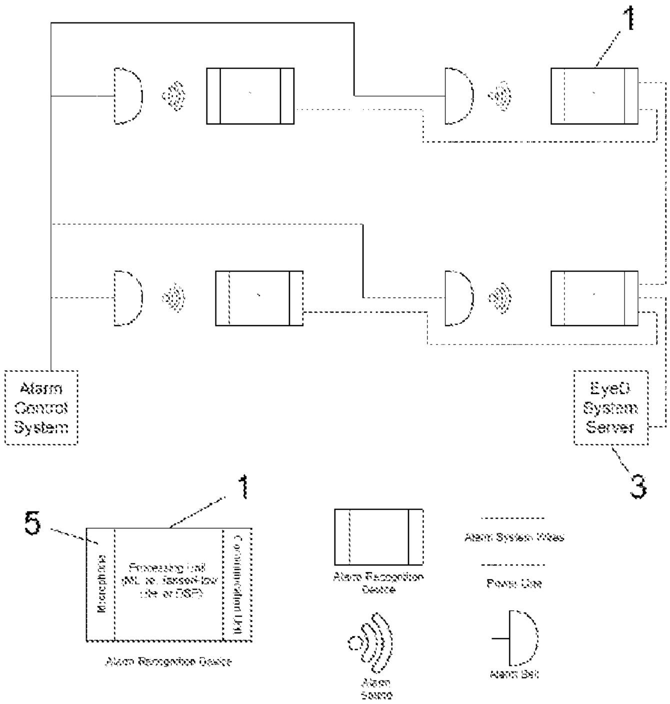
(57)	Abstract	

There is provided an alarm detection system for a vessel comprising: one or more processing units each configured to detect one or more of sound, motion, electrical, and visual data and comprising machine learning software configured to accept the data as input and to classify the data as ambient class or alarm class data; a central control unit coupled to the one or more processing units, wherein the processing units are each configured to send an indication to the central control unit when alarm class data is detected. There is also provided a method for monitoring an alarm system on board a vessel.



AN ALARM DETECTION SYSTEM

The invention described herein relates to an alarm detection system. In particular, the invention relates to an alarm detection system for use on seafaring vessels. The system monitors the state of alarm devices onboard vessels in order to improve response times.

Most domestic and commercial buildings will nowadays have some type of integrated alarm system fitted. Smoke and CO detectors are, for example, legally required to be fitted within rental properties and workplaces in most countries and the use of burglar alarms is now also widespread. Although a loud sound can be useful in deterring a burglar or alerting neighbours or residents, in a case where the home owner is not in or if no one is present in the workplace the alarm may be useless unless further action can be taken. In some cases, such systems are configured to automatically alert emergency services or to send a text message to a remote location when an alarm is triggered.

It is known to use a microphone in a mobile phone or similar device to record and then to process sounds within a particular environment. A user can, for example, identify a song playing in a restaurant using an app which analyses ambient sounds. Such applications work by way of a large online catalogue of song data or “fingerprints” which can be matched to the sound detected. Each fingerprint comprises information regarding the frequencies of sound which make up the song (extracted from a spectrogram). To save time and processing effort, only the highest amplitude sounds are matched in some cases. This can be effective in identifying a song, even in a database of thousands.

Similar technology can be used in order to distinguish sounds within a home and to inform a remote user, such as detecting the sound of a break-in or of an alarm going off and forwarding an alert to a mobile phone. Obviously, this information can be useful in informing a response to such events. US9772671B1 describes an alarm detection system which uses a particular configuration of an electrical circuit to switch on a processor if sound above a certain amplitude threshold and having a particular frequency. The processor is configured to send a message via wireless means such as Bluetooth^RTM^ or Zigbee^RTM^ to a remote device in order to alert a user who is not present in the building. US-A-2018/0365975 describes an event detection system which uses channel state information in radio frequency signals received at a receiver from a transmitter to detect events relating to the position of objects within a building. US-A-2015/0187192 relates to a network of sensors (i.e. motion detectors or smoke detectors) providing data relating to a control environment to a central server.

Onboard marine vessels there are particular considerations in terms of how such an alarm detection system might operate. On a ship, wireless communication systems may not always be available, and so improving the way in which data is processed and minimising the amount of data required to be transferred is tantamount. Systems suitable for use in the home and on land may not function in a marine environment because of a reliance on the immediate transfer of data to a remote location. The integration of alarm detection systems with existing alarm systems onboard seafaring vessels is also complex and expensive. The system described below provides a simple and cost-effective solution which can be tailored to a particular vessel on which there may be present an existing alarm system, and which enables crew members to be alerted to an alarm event and provided with useful information in a situation where wireless communication channels are active at most intermittently.

According to a first aspect of the present invention, there is provided an alarm detection system for a vessel comprising: two or more processing units to be located in different areas of the vessel, each unit being configured to detect one or more of sound, motion, electrical, and visual data and comprising machine learning software configured to accept the data as input and to classify the data as ambient class or alarm class data; and a central control unit coupled to the two or more processing units, wherein the two or more processing units are each configured to send an indication to the central control unit when alarm class data is detected by that processing unit, wherein at least one activation profile specifying an action is stored on each processing unit and is associated with the or each alarm class data, wherein the system is configured to access the activation profile when the software detects the alarm class data thus causing the action to be performed, and wherein the action comprises sending select information, specified as part of the activation profile, from that processing unit to the central control unit.

The system provides an efficient way to quickly elicit the correct response to an alarm being sounded on board the ship. This is achieved in a manner which is easily adaptable to the specific configuration of an alarm system or to the layout of a particular vessel. Where software is used to determine whether sensor data corresponds to alarm data or not, the use of software that is located on the processing units themselves rather than centrally means that minimal data is required to be transmitted to another location. This is important in a situation where the processing units are located remotely from the central control unit (remote processing units), for example when they are located in different rooms on the vessel. This, along with the use of machine learning software as part of the processing, also means that the system can adapt over time to its surroundings or can be flexible for use in many different ways. A decision as to when a response should be elicited will depend on how training data is labelled, for example. Alarm data can also be used to further train the model following an alarm event or a drill, which means that the system can continuously improve.

Machine learning software, as described in more detail below, refers to software which is trained using training data to successfully allocate incoming data to one of two or more groups. The initial, or training, data is labelled with the correct group, and the machine learning software usually considers many instances of the training data in order to find the most suitable patterns and/or parameters to be used to correctly classify the real data. Training data may be pre-recorded or synthetic, or controlled alarm events may be used to train the model, or both.

The alarm detection system comprises two or more processing units. The processing units may be located in different rooms or in different areas of the vessel. The alarm detection system in such a case can be referred to as a distributed alarm detection system. Location in separate areas of the vessel may refer to the fact that processing units are located far enough apart or are separated by physical barriers such that for at least one alarm located on the vessel, one processing unit will classify sensor data collected while the alarm is activated (or the alarm event is occurring) as alarm data whilst the other will classify data collected while the alarm is activated as ambient data. Separate areas may refer to processing units being separated by physical structures such as walls, i.e. not being within a direct line of sight of one another.

In embodiments, the central control unit comprises a user interface and is configured to communicate the indication to the user via the user interface. The controller includes some means by which the indication can be directly communicated to a personnel member. This may be in the form of a display screen which may display a simple indication that an alarm has sounded, or an alarm event has been detected. The interface may provide additional information about the type and location of the alarm or event, as well as information about the action to be taken in response. The control unit may be configured to collect data directly from each of the one or more processing units in the system (rather than via other units). Crew members, or select crew members, may be provided with personal devices which receive notifications when an alarm event is detected by the system. These may communicate wirelessly with the controller or with one or more of the processing units.

In embodiments, the one or more processing units each comprise a processor and one or more sensors for detecting the one or more of sound, motion, electrical, and visual data, and the one or more sensors are connected to the processor via wired or wireless communication means. The processor may be a simple embedded processor. An alarm event can represent the sounding of an alarm, but can also relate to other sounds, sights, or events which should be considered as representing an emergency situation, such as the sound of shouting for help or screaming, the sound of a malfunctioning engine or machine part on the ship, a flashing light, and so on. The machine learning software means that the system is flexible enough to be adapted to respond to one or more of the above.

In embodiments, the central control unit is coupled to each of the processing units via wired connection and the indication is sent via the wired connection. This may be particularly important on a ship which is offshore since a wireless connection may not always be available. In embodiments, the wired connection is via a powerline. In embodiments, the processing units are included within nodes plugged into an existing powerline system. The system can be installed simply by plugging the nodes into power sockets in the areas to be monitored. A central control unit also needs to be coupled to the powerline system and can also be in the form of a pluggable node located on the bridge or elsewhere. As an alternative to a wired connection between one or more of the processing units and the central control unit, a wireless connection (e.g. UWB) can be used. The processing units can also be capable of communicating between themselves using a wired or wireless connection. The system may include both wireless and wired connections between units for use in different situations. A wireless connection can be used in a normal situation, for example, and the wired connection if the wireless connection is intermittent or not available for any reason.

At least one activation profile is stored on the processing unit associated with the or each alarm class data and specifying an action, the activation profile being accessed when the software detects the associated alarm class data thus causing the action to be performed.

In embodiments, the action specified is to begin recording sensor data received at the processing unit. The recorded sensor data is then available to be used as training data at a later stage in order to improve the model. Once the emergency situation has been averted, recorded data can be labelled as alarm class data associated with a particular alarm. The sensor may be part of the processing unit along with a processor, which will usually have machine learning capabilities. Sensor data can be recorded at the processing unit, or can be sent to the central unit or to another location for storage there. Recording at the processing unit may be more convenient, particularly where data connectivity is low, and recorded data can be sent to the central unit or another storage location at a later time if desired.

In embodiments, in response to a subsequent detection of ambient data by the software, the processing unit stops recording sensor data. This means that there will be data available covering the whole time period during which the alarm was sounding. The recorded sensor data may also be sent to the central control unit or to another storage location at this stage if it was recorded on the processing unit while the alarm was sounding. Data collected when no alarms are sounding may include voice data from conversations. This data will not be recorded or forwarded to a central control unit, which will be beneficial in terms of respecting the privacy of the crew members onboard. Recording of such data during an emergency situation, however, may well be important later when it is necessary to determine how the situation was dealt with and what caused it. Additional sensors, such as a microphone or a thermometer, may be included as part of the processing unit or control unit or another part of the system. Data from this or these additional sensors may be recorded during the emergency situation as well as or instead of the sensor data used to determine whether an alarm event is occurring.

In embodiments, the action comprises activation or change in status of a remote crew monitoring system. Obviously, knowledge of the whereabouts of crew members is paramount in an emergency situation. This information can automatically begin to be collected and passed to the central unit as soon as an alarm is activated. Again, the amount of data that needs to be transferred during a normal (non-emergency) situation is minimised since the crew monitoring system need not necessarily be active during these times.

In embodiments, the remote crew monitoring system comprises nodes configured to communicate via radio communication means both with mobile units to be carried by crew members and with a central crew monitoring control unit, and wherein processing units are included in the same housing as the nodes of the remote crew monitoring system. The central crew monitoring control unit may be located in the same housing or in a different housing to the central control unit of the alarm detection system.

According to a second aspect of the present invention, there is provided a method for monitoring an alarm system on board a vessel, the method comprising: detecting, with each of two or more processing units located in different areas of the vessel, one or more of sound, motion, electrical, and visual data; passing the data as input to machine learning software stored on that processing unit and configured to classify the data as ambient class or alarm class data; sending, by each of the two or more processing units, an indication to a central control unit when alarm class data is detected by that processing unit; accessing, by each of the two or more processing units, an activation profile specifying an action thus causing the action to be performed when alarm class data is detected by that processing unit, wherein the action comprises sending select information, specified as part of the activation profile, from that processing unit to the central control unit.

In embodiments, the method comprises, prior to detecting the data, training a model of the machine learning software to classify the data using training data.

In embodiments, the method comprises the step of validating the model using test data subsequent to training the model. A verification step is generally required following the training step and prior to use of the system in-situ. Similarly, when the model is retrained using additional training data, a further verification step may be carried out subsequent to this. Using the training data, the machine learning software is able to find the most suitable algorithm for classification of alarm data in different scenarios and in different locations.

According to a third aspect of the present invention, there is provided an alarm detection system for a vessel comprising: one or more processing units, each processing unit being configured to detect one or more of sound, motion, electrical, and visual data and to classify the data as ambient class or alarm class data; and a central control unit coupled to the one or more processing units, wherein the processing units are each configured to send an indication to the central control unit when alarm class data is detected. Classifying of data may use pre-defined parameters such as volume, frequency, or intensity thresholds to classify the data into alarm or ambient class data. Alternatively, the classification step may use machine learning software. In embodiments, the sensor is configured to detect engine vibrations. In embodiment, the sensor is a microphone.

The system may be configured to detect a particular event, such as an engine malfunction in the engine room, by choosing specific pre-defined parameters for a processing unit near to the engine. In some cases, the processor may be configured to recognize a change in the frequency of an engine sound. In such a case the sensor on the processing unit can be a microphone or vibration sensor or any other sensor which can detect movement of the engine. If the frequency of the engine sound or the vibrations from the engine change due to a malfunction, the system may begin to classify the sensor data received as alarm class data (e.g. because a particular frequency threshold has been exceeded or has not been met or because machine learning software integrated in the processing unit has been trained to recognize abnormal engine motions).

The system may detect sound data in a room onboard the vessel, and a person shouting, or shouting a particular word, may be classified as alarm data (e.g. because a particular amplitude threshold is exceeded or because the system uses machine learning and has been trained to recognize calls for help). This will trigger an immediate response by the system.

Rather than or as well as the central control unit, each processing unit may be coupled to a local control unit, and may send the indication there either instead of, or as well as, sending it to the central control unit. This way the alarm system can notify those in the vicinity and provide them with important information even if connection to the main control system is cut. The processing units in each area may send indications to a personal wristband or unit worn by a crew member working in the vicinity, or to all crew members working in the area. A group of processing units may be coupled to a local processor.

In an embodiment, the system includes two or more processing units. In an embodiment, the processing units are configured to be installed in different areas or rooms of the vessel such that they are separated by physical barriers, which may be walls or steel walls. Processing is therefore carried out at the distributed processors which are collocated with the sensors. Only an indication that alarm data has been detected needs to be sent to the central controller or crew interfaces, which simplifies data transfer. This is particularly important on a marine vessel where connections may be intermittent and there may be limited bandwidth for wireless transfer of data.

In embodiments, the central control unit comprises a user interface and is configured to communicate the indication to the user via the user interface.

In embodiments, the one or more processing units each comprise a processor and one or more sensors for detecting the one or more of sound, motion, electrical, and visual data, and the one or more sensors are connected to the processor via wired or wireless communication means.

In embodiments, the central control unit is coupled to each of the processing units via wired connection and the indication is sent via the wired connection. This may be particularly important on a ship which is offshore since a wireless connection may not always be available.

In embodiments, the wired connection is via a powerline. In embodiments, the processing units are included within nodes plugged into an existing powerline system.

In embodiments, at least one activation profile is stored on the processing unit associated with the or each alarm class data and specifying an action, the activation profile being accessed when the software detects the associated alarm data thus causing the action to be performed.

In embodiments, the action specified is to begin recording sensor data received at the processing unit.

In embodiments, in response to a subsequent detection of ambient data by the software, the processing unit stops recording sensor data.

In embodiments, the action comprises activation or change in status of a remote crew monitoring system.

In embodiments, the remote crew monitoring system comprises nodes configured to communicate via radio communication means both with mobile units to be carried by crew members and with a central crew monitoring control unit, and wherein processing units are included in the same housing as the nodes of the remote crew monitoring system. The central crew monitoring control unit may be located in the same housing or in a different housing to the central control unit of the alarm detection system.

In an embodiment, the processing units are coupled to the controller via a network of powerlines.

The invention will be described in more detail with reference to the figures in which:

Figure 1 shows an alarm detection system and alarm control system;

Figure 2 shows a flowchart illustrating an example process of associating alarms with particular activation profiles;

Figure 3 shows a flowchart illustrating activation of the activation profiles in response to detection of a sound by software;

Figure 4 shows a flowchart illustrating the training and monitoring stages associated with use of the alarm detection system.

Figure 1 shows the components of an alarm detection system. The system includes a number of processing units or detection units 1 which may be distributed around the ship in different rooms and on different levels. These may be located particularly in rooms or areas of the ship where alarms are located, on the bridge, in an area where particular sounds need to be monitored, or in an area where an emergency situation is more likely to occur. The processing units may therefore be separated by physical barriers such as steel walls. The system also includes a central control unit 3 located on the ship and connected to the detection units. Communication between the detection units and control unit may be by powerline communication or by another wired form of communication, which will prevent interruption to wireless connection onboard a vessel from effecting the performance of the detection system. Connection between the processing units and the central control unit may be via one or more other units or may be direct.

Each processing unit may comprise at least one sensor 5 configured to detect a signal emitted as the result of an emergency situation. The signal may be a sound emitted by an alarm such as a smoke alarm or an alarm detecting a leak, engine malfunction, man overboard, excess carbon dioxide, a general alarm, and so on. The sensor in such a case may be a microphone or may comprise a microphone. The sensor may also be configured to detect electric current flowing through a wire coupled to the alarm, such as by induction. The processing unit may also comprise a software module, a communication module, and the appropriate hardware to support the desired software and functionality. The processing unit is itself configured to detect signals such as sound waves in the immediate vicinity of the unit, or in a remote location in embodiments, and to analyse these signals in order to determine whether these are to be classified as alarm signals or as ambient signals. This process uses machine learning capabilities to enable the functionality of the software to improve over time as is described in more detail below. The detection unit is also configured to select and activate an action profile associated with the alarm signal if a detected signal is classified as an alarm signal. In figure 1, the system includes powerline connections between units. Wireless connections may be used as well or instead, as mentioned above.

Figure 2 illustrates the process of associating a particular alarm sound with an activation profile. The sound is detected by the sensor and identified by the software as relating to alarm class data and potentially as relating to a particular event, alarm or type of alarm. Detail of one way in which machine learning software can be trained to recognise a signal corresponding to an alarm is provided herein, but it is possible in some cases to use a simple fingerprint of the sound using predefined parameters such as the amplitude, frequency, and so on of the sound waves present in the signal can be used to recognise the sound using a pre-defined set of rules and/or thresholds if machine learning capabilities are not available for any reason. The sound recognised by the processing software is linked to an activation profile which includes or is linked to various actions that should be performed by the system in the event that the alarm sound is detected. The activation profile linked to a particular alarm or alarm type and to a particular action is then saved as part of a database of activation profiles to be installed on (or already created on) the relevant processing unit.

Activation profiles will depend on the alarms or events which need to be detected by a particular processing unit and will thus vary depending on location of the unit on the ship or in the building. In figure 3 it is illustrated how activation profiles may be linked specifically to a type of alarm and activated on detection of a signal from that particular alarm type. In this case the processing unit is configured with a microphone as a sensor to detect the sound of an active alarm as the alarm data. Separate activation profiles are associated with each of a general alarm, a fire alarm, and a man overboard alarm. Different activation profiles may be associated with emergency alarms in general and with other types of alarm (those which indicate a change in environment such as a rise in temperature above a particular level, for example). In some circumstances, the activation profiles may also be stored on the central unit as well as or instead of being stored on the separate processing unit or units, and information regarding the detection of an alarm sent to the central unit for matching with an activation profile which is then activated.

Where the system uses a microphone as the sensor in order to detect alarm sounds, different alarms may emit sounds at different frequencies/pitches and amplitudes which will then be detected by the microphone and input to the software of the processing unit for analysis. Notes may also alternate or switch on and off at a different rate. The sounds emitted by alarms are usually designed to be distinguishable so that a person in the vicinity is able to determine quickly which type of alarm has been set off and can react accordingly. Without additional software or circuitry, though, a person may be incapable of determining quickly what the specific emergency situation is and what is the most appropriate action to take in order to avert this. The processing units of the alarm detection system described herein are capable of analysing sounds in order to pick out those associated with a particular alarm. As described in more detail below, the processing unit itself includes the processing capability and required information to determine that an alarm has been activated and to access an activation profile associated with that particular alarm. Select information required by crew members can then be sent to the central control unit and relayed to the crew.

The microphone or other sensor may be located some distance away from the rest of the processing unit or may be within the same housing. Microphones can be connected wirelessly to the processing units, but a wired connection between and/or collocation of the sensor and processing software will be more effective in particular where wireless connection may not be completely reliable. The remote processing unit also comprises a chip supporting the processing software, usually with machine learning capability, which can carry out the analysis of signals from the microphone or other sensor and which can associate these with a particular alarm. A suitable chip to use for this purpose is a Coral chip with support for TensorFlow Lite^{RTM} (a framework for machine learning provided by Google^{RTM}) or Jetson platform from NVIDIA with support for all popular machine learning frameworks.

In some embodiments the software will be configured to access an activation profile associated with the triggering of a particular alarm, and in response may forward only select information included in the activation profile, by wired or wireless connection, to the control unit and/or to another location. The select information may consist only of an action to be taken by a particular crew member or may additionally comprise some information about the situation, such as location of the triggered alarm and the type of alarm. Alternatively, information about immediate actions to be taken by various crew members may be forwarded initially, and additional information can be sent at a later stage once the emergency situation has been dealt with. This way information overload is avoided, and the amount of data required to be transported over the network initially is reduced.

Much of the processing in this type of system may be distributed in that it takes place at the separate processing units which are each located in the vicinity of at least one alarm. Only minimal information needs to be transmitted subsequently to enable the required actions to be taken. Where wired connection is provided between the processing unit or units and the central unit, the system also does not rely on transmission by wireless means. This can be of paramount importance on a seafaring vessel where wireless data transport may be available only intermittently.

The processing chips present in each of the processing units 1 may include software which has machine learning capabilities. Software determined models take signal data from the sensor as input and use various parameters associated with the data to classify a section of data taken over a time period, such as a time period of between 0.1 and 60 seconds, preferably between 0.1 seconds and 30 seconds, preferably between 0.5 seconds and 2 seconds, and most preferably over a period of around 1 second. In its simplest form, the model may classify data in a binary manner as either ambient data or alarm data. In such a case the particular remote processing unit may be located in the vicinity of only one alarm so that the ability to distinguish between different alarms may not be required. Data may be analysed continuously or periodically, for example by analysing a sample of data (a section of data taken over a particular time period as described above) every 5 to 20 seconds, preferably around every 10 seconds.

The model will initially be trained either by activating the alarm or using recorded data representing the alarm (a recording of the alarm sound, for example). The training data has already been labelled as either alarm or ambient data. The model then determines using the training data which are the most effective parameters to use to classify the data and if applicable which thresholds should be applied to these parameters. A validation step may follow, in which test data is used to check that the model is functioning as expected or to determine the error in the model's performance. The model may be trained in place using training data from the environment in which the associated remote processing unit is to be located. This is preferable and is particularly useful where the system is to be used on a marine vessel, as it ensures that ambient noises in the vicinity of the unit are taken into account during the training phase.

The model can be trained prior to installation on the remote processing unit hardware or may be trained when it is already installed. If trained prior to installation, a computer such as a general PC may be used to train the model and training data may be pre-recorded at the alarm location. The training data may otherwise be associated and provided with an alarm in which case ambient data at the specific location may not be available but generic ambient data can be used for training. A PC will generally have more processing power than is available on the remote processing units and so may be more effective during the training phase. The PC may include graphics processors (for example two standard graphics cards) which may be used to process the input test data. Graphics processors are well optimised to perform the functions required for solving algorithms and training a model such as those described herein.

Once the trained model is in place as software on the chip, the remote processing unit can begin processing incoming data from the sensor either continuously or periodically to determine whether alarm data is detected.

If only ambient data is detected, then it may be that no further action is taken. In such a case ambient noise data, which may include voice data, will not be stored on the processing unit and will not be transferred by the processing unit to another location. This way data relating to conversations on board the vessel, which may be private, is not available at a later date and cannot be misused. If, on the other hand, alarm data is detected then an activation profile associated with the alarm data may be accessed. This will include information for transmission to the control unit or to other devices or will specify actions to be taken in order to mitigate the situation. If alarm data is detected, then this can result in an activation profile associated with the detected alarm data being accessed. Several activation profiles may be present and associated with different alarms which can be distinguished by the model. Accessing the activation profile may cause specific actions specified in the profile to be taken as set out in more detail below.

Figure 4 illustrates the overall process in a situation where a model is installed on the processing units after it has been trained and where data is forwarded to a central control unit as a result of profile activation. Data for different alarms may be distinguished by the processing software (this is not shown in the flow chart) in which case the activation profile will be specific to the particular alarm data detected.

In a more complex situation where more than one alarm is present and detectable by the sensor in the processing unit, the model can be trained to distinguish between different alarms. The training step, validation step, and the subsequent monitoring steps will be similar in this case except that training data is classified into more than two groups and data from the sensor is consequently also classified into more than two groups by the model corresponding to ambient data, data associated with alarm 1, data associated with alarm 2, and so on. Alternatively, once data for a particular time period has been identified as alarm data the model classifies the alarm data into data associated with each of the different alarms.

An activation profile associated with an alarm may not be accessed until data for two or more consecutive time periods has been identified as alarm class data for a particular alarm in order to avoid false detections. Where two alarms are present, the model may also be trained to detect activation of both alarms together which will result in a different pattern of noise or signal data being forwarded by the sensor. This may be associated with its own activation profile.

Training of the model on each of the processing units can continue once the software is installed thereon. Data detected by the sensor may be recorded and classified (either manually or automatically) for use as training data. For example, if a drill is to take place during a known time period then data detected during this period can be classified as alarm data and used as training data for the model. Likewise, ambient data in periods where it is known that an alarm was not triggered can be classified as ambient data and used as training data for the model. The model can be trained in-situ on the processing unit using processing means available thereon. The processing unit may be equipped with one or more graphics cards or other processing means for this purpose. Some units, such as the Coral chip mentioned above, do not generally require additional graphics cards or computation units in order to perform the required training operations. It is preferred that units represent embedded power saving devices, generally with battery back-up, rather than the more powerful computing unit required to support additional graphics cards and the like. Training data will relate to a specific location and a specific sensor associated with each processing unit, and the model is slowly over time tailored more and more to its particular location and use. Training may take place only during a drill or as part of a maintenance operation. In the latter case, which will generally occur when the ship is in port, the model may again be trained on a PC with associated graphics cards before being reinstalled on the processing unit as an updated version of the model.

On a ship in particular there will often be additional background sounds such as talking, banging of equipment, and so on, which will increase the noise level in the data. Preferably training data should include similar ambient sounds in order to better train the software for the specific environment of each processing unit. The performance of these units can then be tailored for a particular vessel, and for a particular location on the vessel, and performance will improve over time. The models located as software on each chip in a non-distributed or distributed system can be trained using both ambient data and data recorded during an alarm event to distinguish between the two. As the amount of training data increases over time, the model can be updated periodically by undergoing further training using the additional data available. It may be that a user is required to enter information after an alarm event in order to complete the training data set.

By recording every single alarm locally to the software and linking that particular alarm sound to the action required, a solution requiring minimal processing and transfer of data is provided in a system which can be adapted to each specific environment. The risk of failure of the system to identify a sound is minimal, and this would require a failure of the hardware on the source side or from the sensor. Back-up sensors such as back-up microphones can be included in order to mitigate for failure of the main sensor. As mentioned, sensors may be of various different types. Microphones as sensors will be a good choice, given that alarms are generally designed to emit a loud sound which can be easily detected by a microphone. Other sensors can, however, be used. Light sensors can detect flashing lights which may be associated with an alarm being activated, and motion detectors may be able to detect vibrations caused by the alarm being activated. More than one type of sensor can be included on each processing unit to provide some redundancy. In such a case an activation profile can be activated if data from one of the sensors is considered by the processing software to correspond to alarm data. As an alternative, data from both sensors can be required to be classified as alarm data before an activation profile will be activated.

The software linked to a processing unit may start automatically during an emergency situation onboard a vessel. This may be in response to activation of a central alarm or activation of the system itself by a user, for example by pressing a button on the bridge or on a mobile unit carried by a crew member. If many processing units are present in a distributed system, different alarms all around the ship will then begin to be monitored and where an alarm has been activated and this will be recognised by the processing unit nearest to that alarm. This will cause information about necessary actions or identifying the issue to be passed to the central unit. Information may also automatically be passed by the central control unit, or in some cases directly from the processing unit, to the crew member who has activated the alarm or system.

As mentioned, it is preferable that once alarm data is detected at one of the processing units, information specified in the activation profile is sent by wired communication to the central control unit. This is important particularly in cases where wireless communication may not always be reliable, however it is possible to send the necessary signals between units via wireless means (via RF communication, for example). Powerline communication systems may connect each of the processing units with the central control unit. Processing units may comprise or may form part of nodes that plug into electric sockets located in different rooms or areas of a building or vessel, thus utilising the already existing powerlines to provide reliable data transfer in an emergency situation. More than one powerline may connect each processing unit with the central control unit in order to ensure that data can be transferred even when one of the powerlines is damaged, for example by a fire. The one or more powerlines may provide the only means of data transfer between the processing unit and the central control unit or additional means, such as wireless means, may be provided alongside these.

Actions linked to particular alarm sounds in the activation profiles stored on each processing unit may be automatically executed once the activation profile is activated/accessed. In one embodiment, one of the actions carried out once the activation profile is accessed may comprise the switching on/activation of a crew monitoring system.

The crew monitoring system may work by way of radio tags on mobile units which are carried by each crew member and/or passenger and which communicate with nodes to track the position of personnel onboard a vessel, preferably via radio communication. The mobile units may be capable of processing various sensor data which may inform as to whether a passenger has fallen overboard or is ill, for example, and such information can also be sent to the local node. Local nodes are coupled to a central control system, possibly by way of wired communication. Such systems are particularly critical during an emergency situation and may only be activated as an action performed by the alarm detection system when an alarm is detected. Monitoring systems may be activated only for one or more nodes in the vicinity of the alarm that has been triggered. This helps to save power in a normal situation and ensures that the required information is available in an emergency.

The nodes coupled to or including the processing units of the alarm detection system may be the same as the nodes which communicate with radio tags to collect data about the whereabouts of crew members on a vessel and may be located within the same housing. These multifunctional nodes may be plugged into the existing powerline system onboard the vessel at power sockets. The powerline communication system from the nodes to the central controller can then be used to transfer any data specified in the activation profile for the detected alarm as well as data used to track crew members or sensor data from crew mobile units (or the activation profile may specify that such data should be sent and/or stored). Where nodes each comprise processing means to determine when an alarm has been activated and to access an associated activation profile as well as means to communicate with mobile units carried by crew members, it may be that only the node by which an alarm has been identified is activated to locate crew members and send position or sensor data back to the central control. In another example all nodes on board the ship are activated to receive data relating at least to crew positions, and to send this back to the central control if any of the nodes detect alarm class data.

On board a ship the most important alarms, which will typically all be present, are fire alarms, man overboard (MOB) alarms, and general alarms. The detection of the activation of any of these alarms by the alarm detection system may trigger the activation of the crew monitoring system. Each of these alarms, in addition, may result in a different activation profile being accessed wherein the crew are given different roles or are instructed to perform different actions, or wherein monitoring of crew in a specific area of the ship (such as an area close to the activated alarm or likely to be most affected by the source of the alarm) is given priority. A different subsection of the crew or area of the vessel may also be monitored depending on the type of alarm that has been triggered or the whereabouts of that alarm. Information may be sent to and displayed on display devices carried by specific crew members, such as the captain or officers on duty who need to be alerted. This may be achieved by wireless or wired transmission from the central control unit or by wireless or wired transmission directly from the processing unit to the crew member. This may be, for example, to a mobile unit carried by the crew member or to a PC or display device to which they have access. The central control unit will generally be located on the bridge in order that it is easily accessible by senior ranking crew members at all times.

A number of variations of the above described embodiments can be envisaged. For instance, an engine that malfunctions in a manner that cannot be detected by other sensors within the engine may produce a particular sound. This sound can be detected by a sensor (such as a microphone) of one of the processing units of the alarm detection system and then be recognised as alarm class data by the system. Crew members can then be alerted, and the appropriate action can be taken sufficiently quickly. The processing units can be configured to process signals in a similar manner from one or more of a number of sensors such as accelerometers, lights sensors, gas sensors, thermometers, pressure sensors, and so on. Data can be processed at the processing unit and an indication sent to the main control unit only when the data is classified as unusual (alarm class data). Unusual data may correspond to a high level of a particular gas, a particularly high or low pressure, a high temperature, and so on.

The classification into normal or unusual/abnormal data (ambient or alarm class data) can be carried out by machine learning software in this case as for the alarm detection described above. The same hardware and software can be used to recognise particular trigger words or strings of words such as the word “help” which may trigger an indication to be sent to the control unit. A microphone in this case is used as the sensor and the machine learning software is trained to classify sound data into normal speech and abnormal speech (when the word “help” or another trigger word is recognised). The trigger word may be required to be spoken at above a particular amplitude in order to be classified as abnormal.

How the data is classified by the model on each of the processing units of the system will obviously depend on the training data used in the training step, which makes the whole system extremely flexible. Processing units in different areas of the ship can be trained to classify data in different ways to perform different functions.

In an example for use on a marine vessel, the system may include a detection unit located on the bridge (which represents a secure location in which alarm sounds are generally audible). The central control unit may be located on the bridge or in a separate area of the vessel, but it should be located in a place where crew members are able to respond to the information provided. Even if the crew members are able to hear the alarm themselves from the location of the control unit, it can take time to identify where the alarm has been sounded or to determine which alarm a particular sound corresponds to or what actions should be taken in response, so that the system helps to improve response times even in a situation where all units are collocated. As mentioned, simple processing is carried out at the processing unit and basic information provided to the central control to avoid the need for large amounts of data to be transferred. The system may include a sensor as part of a remote detection unit located in the engine room for monitoring the engine sound. If an unusual sound is detected by the remote detection unit then this is communicated to the central control unit.

The invention is particularly applicable to the maritime industry, such as on cruise ships, offshore vessels, and oil rigs, all of which face the same issues in terms of connectivity and the need for quick response times. It could, however, also be implemented in onshore infrastructures, where other types of alarm are used. The system can, for example, be used in a commercial or residential building with processing units located in different rooms and connected to a central control unit, potentially via powerline communication as described above. The system would then be able to function where no wireless communication is available.

Claims

1. An alarm detection system for a vessel comprising: two or more processing units (1) to be located in different areas of the vessel, each processing unit being configured to detect one or more of sound, motion, electrical, and visual data, and each comprising machine learning software configured to accept the data as input and to classify the data as ambient class or alarm class data; characterized in that the system comprises a central control unit (3) coupled to the two or more processing units (1), and the processing units are each configured to send an indication to the central control unit (3) when alarm class data is detected by that processing unit, wherein at least one activation profile specifying an action is stored on each processing unit and is associated with the or each alarm class data, wherein the system is configured to access the activation profile when the software detects the alarm class data thus causing the action to be performed, and wherein the action comprises sending select information, specified as part of the activation profile, from that processing unit to the central control unit (3).

2. The alarm detection system of claim 1, wherein the central control unit (3) comprises a user interface and is configured to communicate the indication to a user via the user interface.

3. The alarm detection system of any of claims 1 and 2, wherein the two or more processing units (1) comprise a processor and one or more sensors (5) for detecting the one or more of sound, motion, electrical, and visual data, and wherein the one or more sensors are connected to the processor (1) via wired or wireless communication means.

4. The alarm detection system of any of claims 1 to 3, wherein the central control unit (3) is coupled to each of the two or more processing units (1) via wired connection and the indication is sent via the wired connection.

5. The alarm detection system of claim 4, wherein the wired connection uses one or more powerlines to send the indication.

6. The alarm detection system of claim 5, wherein the processing units (1) are included within nodes plugged into an existing powerline system.

7. The alarm detection system of any of claims 1 to 6, wherein the action specified is to begin recording sensor data received at the processing unit (1).

8. The alarm detection system of claim 7, wherein in response to a subsequent detection of ambient data by the software of the processing unit (1), the processing unit stops recording sensor data.

9. The alarm detection system of any of claims 1 to 8, wherein the action comprises activation of a remote crew monitoring system.

10. The alarm detection system of claim 9, wherein the remote crew monitoring system comprises nodes configured to communicate via radio communication with mobile units to be carried by crew members and with a central control unit, and wherein processing units are included in the same housing as the nodes of the remote crew monitoring system.

11. A method for monitoring an alarm system on board a vessel, the method comprising: detecting, with each of two or more processing units (1) located in different areas of the vessel, one or more of sound, motion, electrical, and visual data; passing the data as input to machine learning software stored on that processing unit and configured to classify the data as ambient class or alarm class data; characterized in that the method comprises sending, by each of the two or more processing units (1), an indication to a central control unit (3) when alarm class data is detected by that processing unit; and accessing, by each of the two or more processing units (1), an activation profile specifying an action thus causing the action to be performed when alarm class data is detected by that processing unit, wherein the action comprises sending select information, specified as part of the activation profile, from that processing unit to the central control unit (3).

12. A method according to claim 11, comprising, prior to detecting the data, training a model of the machine learning software to classify the data using training data.

13. A method according to any of claim 12, comprising the step of validating the model using test data subsequent to training the model.

Patentkrav

1. Et alarmdeteksjonssystem for et fartøy som omfatter:
to eller flere prosesseringsenheter (1) som befinner seg i forskjellige områder av fartøyet, der hver prosesseringsenhet er konfigurert for å detektere én eller flere av lydbasert, bevegelsesbasert, elektrisk og visuell data, og der hver omfatter programvare for maskinlæring konfigurert for å godta dataen som inndata og å klassifisere dataen som omgivelsesklassifisert eller alarmklassifisert data;
karakterisert ved at systemet omfatter en sentral kontrollenhet (3) koblet til de to eller flere prosesseringsenhetene (1), og hver av prosesseringsenhetene er konfigurert for å sende en indikasjon til den sentrale kontrollenheten (3) når alarmklassifisert data blir detektert av denne prosesseringsenheten, hvori minst én aktiveringsprofil som spesifiserer en handling er lagret på hver prosesseringsenhet og er tilknyttet til den alarmklassifiserte dataen eller hver alarmklassifiserte data, hvori systemet er konfigurert for å få tilgang til aktiveringsprofilen når programvaren detekterer den alarmklassifiserte dataen, noe som medfører at handlingen blir utført, og hvori handlingen omfatter å sende utvalgt informasjon, spesifisert som en del av aktiveringsprofilen, fra denne prosesseringsenheten til den sentrale kontrollenheten (3).

2. Alarmdeteksjonssystemet ifølge krav 1, hvori den sentrale kontrollenheten (3) omfatter et brukergrensesnitt og er konfigurert for å kommunisere indikasjonen til en bruker via brukergrensesnittet.

3. Alarmdeteksjonssystemet ifølge et hvilket som helst av kravene 1 eller 2, hvori de to eller flere prosesseringsenhetene (1) omfatter en prosessor og én eller flere sensorer (5) for å detektere den ene eller flere av lydbasert, bevegelsesbasert, elektrisk og visuell data, og hvori den ene eller flere sensorene er koblet til prosessoren (1) via kablede eller trådløse kommunikasjonsmidler.

4. Alarmdeteksjonssystemet ifølge et hvilket som helst av kravene 1 til 3, hvori den sentrale kontrollenheten (3) er koblet til hver av de to eller flere prosesseringsenhetene (1) via en kablet tilkobling og indikasjonen blir sendt via den trådede tilkoblingen.

5. Alarmdeteksjonssystemet ifølge krav 4, hvori den kablede tilkoblingen anvender én eller flere elektriske ledninger for å sende indikasjonen.

6. Alarmdeteksjonssystemet ifølge krav 5, hvori prosesseringsenhetene (1) er omfattet inni noder plugget inn i et eksisterende elektrisk ledningssystem.

7. Alarmdeteksjonssystemet ifølge et hvilket som helst av kravene 1 til 6, hvori den spesifiserte handlingen er å starte registrering av sensordata mottat ved prosesseringsenheten (1).

8. Alarmdeteksjonssystemet ifølge krav 7, hvori som respons til en påfølgende deteksjon av omgivelsesdata av programvaren til prosesseringsenheten (1), stanser prosesseringsenheten registrering av sensordata.

9. Alarmdeteksjonssystemet ifølge et hvilket som helst av kravene 1 til 8, hvori handlingen omfatter aktivering av et fjernstyrt mannskapsovervåkingssystem.

10. Alarmdeteksjonssystemet ifølge krav 9, hvori det fjernstyrte mannskapsovervåkingssystemet omfatter noder konfigurert for å kommunisere via radiokommunikasjon med mobilenheter som bæres av mannskap og med en sentral kontrollenhet, og hvori prosesseringsenheter er inkludert i det samme huset som nodene til det fjernstyrte mannskapsovervåkingssystemet.

11. En fremgangsmåte for overvåking av et alarmsystem ombord et fartøy, der fremgangsmåten omfatter å: detektere, med hver av to eller flere prosesseringsenheter (1) som befinner seg i forskjellige områder av fartøyet, én eller flere av lydbasert, bevegelsesbasert, elektrisk og visuell data; videresende dataen som inndata til programvare for maskinlæring lagret på denne prosesseringsenheten og konfigurert for å klassifisere dataen som omgivelsesklassifisert eller alarmklassifisert data; karakterisert ved at fremgangsmåten omfatter å sende, gjennom hver av de to eller flere prosesseringsenhetene (1), en indikasjon til en sentral kontrollenhet (3) når alarmklassifisert data er detektert av denne prosesseringsenheten; og å få tilgang til, gjennom hver av de to eller flere prosesseringsenhetene (1), en aktiveringsprofil som spesifiserer en handling som dermed medfører at handlingen blir utført når alarmklassifisert data er detektert av denne

prosesseringsenheten, hvori handlingen omfatter å sende utvalgt informasjon, spesifisert som en del av aktiveringsprofilen, fra denne prosesseringsenheten til den sentrale kontrollenheten (3).

12. En fremgangsmåte ifølge krav 11, som omfatter, i forkant av deteksjon av dataen, å lære opp en modell av programvaren for maskinlæring til å klassifisere dataen gjennom anvendelse av opplæringsdata.

13. En fremgangsmåte ifølge et hvilket som helst av krav 12, som omfatter trinnet med å validere modellen ved å anvende testdata etter opplæring av modellen.

Figure 1

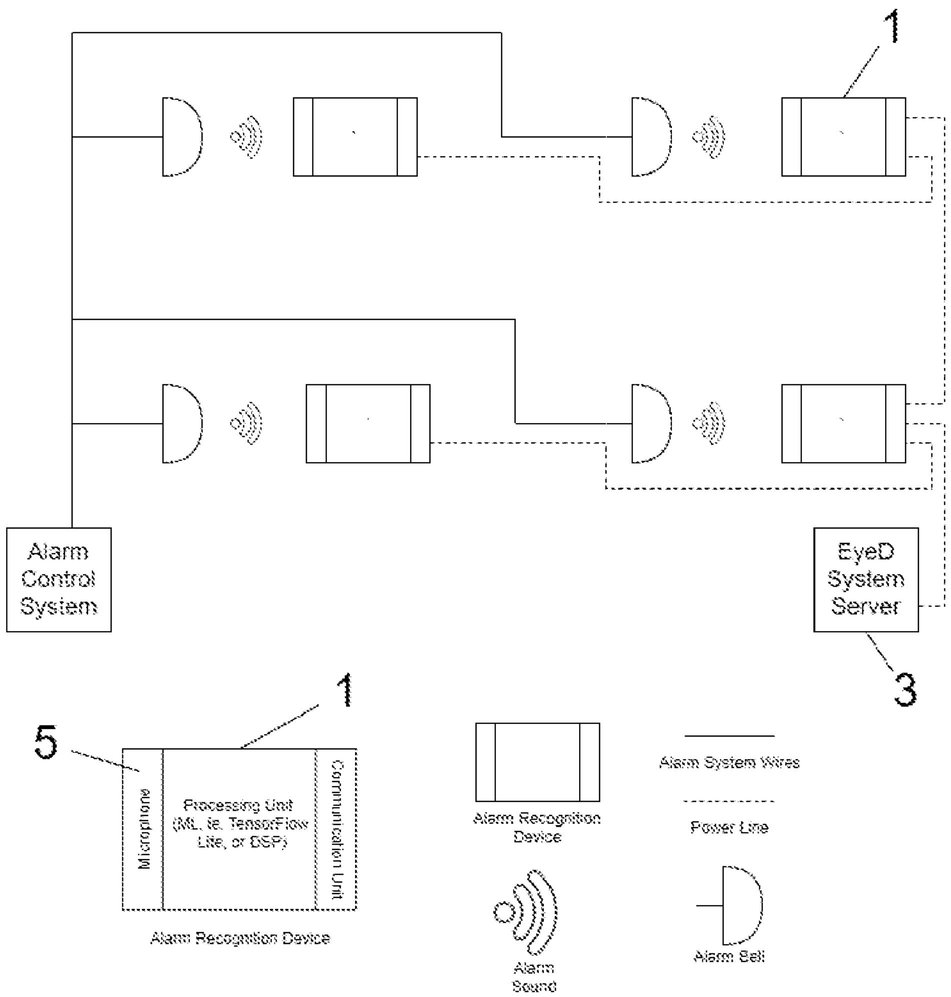


Figure 2

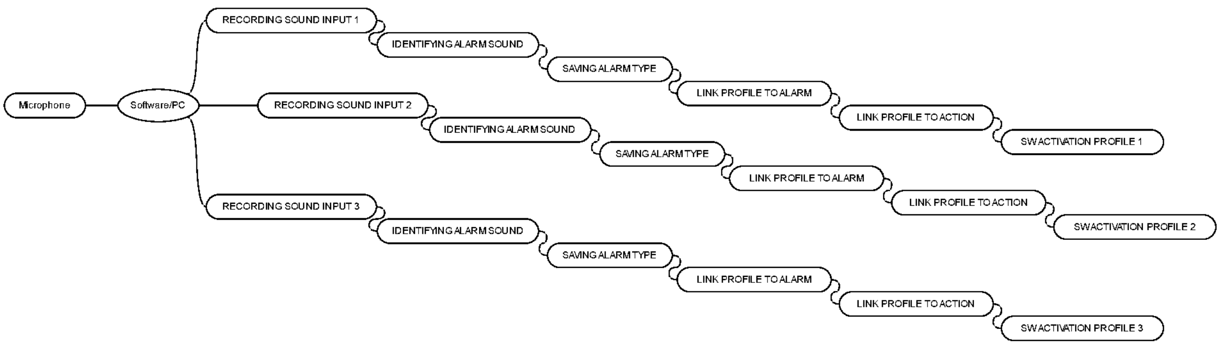


Figure 3

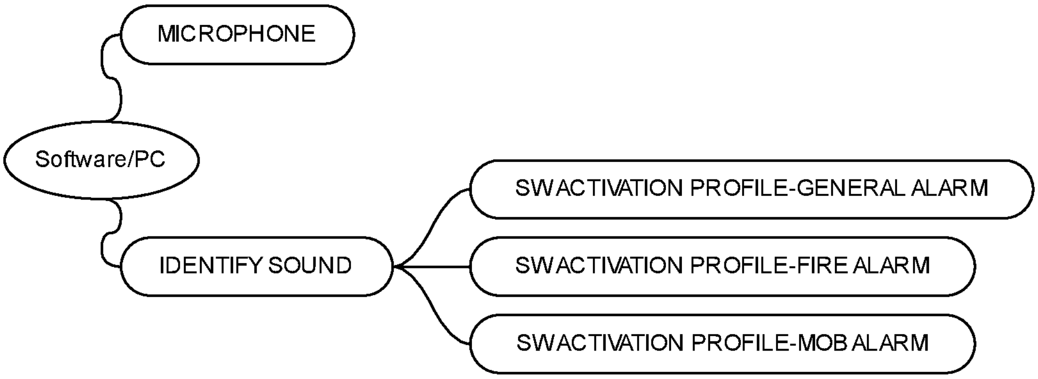


Figure 4