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(71) Applicant: **Eldor Communication Technologies Ltd**
48091 Rosh Haain (IL)

(72) Inventor: **Offry, Alon**
40300 Kfar Yona (IL)

(74) Representative: **Modiano, Micaela Nadia**
Modiano Josif Pisanty & Staub Ltd
Thierschstrasse 11
80538 München (DE)

(54) A system and method for providing reliable collision hazard detection

(57) In accordance with an embodiment of the invention, there is provided a system for detecting a collision hazard at a predefined area along a railroad including, one or more conductive loops, one or more train detectors, railway control interface and a processing unit. The one or more inductive loops may be adapted to sense a presence of a potentially hazardous object within the predefined area of the railroad and may be adapted to provide information indicative of a progress of the potentially hazardous object through the predefined area or a lack thereof. The one or more train detectors may be adapted to indicate a train approaching the system. The railway control interface may be adapted to receive railway control information that is indicative of an approach by a train to the predefined area and/or that is indicative of a passage of a train through the predefined area. The processing unit may be adapted to process data received from the one or more inductive loops, from the one or more train detectors and from the railway control interface. The processing unit may be adapted to switch from a standby state to an alert state when it is determined that a potentially hazardous object is substantially immobile while within the predefined area; and the processing unit may be adapted to switch from the standby state or from the alert state to an alarm state when it is determined that while a train is approaching the predefined area or while a train is passing through the predefined area, there is a potentially hazardous object within the predefined area.

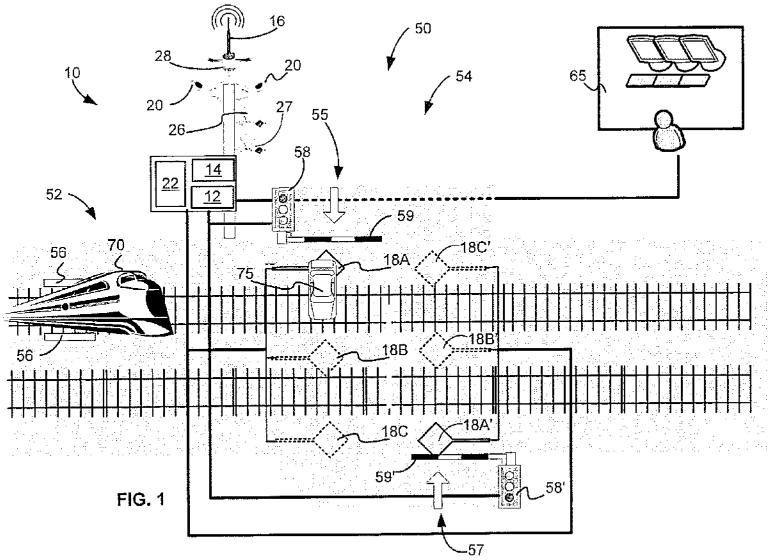

FIG. 1

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Description

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of US Provisional Application No. 61/006,384 filled on January 10, 2008,

FIELD OF THE INVENTION

[0002] The present invention is in the field of railroad/railway collision hazard detection.

BACKGROUND OF THE INVENTION

[0003] Trains have been in the service of mankind for nearly two centuries, Modern trains travel at relatively high speeds and are used to carry massive payloads over land. The speed of a train and its mass create a tremendous momentum and make it difficult to stop the motion of the train within a short distance. Therefore, if there is a significant obstacle in the path of a speeding train, it is crucial to take preventive or containment action well in advance of the train's approach to the obstacle.

[0004] Alongside the necessity to accurately detect any potential hazardous situation, collision hazard detection systems should also be able to avoid, as much as possible, false alarms. Electronic detection equipment may sometimes produce false alarms, for example, due to misleading conditions or incorrect analysis of reality. Trains and railways are an expensive and crucial resource in modern society, and unnecessary downtime should be avoided but not at the cost of risking collisions and accidents.

SUMMARY OF THE INVENTION

[0005] In accordance with an embodiment of the invention, there is provided a system for detecting a collision hazard at a predefined area along a railroad. According to some embodiments, the system may include:

- one or more inductive loops for sensing a presence of a potentially hazardous object within the predefined area of the railroad and for providing information indicative of a progress of the potentially hazardous object through the predefined area or a lack thereof;
- one or more train detectors adapted to indicate a train approaching the system;
- a railway control interface that is adapted to receive railway control information that is indicative of an approach by a train to the predefined area and/or that is indicative of a passage of a train through the predefined area
- a processing unit adapted to process data received from the one or more inductive loops, from the one or more train detectors and from the railway control interface,
- wherein the processing unit is adapted to switch from a standby state to an alert state when it is determined that a potentially hazardous object is substantially immobile while within the predefined area, and
- wherein the processing unit is adapted to switch from the standby state or from the alert state to an alarm state when it is determined that while a train is approaching the predefined area or while a train is passing through the predefined area, there is a potentially hazardous object within the predefined area.

[0006] In accordance with further embodiments, the processing unit may be adapted to switch to the alert state while there is no train approaching or passing through the predefined area and when a potentially hazardous object has failed to complete a crossing of the predefined area within a time duration that is more than a first time threshold, and wherein the processing unit may be adapted to switch to the alarm mode, when while a train is approaching or passing through the predefined area an indication is received that a potentially hazardous object is detected as being within the predefined area for a duration that is more than a second threshold, and wherein the second time threshold is substantially shorter than the first threshold.

[0007] In accordance with an embodiment of the invention, the processing unit may be responsive to receiving an indication from the train detectors that a train is in a vicinity of the system for entering an intermediate mode and for ignoring signals from the inductive loops while the system is in the intermediate mode.

[0008] In accordance with an embodiment of the invention, the system may include a plurality of inductive loops arranged in sequence and each one of the plurality of inductive loops may be adapted to sense a presence of a potentially hazardous object within a respective one of a plurality of successive sectors, and wherein the processing unit may be adapted to process data received from the plurality of inductive loops to determine presence of a potentially hazardous object within the predefined area and to determine a sector location of the potentially hazardous object within the predefined area, and wherein the processing unit may be further adapted to characterize progress or lack thereof of the potentially hazardous object through the predefined area based on a sector location of the potentially hazardous object over time.

[0009] In accordance with an embodiment of the invention, there is still further provided a system comprising a visible and/or non-visible light camera adapted to provide digital images of the predefined area, and wherein the processing unit may be adapted to determine, based on the digital images and based on information received from the inductive loops, whether a potentially hazardous object is located within the predefined area and/or the processing unit may be adapted to characterize, based on the digital images and based on information received from the inductive loops, a motion of a potentially hazardous object within the predefined area.

[0010] In accordance with an embodiment of the invention, the system may further include an imaging reliability indicator selector that is adapted to obtain data with respect to relevant imaging conditions within or around the predefined area and to generate an imaging reliability indication based on the imaging conditions, and wherein the processing unit may be adapted to factorize each of the inductive loops and the visible and/or non-visible light camera inputs based on the imaging reliability indication.

[0011] In accordance with an embodiment of the invention, the processing unit may be adapted to utilize geometric simulation to process, substantially in real-time, current and/or projected position of a potentially hazardous object that is located within or moving through the predefined area.

[0012] In accordance with an embodiment of the invention, the system may include a communication module that is connectable to a local railway control facility via a Wide Area Network and/or to a railway central control facility via Wide Area Network and/or to a train approaching the predefined area via a wireless communication infrastructure, and wherein the processing module may be adapted to utilize the communication module to communicate an alert upon switching to the alert state, and an alarm upon switching to the alarm state. In accordance with an embodiment of the invention, the communication module may be connected to the railway central control facility via a Wide Area Network. In accordance with an embodiment of the invention, the communication module may be connected to the train approaching the predefined area via a wireless communication network.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] In order to understand the invention and to see how it may be carried out in practice, embodiments will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

[0014] **FIG. 1** is a high level illustration of a system for detecting a collision hazard that is installed at a level-crossing where on one level a railway line and a road intersect, in accordance with some embodiments of the invention;

[0015] **FIG.2** is an exploded view of the system for detecting a collision hazard of **FIG. 1**; and

[0016] **FIG. 3** is a flowchart illustration of a method of detecting a collision hazard within a predefined area, according to some embodiments of the invention.

[0017] It will be appreciated that for simplicity and clarity of illustration, elements shown in the figures have not necessarily been drawn to scale. For example, the dimensions of some of the elements may be exaggerated relative to other elements for clarity. Further, where considered appropriate, reference numerals may be repeated among the figures to indicate corresponding or analogous elements.

DETAILED DESCRIPTION OF EMBODIMENTS

[0018] In the following detailed description, numerous specific details are set forth in order to provide a thorough understanding of the invention. However, it will be understood by those skilled in the art that the present invention may be practiced without these specific details. In other instances, well-known methods, procedures and components have not been described in detail so as not to obscure the present invention.

[0019] Some embodiments of the present invention relate to a system for detecting a collision hazard at a predefined area along a railroad. Throughout the description and the claims the terms "railroad" and "railway" and similar terms are used interchangeably and should be assigned with the same meaning. In **FIG. 1**, there is shown a system for detecting a collision hazard that is installed at a level-crossing where on one level a railway line and a road intersect, in accordance with some embodiments of the invention Similar hazard detection systems may be located at other level-crossing locations along the same or other railway lines or at other areas of interest along the railway, such as railway switches. In accordance with another example, several units of the system **10** may be installed at predefined intervals along the railway **52** or along a segment of the railway **52** to provide substantially full coverage of an extended area.

[0020] Additional reference is now made to **FIG. 2**, which is an exploded view of the system for detecting a collision hazard of **FIG. 1**. According to some embodiments of the invention, the system for detecting a collision hazard **10** may include a network interface card (NIC) **12** or some other network interface module to enable the hazard detection system to establish a data link with other facilities or systems. According to one example, the hazard detection system **10** may be connected to a remote location via a WAN network **41**. The system may also be connected to network infrastructure via a physical medium such as twisted-pair wires, optical cables, coaxial cables, etc and may use any suitable protocol (or protocol suite), such as TCP\IP for example, to communicate over the network. In addition to the wired connection infrastructure, the hazard detection system may be adapted to communicate wirelessly, for example, using RF communication **42** to transfer alarm/alert status and images to the train **70** driver. For example, one or more of the following wireless communication technologies may be used: WiFi wireless communication (WiFi 802.11x), WiMAX (Worldwide Interoperability for Microwave Access), MESH, 3G and future data cellular communication (a commonly used term relating to the third generation of wide area cellular telephone networks). The system **10** may include a wireless communication module **14** and an antenna **16** to facilitate the wireless communication.

[0021] As is shown in **FIG. 2** and according to some embodiments of the invention, the system for detecting a collision hazard **10** may be connected via the WAN network **41** to a railway central control facility **60**, The system **10** may be connected via a wireless infrastructure **42** installed along the railway, to a train 70 traveling along the railway **52**, According to some embodiments, the system **10** may be adapted to connect to any train that is within range of its wireless communication equipment. More specifically, the system **10** may be adapted to connect to a computer onboard a train **70**, such as the one used by an operator of the train to monitor and control the operation of the train **70**. According to further embodiments, the system **10** may be also connected to a local railway control station facility **65** and possibly also to additional control facilities which are associated with other areas of the railway **52.** Communication to and from the system **10** may be encrypted to avoid interception by non-addressees. It would be appreciated that the system **10** may include other communication equipment either in addition or as alternative to that which was described above, and that the system **10** may be adapted to use any currently know or yet to be devised in the future communication technology to communicate with the train **70**, the central control facility **60** or the local railway control station **65**.

[0022] The communication links may also be used to enable remote configuration, calibration maintenance, and control of the various components of the system **10**. For example, according to one embodiment of the invention, a setup of a routine and periodic recalibration sequence may be initiated and implemented with respect to the system **10** over a network link. The sequence may include, for example, resetting of imaging equipment unit (s) (described in greater detail below) imaging parameters and direction, resetting image analysis and processing procedures, reconfiguring storage devices. In addition, downloading/uploading of data such as system data and content such as video files, data stream from various other input devices may also take place. Logging or archiving data and content is a further activity which may involve utilizing a communication link with the system **10**.

[0023] According to some embodiments of the invention, the system **10** may include or may be associated with one or more inductive loops **18**, train detectors **20** and a processing unit **22**. The processing unit **22** may include a railway control interface **24** that is adapted to receive railway control information indicative of an approach by a train **70** to the predefined area **50** and/or that is indicative of a passage of a train **70** through the predefined area **50**. The inductive loops **18** may be adapted to sense a presence of a potentially hazardous object **75**, for example, a motorized vehicle, within the predefined area **50** with which the system **10** is associated. The inductive loops **18**, either independently or in cooperation with the processing unit **22** may be adapted to provide information indicative of a potentially hazardous object **75** entering or exiting the predefined area **50** or the presence of the object **75** within the predefined area **50.** The inductive loops **18** may also provide an indication with respect to a progress of the potentially hazardous object 75 through the predefined area **50** (or a lack of progress). The operation and the functionality of the inductive loops **18** shall be described in greater detail below. The train detector(s) **20** may be adapted to provide information indicative of a train **70** entering or being in a vicinity of the predefined area **50**. The processing unit **22** may be adapted to process data received from the inductive loop(s) **18** and to process data received from the train detector(s) **20**. The processing unit **22** may be configured to switch to different states according to the inputs from the inductive loop(s) **18**, from the train detector(s) **20** and from the railway control interface **24**. The processing unit **22** may be configured to take into account data from other sources as will be described in detail below.

[0024] It would be appreciated that the inductive loop (s) **18** are capable of detecting metal objects **75** or objects which include metal parts, such as vehicles of different sizes. Typically, when a vehicle **75** passes over an inductive loop, the loop's inductance changes and a readable signal which reflects the change can be obtained. By monitoring the loop's **18** inductance the processing unit **22** may be adapted to determine whether an object **75**, such as a vehicle, is in the loop's **18** vicinity. The processing unit **22** may also be adapted to determine whether the object **75** detected by the loop is in motion or is immobile. The processing unit **22** may also be adapted to use the signal from the inductive loops **18** to determine an object's **75** rate of progress. It would be appreciated that the inductive loop(s) **18** may be capable of detecting a range of metal object sizes and vehicles starting with motorcycles and up to larger vehicles such as busses or trucks.

[0025] According to some embodiments of the invention, the signal received from the inductive loop(s) **18** may be used to classify the detected object **75**. For example, the processing unit **22** may be adapted to process the signal received from the loops **18** to obtain a "footprint" pattern of an object **75** detected by the loop(s) **18**, and the processing unit **22** may classify the object **75** according to its footprint. For example, the processing unit **22** may classify the object as a sedan or as a truck based on the object's **75** footprint pattern which corresponds to the signal provided by the inductive loops in connection with that object **75**. The processing unit **22** may be adapted to associate a different set of attributes to different classes of objects and some of the system's **10** functions and operations may be adapted according to an object's **75** class. For example, if it is determined that the object is a bus or a truck special alarms and/or containment measures may be triggered in case of a collision hazard.

[0026] In addition to the inductive loop(s) **18**, the system **10** may also include a railway control interface **24** which is configured to receive an indication that a train **70** is approaching the predefined area **50**. Based on the information from the railway control interface **24**, the processing unit **22** may be adapted to determine whether a train **70** is approaching the predefined area or not. For example, as long as no indication is received through the railway control interface **24** that a train **70** is approaching the predefined area, the processing unit **22** may be configured to determine that there is no train that is currently approaching the predefined area. By way of non-limiting example, the source of the signal received through railway control interface may be based on a sensing system of the train signalization system or may be a manually induced signal, for example, generated by the operator of an upstream train station.

[0027] The railway control interface **24** may be connected to a railway signalization system (not shown). The railway control information may be used to determine whether or not a train **70** is approaching the predefined area **50**. According to further embodiments, the railway control interface **24** may be adapted to receive an indication that a train is approaching the predefined area **50** from other sources, for example, via a sensor that is adapted to detect that a barrier at a level crossing is being lowered (or is being elevated) or via a sensor that is adapted to detect that a signal light **58** is signaling that a train **70** is approaching the predefined area **50** (or not). According to some embodiments, the data received through the railway control interface **24** may enable prewarning and a significant reaction time in advance of the train's **70** arrival at the predefined area **50**, as will be described below.

[0028] According to some embodiments, the processing unit **22** is adapted to switch to the alert state when, while there is no train approaching or passing through the predefined area **50**, a potentially hazardous object **75** fails to complete a crossing of the predefined area **50** within a time duration that is more than a first time threshold. For example, in **FIG. 1** the processing unit **22** may be adapted to switch to the alert state when, while there is no train **70** (or any other) in the vicinity of predefined level-crossing **50** or that is approaching the level-crossing **50**, a potentially hazardous object **75**, e.g., a motorized vehicle, has failed to complete a crossing of the level-crossing **50** within a time duration that is more than a first time threshold.

[0029] It would be appreciated that an inductive loop **18** may be used to sense the presence or the vicinity of a vehicle, and when properly positioned within the predefined area **50**, the information provided by the inductive loop **18** may be used to determine the duration of the vehicle's presence within the predefined area **50**. According to some embodiments, the first trigger (threshold) that is used to invoke the alert state may be selected so that it represents total immobility or at least a very slow crossing of the level crossing **50**. By way of example, the first threshold may be in the order of several seconds to few tens of seconds. This threshold may be adjustable, for example, according to customer demand and/or safety regulations.

[0030] According to further embodiments, the processing unit **22** is adapted to switch to the alarm state when, while a train **70** is approaching or passing through the redefined area **50**, an indication is received that a potentially hazardous object **75** is detected as being within the predefined area **50** for a duration that is more than a second threshold, and wherein the second time threshold is substantially shorter than the first threshold. According to some embodiments of the invention, the second trigger (threshold) that is implemented by the processing unit **22** for triggering an alarm state may be relatively short, in order to enable the system **10** a short response time in case of' immediate danger, e.g., a vehicle is within a potential collision danger zone. In accordance with one example, the second threshold may be long enough to substantially eliminate false-positive detection. This threshold may be adjustable, for example, according to customer demand and/or safety regulations. It would be appreciated that an inductive loop **18** may be used to sense the entry of a vehicle (typically being at least partially metallic) into a potential collision danger zone. According to some embodiments of the invention, the alert state may be triggered substantially immediately upon detection of a potentially hazardous object **75** entering into the danger zone or area.

[0031] According to some embodiments, in addition to the railway control interface **24**, which is used to obtain information that a train is approaching the predefined area **50**, the system **10** may include its own train detector (s) **20**. The system's train detector **20** may be adapted to detect a train **70** when it is in the vicinity (i.e., within a relatively short distance) of the system **10.** For example, the train detector(s) **20** may be adapted to detect a train **70** from a distance of few tens of meters while the train **70** is traveling at various speeds. It would be appreciated that a train **70**, being a substantially large metal mass, when entering the vicinity of the system **10**, and particularly the vicinity of the inductive loop **18**, may trigger false alarms.

[0032] According to some embodiments, upon receiving an indication from the train detector **20** that a train **70** is within the vicinity of the system **10**, the signal from the inductive loop(s) **18** may be blocked or ignored by the system **10.** In one embodiment, the train **70** may be regarded as being in the vicinity of the system **10** as long as no indication to the contrary, i.e., that the train **70** had left the vicinity of the system **10**, is received from the train detector **20**. In a further embodiment, the train detector **20** only issues indications about the train's **70** vicinity to the system **10** and only while such vicinity exists. In this case, the train **70** may be regarded as being in the vicinity of the system **10** only during a period at which the vicinity indications are received (and once the indications stop, it is concluded that the train **70** is no longer in the vicinity of the system **10**). Normal operation of the inductive loops **18** is resumed.

[0033] However, according to further embodiments, when a train **70** is within the vicinity of the system **10** and during the intermediate mode, the system **10** may continue to operate in other respects, and may continue to monitor the predefined area, for example, using the imaging units which shall be described below. The system **10** may also continue recording events as captured by its sensors during the intermediate mode, for example, for purposes of *post mortem* investigation, training and/or as legal evidence.

[0034] According to some embodiments of the invention, the train eletector(s) **20** may include Infrared (IR) sensors **24**. The IR sensors **24** may be capable of detecting an IR signature of a train **70** while the train is within a certain distance from the predefined area **50**, for example, few tens of meters.

[0035] As in shown in **FIGs. 1** and **2** and according to some embodiments, the system **10** may be implemented with a plurality of inductive loops **18A-18C.** The plurality of inductive loops **18A-18C** may be arranged in sequence and each one of the plurality of inductive loops **18A-18C** is adapted to sense a presence of a potentially hazardous object **75** within a respective one of a plurality of successive sectors. The processing unit **22** is adapted to process data received from the plurality of inductive loops **18A-18C** to determine presence of a potentially hazardous object **75** within the predefined area **50** and to determine a sector location of the potentially hazardous object within the predefined area **50**. The reading of data may be synchronized across the plurality of inductive loops **18A-18E** The processing unit **22** may be further adapted to characterize progress or lack thereof of the potentially hazardous object **75** through the predefined area **50** based on a sector location of the potentially hazardous object **75** over time.

[0036] The reading of data or the processing of data from the inductive loops **18A-18C** may be synchronous. Synchronization among the inductive loops **18A-18C** may be used to overcome interference among the plurality of inductive loops **18A-18C**. In this respect, it would be appreciated that the inductive loops **18A-18C** may be installed in proximity to one another. When a vehicle travels over the loops **18A-18C** it can affect the electromagnetic field of two or more loops concurrently, depending on the relative size of the loops and the vehicle. Therefore, interference may occur. According to some embodiments, the processing unit **22** may be configured to multiplex the inputs from the various inductive loops **18A-18C**, such that the inputs from the loops **18A-18C** are processed one by one in a synchronized sequence, to thereby eliminate or substantially reduce effects of mutual interference of adjacent loops It would be appreciated, that multiplexing the inputs from the various inductive loops **18A-18C** may enhance the detection capabilities of the inductive loops **18A-18C.**

[0037] According to some embodiments, the processing unit **22** may be adapted to use the input from the sequential inductive loops **18A-18C** to more accurately position the potentially hazardous object **75** within the predefined area or to improve the reliability of the information provided by the inductive loops **18A-18C** (e.g., by cross referencing the information from several different inductive loops). According to further embodiments, the input from the sequential inductive loops **18A-18C** may provide a more detailed representation of the hazardous object **75** progress through the predefined area **50** or some portion thereof. Furthermore, it would be appreciated that a plurality of inductive loops may also be necessary in case that the predefined area **50** is characterized by multiple lanes and/or intersecting traffic (traffic which crosses the railway line) arriving from multiple directions.

[0038] As was mentioned above, the system for detecting a collision hazard **10** according to some embodiments of the invention includes one or more inductive loops **18** used for detecting a presence of a potentially hazardous object **75** and a progress of the potentially hazardous object **75** within the predefined area **50** or the lack thereof. According to some embodiments of the invention, the system for detecting a collision hazard 10 may further include a visible light imaging unit **27** and/or non-visible light imaging unit(s) **26**. The imaging unit(s) **26**, **27** may be adapted to provide digital images of the predefined area **50**. By way of example, the imaging unite (s) **26, 27** may be adapted to provide color images during the day and high sensitivity monochrome images at night. Further by way of example, the imaging unit(s) **26**, **27** may be adapted to generate Motion JPEG or MPEG images or RS 170 composite video stream or some other digital video output. The imaging unit(s) **26**, **27** may be weather resistant and be suitable for being operated outdoors. Still further by way of example, the imaging unit (s) **26**, **27** may be mounted on a motorized gimbal to enable pan and tilt of the imaging unit(s) **26**, **27** to adjust the image frame as desired. The motorized gimbal may be operated automatically (e.g., a wide scan may be routinely performed) and/or may be operated manually, for example, by a remote operator and possibly over a network connection. The imaging unit(s) **26** may also be adapted to zoom in and out and remote zooming may also be enabled (e.g., by a remote operator).

[0039] According to some embodiments, the imaging unit **26** may include a thermal imaging device operating in the infrared spectrum of the light For example, the imaging unit(s) **26** may include an uncooled microbolometric camera and a day/night CCD camera **27**. Alternative day/night imaging technologies may also be used. The cameras may be NTSC or PAL or may generate Motion JPEG or MPEG or some other digital video output. According to some embodiments, the signal received from the thermal imaging unit **26** may be adjusted (for example, by a controller of the imaging unit) and adapted for day and night operation. The thermal imaging unit **26** may also be calibrated from time to time including for day and night operation in order to substantially reduce the rate of false alarms. It would also be appreciated that, when properly calibrated, a thermal imaging unit is typically not significantly impacted by harsh light conditions during the day or by a reduction of light intensity during the night. Furthermore, a thermal imaging unit is typically also largely insensitive to harsh weather conditions which in other imaging technologies may lead to low visibility, shadows and light spots. Still further, thermal imaging technology can be used to overcome some of the potential false detection issues related to a misleading interpretation caused by vehicle headlights.

[0040] According to some embodiments, the output from the imaging unit(s) **26** may be fed to the processing unit **22** and possibly may also be stored on a local or remote hared drive (not shown) for backup and archiving. The processing unit **22** may be adapted to utilize geometric simulation to process, substantially in real-time, current and/or projected position of the potentially hazardous object **75.** The processing unit **22** may cross reference or otherwise process the data that is based on the inputs from the imaging unit(s) **26**, **27** and from the inductive loops **18** to determine the position and/or the movement of a hazardous object within the predefined area **50.** According to further embodiments of the invention, the processing unit **22** may be adapted to implement one or more processing steps with respect to input from each of the visible light camera 27, the thermal imaging unit **26** and possibly also the inductive loops **18** and the train detector **20**. According to yet a further embodiment of the invention, the processing unit **22** may be adapted to implement a combined processing step in which the inputs (or the processed inputs) from each of the visible light camera **27**, the thermal imaging unit **26** and possibly also the inductive loops **18** and the train detector **20** are used in the decision process logic. Based on the decision logic the processing unit **22** may draw some conclusion, for example, determine whether one or more conditions for switching to standby mode, alert mode or alarm mode are met An example of a processing algorithm which may be implemented by the processing unit **22** as part of the processing of the video feed or video stream from the imaging unit(s) **26**, **27** and possibly also of the inputs arriving from the inductive loops **18** shall be provided below.

[0041] According to some embodiments of the invention, the system for detecting a collision hazard **10** may further include a weather/visibility conditions sensor **28**. The weather/visibility conditions sensor **28** may be adapted to sense various weather and/or visibility related parameters. Further by way of example, the weather/visibility conditions sensor **28** may be adapted to sense visibility effecting conditions such as fog, dust and low visibility (such as during night) and may provide a signal which reflects the effect of such conditions on visibility. The input from the weather/visibility conditions sensor **28** may be used during processing, for example by the processing unit **22**, to determine if and/or how to use the inputs from the various sources. Thus for example, the input from the thermal imaging unit and the input from the inductive loops **18** may be used while the visible spectrum camera is ignored in case the weather/visibility conditions sensor **28** indicates that the current visibility conditions are poor. In accordance with further embodiments, the signal from the weather/visibility conditions sensor **28** may be used prior to the processing stage to pre-eliminate certain inputs which are less reliable during certain visibility conditions. For example, during low visibility conditions the input from the visible spectrum camera may be disregarded.

[0042] In some embodiments, the output from the imaging unit(s) **26**, **27** may also be provided to one or more of: the central control facility **60**, the local railway control station facility **65** and a computer onboard the train **70**, possibly in compressed form For example, MPEG 4 (or any other suitable format) video stream may be transmitted from the system **10** the central control facility **60.** The connectivity with each of the central control facility **60**, the local railway control station facility **65** and a computer onboard the train **70** was discussed above. The output from the imaging unit(s) **26**, **27** may be selectively distributed and routed, so that the addressee receives only information which is relevant to him/her at any specific time. Thus, for example, a train **70** operator may receive a video stream and/or alarm/alert indication only for one or more areas ahead of this specific train **70** and not the entire data for the entire railway. Furthermore, according to further embodiments, the system **10** may be adapted to take into account visibility conditions for selectively distributed, and possibly also for selectively archiving the output of the imaging unit(s) **26**, **27**. Thus, for example, in case while the signal from the weather/visibility conditions sensor **28** indicates that visibility is low, the system **10** may be adapted to remove the input from the visible spectrum camera **27** from the video stream (or any other data) that is transmitted to external subscribers of the system **10**, such as the central control facility **60**, the local railway control station facility **65** and a computer onboard the train **70.**

[0043] According to some embodiments of the invention, the system **10** may include or may be associated with user interface units which are adapted to issue an alert and/or an alarm indication according to the state determined by the processing unit **22**. The alert and/or the alarm indication may be acoustic, visual, physical or any other kind of indication which is suitable for capturing the attention of a person that is some way involved in the situation. In accordance with one example, the processing unit **22** may be connected, either directly or through the railway control interface **24** and through the railway signalization system to the signal light **58** or to the Stop/Slow Down signals along the railway line **52** and may use the signal light **58** and the other signals to indicate an alert and/or an alarm state or some measures which should be taken in connection with the alert and/or an alarm state. Further by way of example, in a similar manner, the processing unit **22** may be connected to a road barrier **59** which may be used to block the path of vehicles so that they are prevented from entering the level crossing. Still further by way of example, the processing unit

22 may be connected to a dedicated alarm/alert component, such as a loudspeaker and may issue the alert notice/alarm through the dedicated alarm/alert component.

[0044] The configuration of the system **10** described above is one example of a possible configuration of the system according to some embodiments of the invention. However, it will be readily appreciated by those ordinary skill in the art that the system may be otherwise configured to enable detection of a collision hazard at a predefined area along a railroad. For example, as is illustrated in **FIG. 1**, the system **10** may be adapted to monitor and to protect a two-lane level crossing **54**, and possibly also more complex level crossings where more than two lanes intersect. As is shown in **FIG. 1**, in addition to the inductive loops **18A-18C** which are adapted to sense a presence of a potentially hazardous object **75** within a first lane **55** of the level crossing **54**, the system **10** may also include a second set of one or more inductive loops **18A'-18C'** which are adapted to sense a presence of a potentially hazardous object **75** within a second lane **57** of the level crossing **54.** In addition, the system **10** may be operatively connected to the signal light **58'** and to the road barrier **59'** which are associated with the second lane **57.** The system **10** may interact with the signal light **58'** and the road barrier **59'** in a similar manner to that which was described above with reference to the signal light **58** and the road barrier **59** that are associated with the first lane **55**.

[0045] Further according to some embodiments of the invention, the system **10** may be adapted to use a common set of imaging equipment for monitoring both the first and the second lanes **55** and **57** of the level crossing **54.** For example, the field of view of the imaging equipment, and specifically of the visible light imaging unit **27** and/or the non-visible light imaging unit(s) **26** may be sufficient to cover the entire area of interest **50** and specifically both lanes **55** and **57** of the level crossing **54**. However, according to still further embodiments, additional imaging units may be included and deployed by the system **10** in order to completely and fully cover the predefined area **50**. The imaging units **26** and **27** may be installed on a single mast or pole, or the imaging units **26** and **27** may be installed on several different poles (not shown) in order to cover the entire predefined area and/or to provide different views of the predefined area **50**.

[0046] Having described in detail a system for detecting a collision hazard according to some embodiments of the invention, there is now provided a description of a data processing sequence which may be implemented as part of a method of detecting a collision hazard. The method for detecting a collision hazard may be implemented, for example, by the system described above. Reference is now made to **FIG.3,** which is a flowchart illustration of a method of detecting a collision hazard within a predefined area, according to some embodiments of the invention. For clarity, some elements to which reference is made in **FIG. 3**, that are related or are identical to elements in **FIGs.** 1 or 2 appear with the reference numerals of the corresponding elements in the previous Figures. In some embodiments, signals may be received from time to time or continuously from a visible spectrum video camera system **27** (block **302**) and from a thermal camera **26 (block 305).** The input from both the visible spectrum video camera and the thermal camera may relate to at least a portion of the predefined area.

[0047] The image data from the thermal camera is fed to a first stage detection process (**block 310**). At block **310** the image data input from the thermal camera is processed in order to detect a potentially hazardous object motion or immobility within the predefined area of interest. There are various known image processing and motion detection techniques which may be used for processing the input from the thermal camera.

[0048] In parallel to the motion detection process implemented on the thermal imaging sensor's output, the output of the thermal imaging camera and the output of the visible light camera may be input to a splitter and a switch **(block 314),** which may feed the input from each of the thermal imaging camera and the visible light camera to a second stage detection process. The second stage detection process may include both a motion detection process **(block 315)** and a non-motion detection process **(block 316).**

[0049] The splitter/switch may receive a further input from a weather/visibility sensor 28 **(block 303),** which provide an indication with respect to the visibility or weather conditions at the area of interest. As mentioned above, a weather/visibility sensor may provide a signal which reflects the effect of various conditions on visibility. The input from the weather/visibility conditions sensor may be used by the splitter/switch to determine how to switch the data from the thermal imaging camera and/or the visible light camera among the second stage motion detection process and the non-motion detection process. According to the logical input from the weather sensor at block 303 the video image can be used with the thermal image (or not).

[0050] The results of the first stage detection process and the second stage detection process are fed to a decision process logic (**blocks 320**). The decision process logic at block **320** may include cross checking the results of the first stage detection process and the second stage detection process in order to determine whether an object is detected and whether the object is (or is expected to become at a relevant time) a hazardous obstacle on the railway path. Geometric simulation was mentioned above as an example of' a technique which may be used to determine the possibility of a safety hazard scenario, however any other suitable processing technique may be used. The result of applying the decision process logic at **block 320** to the outputs from the first stage detection process and the second stage detection process is one of the inputs of an aggregate decision process (block 330) which shall be described below following the description of the other inputs.

[0051] In addition to the output from the decision process logic at **block 320,** the aggregate decision process at block **330** may further receive a signal from or related to inductive loops array 18 **(block 304).** The input from the inductive loops array may possibly undergo some processing stage (not shown). For example, as part of the inductive loops signal processing, it may be determined whether an object is detected as being within the predefined area or within a certain portion of the predefined area based on the inductive loops signal. The processing of the inductive loops signal may be used to determine whether a detected object is progressing through the predefined area or whether it is immobile. The processing of the inductive loops signal may also be used to determine which type of object this is (a private car or a large vehicle for instance) and the sector location of the object at a certain point in time. It would be appreciated that other information may also be achieved by processing the signal received from the inductive loops array. The processed signal may be input to the aggregate decision process **(block 330).**

[0052] In addition to the inputs related to the thermal imaging camera and the visible light camera and the input related to the inductive loops array, a further input may be received from the train detectors. For example, and as is shown in **FIG.3** the train detectors input may include input from the a train detector array **20 (block 306),** such as the IR sensor **24** that was described above and may also include input from a railway signalization system **(block 308)** with respect to approaching trains. The input from the railway signalization system may include a stop-light state indication and/or a barrier status (both relating to the relevant area). Predefined logic may be implemented in respect of the input from the train detectors and/or to the input from the railway signalization system **(block 322)** to provide to the aggregate decision process (block **330)** information relating to the location and/or progress of the train and possibly other information related to the strain.

[0053] According to some embodiments, the data related to each of the thermal camera, the visible spectrum camera, the inductive loops array, the train detectors and the railway signalization system may be fed to an aggregate decision process **(block 330).** In **FIG. 3,** and according to some embodiments, a single decision process may be implemented with respect to both the location of a potentially hazardous object and the train.

[0054] According to some embodiments, the aggregate decision process (**block 330**) may implement predefined rules and thresholds to determine, based on the inputs mentioned above, which system state should be selected (triggered or maintained). According to further embodiments, the state may be selected from amongst an alarm state, an alert state and a standby state. The result of the aggregate decision process **(block 330)** process may be reported to various subscribers of the system, such as the railroad signalization system and/or a station control system. The report may be issued routinely or when a certain status is triggered, for example, when the system changes its state. Certain results of the aggregate decision process (**block 330**) may also trigger alert, alarm and/or containment measures, such as audio or visual alerts or alarms

[0055] It would be appreciated that **FIG. 3** is merely and example of a decision process which may be implemented by the system according to some embodiments of the invention. For example, according to further embodiments, the system may be adapted to implement a decision process that is based on inputs from the inductive loop(s), the train detector(s) and data received from the railway signalization system through the railway control interface. Based on these inputs it may be determined which system state should be selected (triggered or maintained).

[0056] While certain features of the invention have been illustrated and described herein, many modifications, substitutions, changes, and equivalents will occur to those skilled in the art. It is therefore to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true scope of the invention.

Claims

1. A system for detecting a collision hazard at a predefined area along a railroad, the system comprising:

- one or more inductive loops for sensing a presence of a potentially hazardous object within the predefined area of the railroad and for providing information indicative of a progress of the potentially hazardous object through the predefined area or a lack thereof;
- one or more train detectors adapted to indicate a train approaching the system;
- a railway control interface that is adapted to receive railway control information that is indicative of an approach by a train to the predefined area and/or that is indicative of a passage of a train through the predefined area
- a processing unit adapted to process data received from the one or more inductive loops, from the one or more train detectors and from the railway control interface,
- wherein the processing unit is adapted to switch from a standby state to an alert state when it is determined that a potentially hazardous object is substantially immobile while within the predefined area, and
- wherein the processing unit is adapted to switch from the standby state or from the alert state to an alarm state when it is determined that while a train is approaching the predefined area or while a train is passing through the predefined area, there is a potentially hazardous object within the predefined area.

2. The system according to claim 1, wherein the processing unit is adapted to switch to the alert state while there is no train approaching or passing through the predefined area and when a potentially hazardous object has failed to complete a crossing of the predefined area within a time duration that is more than a first time threshold, and wherein the processing unit is adapted to switch to the alarm mode, when while a train is approaching or passing through the predefined area an indication is received that a potentially hazardous object is detected as being within the predefined area for a duration that is more than a second threshold, and wherein the second time threshold is substantially shorter than the first threshold.

3. The system according to claim 1, wherein the processing unit is responsive to receiving an indication from the train detectors that a train is in a vicinity of the system for entering an intermediate mode and for ignoring signals from the inductive loops while the system is in the intermediate mode.

4. The system according to claim 1, comprising a plurality of inductive loops arranged in sequence and each one of the plurality of' inductive loops is adapted to sense a presence of a potentially hazardous object within a respective one of a plurality of successive sectors, and wherein the processing unit is adapted to process data received from the plurality of inductive loops to determine presence of a potentially hazardous object within the predefined area and to determine a sector location of the potentially hazardous object within the predefined area, and wherein the processing unit is further adapted to characterize progress or lack thereof of the potentially hazardous object though the predefined area based on a sector location of the potentially hazardous object over time.

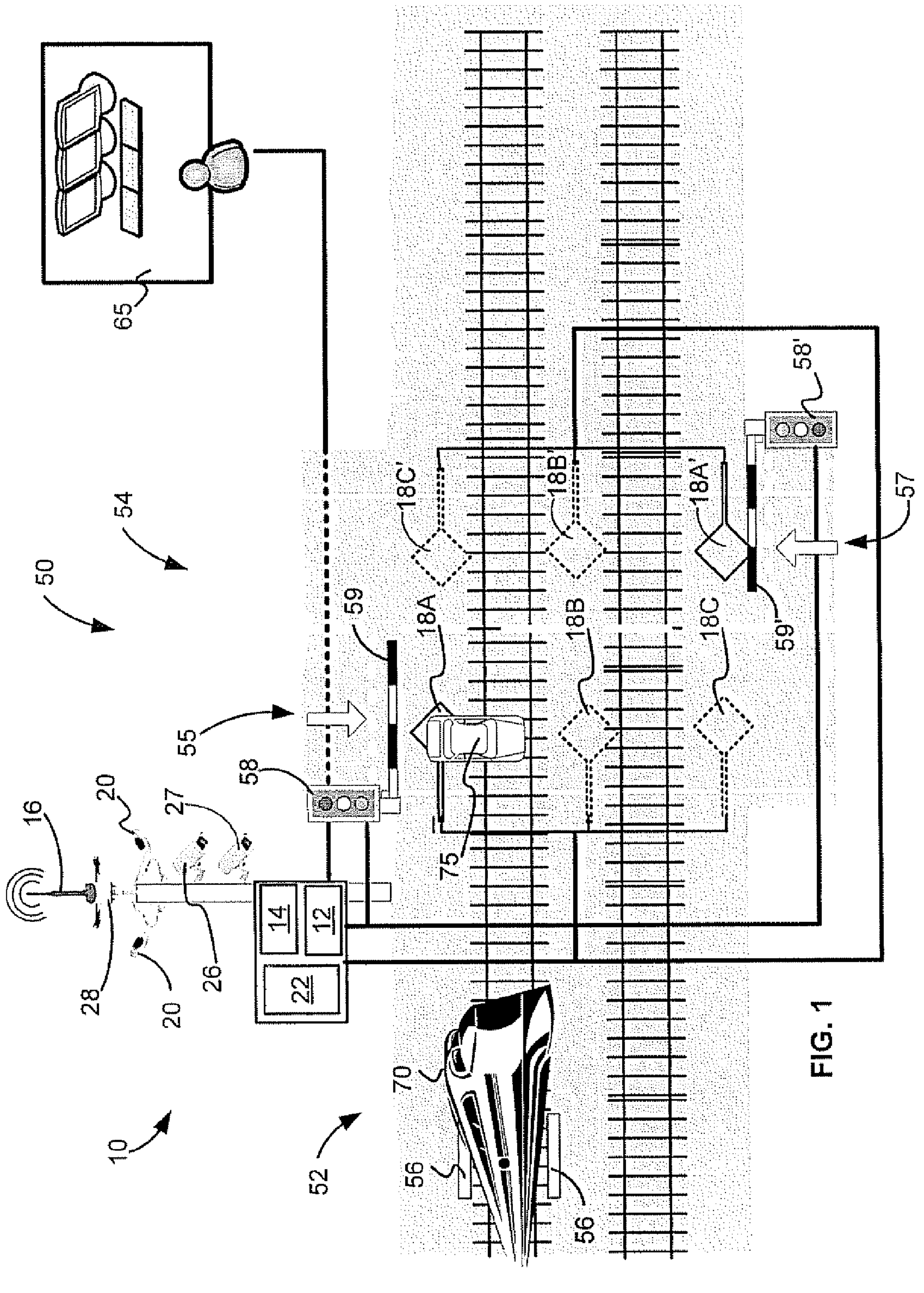
5. The system according to claim 1, further comprising a visible and/or non-visible light camera adapted to provide digital images of the predefined area, and wherein the processing unit is adapted to determine, based on the digital images and based on information received from the inductive loops, whether a potentially hazardous object is located within the predefined area and/or the processing unit is adapted to characterize, based on the digital images and based on information received from the inductive loops, a motion of a potentially hazardous object within the predefined area.

6. The system according to claim 5, further comprising an imaging reliability indicator selector adapted to obtain data with respect to relevant imaging conditions within or around the predefined area and to generate an imaging reliability indication based on the imaging conditions, and wherein the processing unit is adapted to factorize each of the inductive loops and the visible and/or non-visible light camera inputs based on the imaging reliability indication.

7. The system according to claim 5, wherein the processing unit is adapted to utilize geometric simulation to process, substantially in real-time, current and/or projected position of a potentially hazardous object that is located within or moving through the predefined area.

8. The system according to claim 1, further comprising a communication module connectable to a local railway control facility via a Wide Area Network and/or to a railway central control facility via Wide Area Network and/or to a train approaching the predefined area via a wireless communication infrastructure, and wherein the processing module is adapted to utilize the communication module to communicate an alert upon switching to the alert state, and an alarm upon switching to the alarm state.

9. The system according to claim 8, wherein the communication module is connected to the train approaching the predefined area via a wireless communication network.



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70
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59
75
18A
18B
18C
18A'
18B'
18C'
59'
58'
57
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54
65

FIG. 1

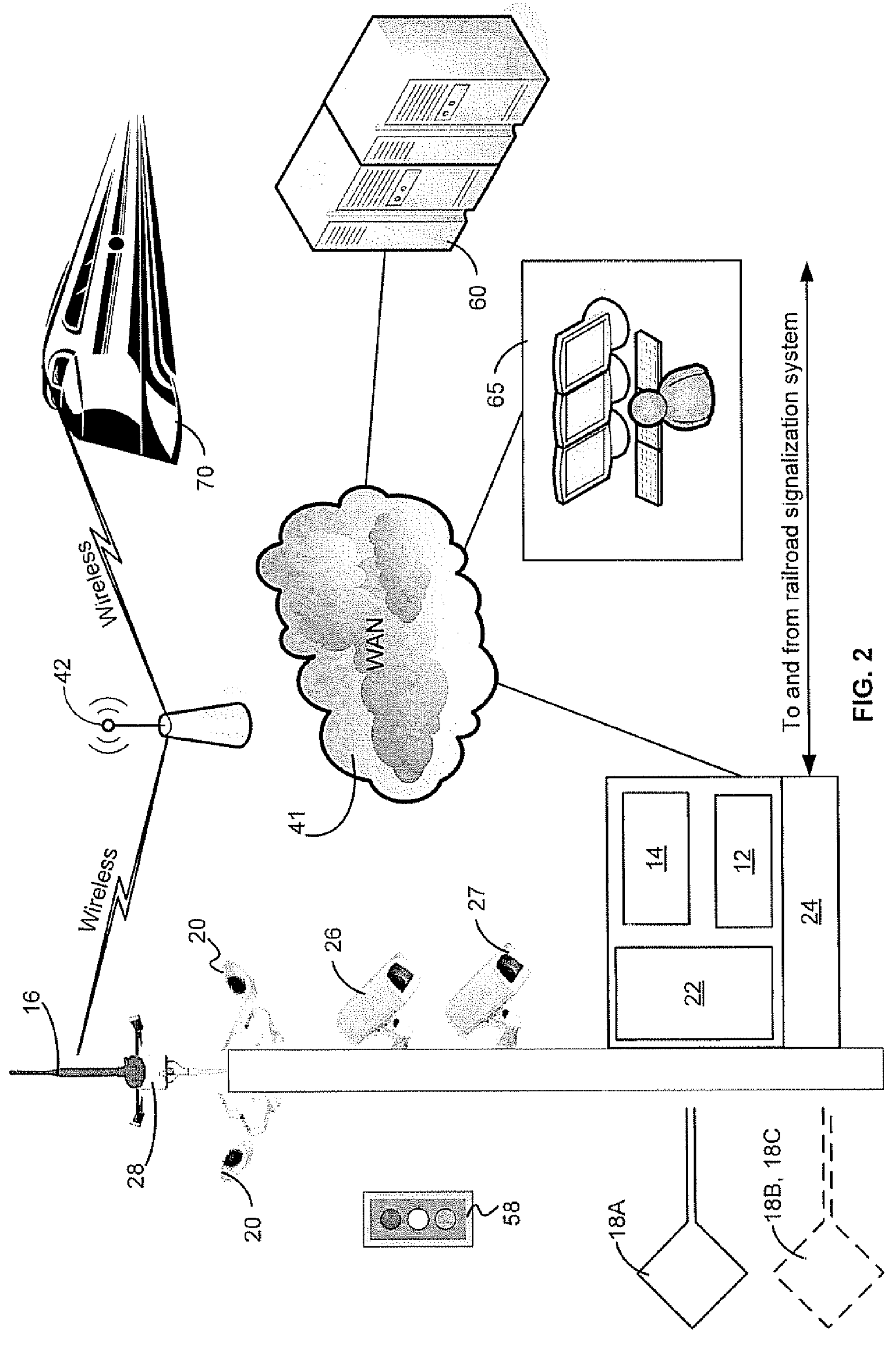
16
28
20
20
58
18A
18B, 18C
Wireless
Wireless
42
70
41
WAN
60
65
26
27
14
12
22
24
To and from railroad signalization system

FIG. 2

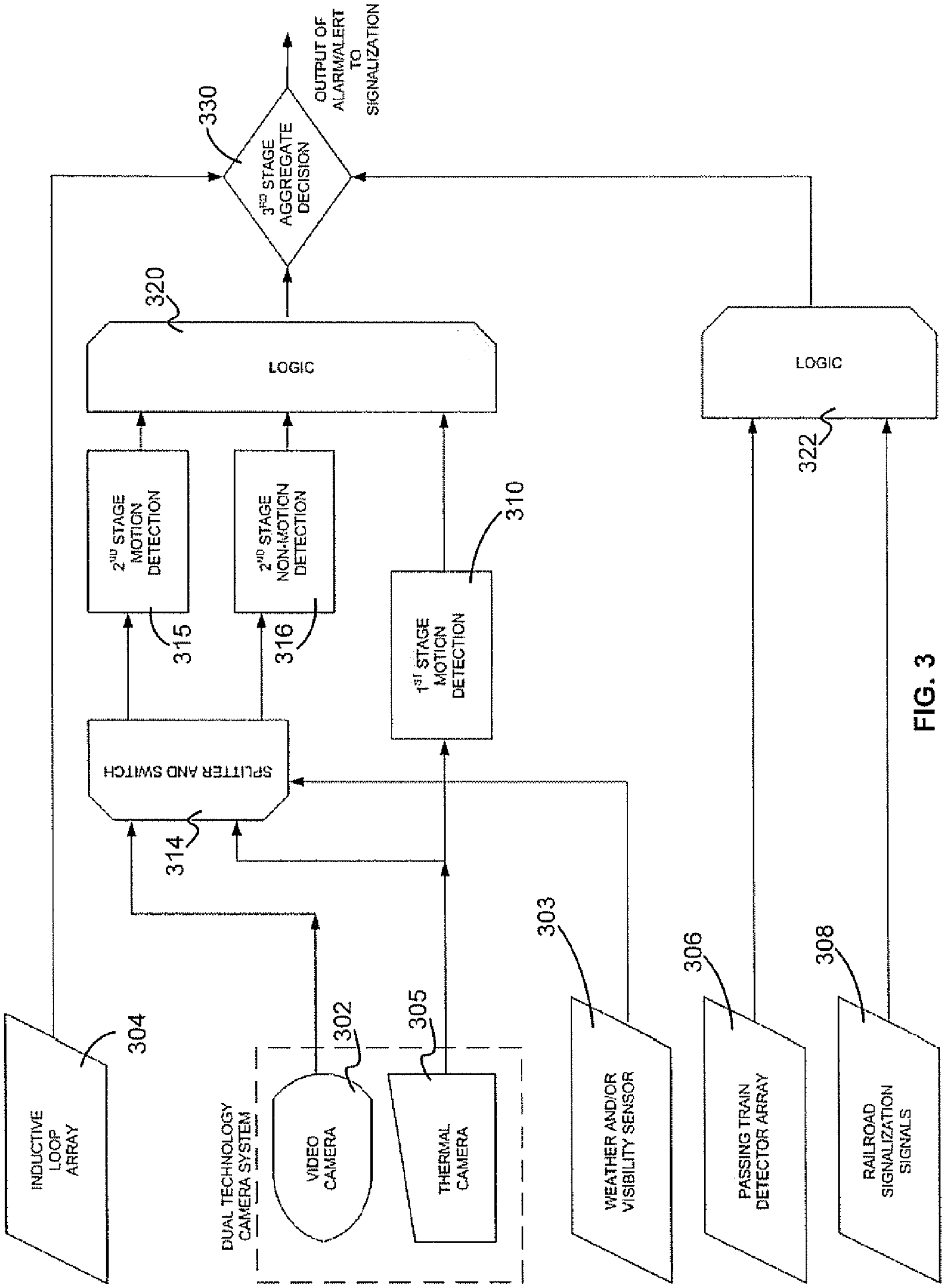
OUTPUT OF ALARM/ALERT TO SIGNALIZATION
330
3RD STAGE AGGREGATE DECISION
320
LOGIC
LOGIC
322
2ND STAGE MOTION DETECTION
315
2ND STAGE NON-MOTION DETECTION
316
310
1ST STAGE MOTION DETECTION
SPLITTER AND SWITCH
314
303
306
308
304
INDUCTIVE LOOP ARRAY
302
305
DUAL TECHNOLOGY CAMERA SYSTEM
VIDEO CAMERA
THERMAL CAMERA
WEATHER AND/OR VISIBILITY SENSOR
PASSING TRAIN DETECTOR ARRAY
RAILROAD SIGNALIZATION SIGNALS

FIG. 3

REFERENCES CITED IN THE DESCRIPTION

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