

MULTI-SENSOR INTRUSION DETECTION SYSTEM

FIELD OF THE INVENTION

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This invention relates to an intrusion detection system using two or more detectors, each for different wavelength ranges of the electromagnetic spectrum. It employs an intrusion behaviour analysis using signals from the different detectors to minimise false alarms, particularly in protecting high-traffic areas.

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BACKGROUND OF THE INVENTION

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Conventional intrusion detection systems for alerting incidences of human or dangerous object intrusion into a designated restricted area are often fraught with false alarms when inappropriate alerts are triggered by non-valid objects straying into such restricted areas such as wind-blown newspaper or clothes, stray animals (e.g. dogs, cats and birds), etc.

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The susceptibility of such intrusion systems to non-valid objects is further compounded in restricted areas such as railway tracks of a train station where the platform has a high traffic of passengers waiting, boarding and disembarking from the trains. Such incidences of inappropriate alerts or false alarms may cause unnecessary disruption to train services. On the other hand, the intrusion system must be robust and accurate to trigger an alarm whenever a valid human or dangerous object intrusion occurs.

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Modern train systems are often automatically operated without drivers or platform masters and, despite the safety "yellow line" establishing a safety clearance strip of about 50 cm along the platform edge, passengers can occasionally unwittingly breach this yellow line to get closer to the platform

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edge. This is especially common upon seeing an approaching train, thus sharply increasing the risks of falling off the platform at such critical moments when the intrusion detection system has only seconds to warn and stop the approaching train from running over the fallen passenger.

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One solution is to physically separate the platform from the rail tracks by a wall provided with doors which will only open when the train has safely berthed, with the train doors corresponding to the platform doors. This solution requires costly equipment to be installed so that the platform and train
10 doors are coordinated to operate in tandem and precise berthing so that the positions of the doors of both sides matches throughout the length of the train in which number of coaches and model may differ. Such physical methods however are not able to warn of the presence of other objects on the track which might disrupt, derail or damage the train.

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Laser scanners have also been used as detectors of intrusion detection systems such as disclosed in US Patent No. 4,949,074 and US Patent No. 6,278,373. Two-dimensional (2-D) laser scanners have been used to scan and cover the tracks along the platform of a train station. However, such 2-D
20 laser scanners are expensive and in order to cover the length of an average station's platform at least four such scanners to be installed out in the open or exposed environment are required to cover a single rail track. The laser sensor of such scanners when installed outdoors are exposed to the elements whereby its effectiveness is affected whereby false alarms may be easily
25 triggered and heavy rains or strong sunlight would confuse the sensor.

Another approach is to use close circuit television (CCTV), i.e. including still and video cameras, as monitoring or image sensors such as that disclosed in US Patent No. 6,429,893 and US Patent No. 6,097,429 with
30 limited effectiveness in image processing of video data in recognising a real intrusion. This is because cameras, being sensors of visible light, are highly susceptible to changing weather and daylight conditions.

In US Patent No. 6,297,844 stereo cameras are used. In US Patent No. 5,825,412 the video camera detection system count the number of pixels of the intruding object and is thus a 2-dimensional capture of the object.

5 Accordingly, a piece of newspaper may be thought to be a large object apart from the other inaccuracies which a camera is susceptible to such as changing weather and fluctuating daylight caused by clouding in the external environment.

10 Any discussion of documents, devices, acts or knowledge in this specification is included to explain the context of the invention. It should not be taken as an admission that any of the material forms a part of the prior art base or the common general knowledge in the relevant art in Singapore or elsewhere on or before the priority date of the disclosure and claims herein.

15 All statements as to the date or representation as to the contents of these documents is based on the information available to the applicant and does not constitute any admission as to the correctness of the dates or contents of these documents.

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SUMMARY OF THE INVENTION

Our invention endeavours to overcome the above-discussed problems by a combination of novel hardware configuration as well as novel data

25 processing logic. The first of our object is to reduce the number of expensive sensing hardware by a combination of sensors capable of detecting electromagnetic spectrum in two different ranges.

Our second object is to reduce the incidence of false alarms by

30 integrally processing detected signals from both sets of sensors. A third object is to employ the combination of two sets of sensors to delineate a perimeter and to reduce the actual area to be scanned for intrusion.

A fourth object is to provide for a 3-dimensional scan of the intruding object so as to ascertain its actual size rather than a 2-dimensional image. A fifth object is to provide a data processing logic flowchart or algorithm that
5 validates two or more intrusion signals from the sensors before allowing an intrusion alert to be generated. A sixth object is to determine within certain time-frames if the intruding object is transient or at rest on the tracks in order for the system to trigger an alert.

10 To achieve the foregoing objects, our intrusion detection system provides for a basic embodiment comprising

- at least a first detector of a first electromagnetic spectrum range;
- at least a second detector of a second electromagnetic spectrum range;

15 wherein the first and second detectors are disposed at different positions to receive respective electromagnetic waves from said designated area, such that

- electromagnetic wave detected of said designated area's normal or lack-of-intrusion profile is assigned as background reference;
20 and
- electromagnetic wave detected of intrusion by objects into said designated area are compared against said background reference to determine if there exist variances, whereupon detecting a predetermined variance, generating a detected
25 signal;

- a signal processing means disposed to receive detected signals from said detectors, wherein the detected signals are integrally processed such that an intrusion-alert signal is only generated upon said signal processor validates that detected signals from both first and second
30 detectors marking an intrusion detection at about the same location in said designated area being received at about the same time.

Preferably, the designated area comprises the rail tracks and platform edge of a train station. The first and second detectors may include any one or combination of photoelectric point-to-point, multi-level beam detectors which may be microwave, radio wave, infrared, laser and visible light detectors.

- 5 Preferably, the first detector is a 2-dimensional laser scanner projecting a virtual wall parallel to and defining at least part of designated area's perimeter such that a breach of this wall triggers a detected signal.

The second detector is preferably a camera, i.e. a still photographic
10 camera and a video camera but is most preferably a pair of stereo cameras which is trained with their optical axes parallel to the platform edge so that the stereo image receivable therewith show a composite image divided vertically into two parts, namely a platform part and a track part, such that the platform edge appears as a single line in the composite image. The stereo composite
15 image captured by the stereo camera pair may be correlated on an array of pixels in the X- and Y-axes corresponding to a grid extending from along the platform edge spanning the train tracks along said platform.

As a preferred embodiment, our intrusion detection system may further
20 include position sensors for detecting the presence of a train in a position that is approaching, berthing or leaving the platform and generating a signal accordingly to be processed by said signal processing means.

In another aspect of our invention, the signal processing means
25 collects background reference data from both the first and second detectors and stores said data for reference. Detected signals from the first and second detectors, retrieves said background reference data, compares the detected signals against said background reference data to obtain variance data, compares said variance data against predetermined variance threshold and,
30 upon detecting said variance data exceeding said predetermined variance threshold, triggers a first intrusion alert.

Preferably, when the position sensors detects a train berthing along the platform, it will indicate to the signal processing means to ignore detected signals from the first and second detectors. When the first intrusion alert is triggered, the signal processing means may preferably initiates a routine in
5 the signal processing means to analyse the intrusion object size using 3-dimensional geometry function of second detector, compare object volume against a predetermined threshold volume, and/or validates if said object has been detected in at least 2 frames before triggering a second intrusion alert.

10 Our intrusion detection system may be configured modularly and multiple modules may be installed to cover the length of a platform or train comprising multiple coaches whereby the modules are integrated to function as a system unit for a train station. Preferably, signals from the detectors are transmitting wirelessly to the signal processing means. Our intrusion
15 detection system may also be made SCADA-enabled or Internet Protocol-enabled for centralised monitoring and control of multiple train stations of a rail service network.

Alternative intrusion detection systems may be configured by
20 employing our working principle which may be reduced to a method for detecting an object intruding into a designated area comprising the steps of:

- operating at least a first detector of a first electromagnetic spectrum range; and
- operating at least a second detector of a second electromagnetic
25 spectrum range;

wherein the first and second detectors are disposed at different positions to receive respective electromagnetic waves from said designated area, such that

- electromagnetic wave detected of said designated area's normal
30 or lack-of-intrusion profile is assigned as background reference; and
- electromagnetic wave detected of intrusion by objects into said

designated area are compared against said background reference to determine if there exist variances, whereupon detecting a predetermined variance, generating a detected signal;

- 5 - receiving and processing detected signals from said detectors, wherein the detected signals are integrally processed such that an intrusion-alert signal is only generated upon said signal processor validates that detected signals from both first and second detectors marking an intrusion detection at about the same location in said designated area
10 being received at about the same time.

Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while
15 indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

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BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be better understood with reference to the accompanying drawings and the detailed description that follows hereinafter
25 wherein specific embodiments are described as non-limiting examples or illustration, in which:

Figure 1 shows a plan view of a schematic configuration of an intrusion detection system for a train station platform according to the present
30 invention;

Figures 2A – 2C show in side elevation view of a schematic configuration of

the intrusion detection system of Figure 1 wherein Figure 2A shows a sensor configuration for a platform without a train berthed thereat, Figure 2B shows a sensor configuration for a platform where a single-coach train is berthed thereat, and Figure 2C shows a sensor configuration for a platform where a two-coach train is berthed thereat; and

Figure 3 shows a logic flowchart or algorithm of an intrusion system according to the invention.

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DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Briefly, the intrusion detection system for a designated area according to our invention basically and generally comprises of a first type of detector for scanning a first electro-magnetic spectrum range, a second detector for scanning a second electromagnetic spectrum range. The two types of detectors may be disposed at different positions to receive the respective electromagnetic waves from said designated area such that a background signal is first collected as reference and intrusion signals are compared to detect significant variances there-in-between to generate a detected signal. A signal processing means integrally processed the signals from the two types of detectors. An intrusion-alert signal is only generated upon the signal processor validates that intrusion is detected by both types of detectors at about the same location and at about the same time.

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The intrusion detection system of the present invention may be better understood by referring to Figure 1 as a preferred embodiment wherein the system is employed for detecting intrusion in a train station, in particular along the platform (10) and the railway tracks (20) along the platform (10). Given the fact that intrusion into the track area (20) is most likely to come only from the platform (10), we reckon that our detection perimeter should begin with the platform edge (12) running along the railway tracks (20).

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Sensor type I: laser scanner

As shown in Figure 1, a pair of well spaced-apart laser scanners (14, 16), as a first type of detector of a first range of electromagnetic spectrum, may be mounted overhead the platform edge (12) so that the laser scanning beam is directed downward and sideward. For a typical train station such as Singapore's Mass Rapid Train (MRT) system, the platform may span no more than 40 metres and a single such laser scanner would be sufficient to cover the entire length of the platform (10). For larger stations, a pair of such costly laser scanners (14, 16) would be required as shown in Figure 1.

The laser scanners (14, 16) may preferably be the 2-dimensional scanning type. A model of such laser scanners include the LMS-291 laser scanner made by SICK AG (Waldkirch, Germany), which offer long detection ranges and reliable detection even under the most difficult of environmental conditions.

Another model of laser scanner contemplated is SIGUARD LS-4 made by Siemens AG (Munich, Germany) which is an optical distance sensor. This device periodically transmits light pulses within a working range of 190°. If the pulses hit an obstacle or a person, the laser scanner will receive the reflected light and evaluate it. The scanner calculates the exact coordinates of the detected obstacle from the light propagation time. If the obstacle/person is within the programmed zone, the scanner will signal an alert or initiates a safe shutdown.

Clearly, other laser scanners, not limited to LMS-291 and SIGUARD LS-4, which provide a scanning field of view of about 180° and at a minimum rate of 25 Hz may be used.

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Preferably, the beam is directed to about 2 cm from the platform edge (12) so that it does not pick up intrusions into yellow line zone (18) by

recalcitrant passengers and passengers bumped into the yellow line zone (18) by the packed crowd that might trigger false alarms. With this configuration, an intrusion will not be detected unless the passenger comes dangerously close to the platform edge (12). The 2 cm gap from the platform edge (12) also ensures that the laser sensors (14, 16) do not pickup false intrusion signals from the train as it moves into or leaves the station.

The 2-D laser scanners scan the platform scene from up to down, giving a scanning field of view of about 180° and at a rate ranging from 25 – 40 Hz. The scanning field is best shown in side elevation view as represented in Figures 2A – 2C with and without the presence of the trains.

From the above configuration of the laser scanners, it is apparent that our approach is, instead of monitoring the platform's yellow line zone (18) and the entire length of the railway tracks (20) along the platform (10), we use the laser scanners (14, 16) to build a virtual wall (22) along the platform edge (12) to define the perimeter of the track area to be protected; thus reducing the area to be monitored for intrusion by taking advantage of the fact that intrusions into the track area (20) is most likely to come only from the platform (10) which must pass through the virtual wall (22). Thus, we will only need to detect intrusions into the track area (20) by first detecting any breaches on the virtual wall (22). This approach significantly reduces the area to be monitored and the number of sensors required for the system.

25 Sensor type II: camera

As for the second type of sensors, a photographic camera is used. The camera may be a photographic still camera or a video camera. Preferably, a pair of stereo cameras (30a, 30b) (including close-circuit television, CCTV) is mounted above each end of the platform (10) trained onto the railway tracks (20), preferably under cover of the roof (32) of the station so that they are less exposed to the weather. The optical axes of each

of the stereo camera pair are aligned with each other so that the platform-track edge appears as a single line in the image displayed while dividing the image into two parts, namely, the platform part and the track part, in the composite image.

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With such a configuration of the laser scanners and stereo CCTV, the protected or designated area will be fully covered by the intrusion detection system. Any intrusion so detected and appearing on the CCTV display as an image will correspond to an intruding object physically lying on or above the railway tracks (20) with a high certainty.

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Although the two types of detectors exemplarily described above are laser scanners and stereo CCTV, i.e. detecting electromagnetic wavelengths of the laser and visible ranges respectively, they may be substituted with detectors for the other ranges of the electromagnetic spectrum as long as they are detectors of different ranges of the spectrum. In particular, the first and second detectors may include any one or combination of microwave, radio wave, infrared, laser and visible light detectors.

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Apart from the laser scanners having 180° scan field, the virtual wall (22) may also be formed by any one, or in combination, of photoelectric point-to-point, multi-level beam detectors forming an array of beams, or in form of a rectilinear scanning arranged to form a virtual wall or fence. The term "photoelectric" device here is intended to cover any electrical current or effect that is produced in the device (e.g. sensor) as a result of incident electromagnetic radiation and not just the visible range of the electromagnetic spectrum.

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In a specific configuration, the CCTV stereo cameras (30a, 30b) are only activated to scan for intrusion upon the breaching of this virtual wall (22). In the present example as illustrated with the accompanying drawings, both the laser scanners (14, 16) forming the virtual wall (22) are concurrently

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operative with the CCTV stereo cameras (30a, 30b). The stereo composite image captured by at least one of the stereo camera pair may be correlated on an array of pixels in the X- and Y-axes corresponding to a grid extending from along the platform edge (12) spanning the railway tracks (20) along said platform (10). The algorithm of our system requires that, in order for an intrusion detected to be valid, it must be able to be detected by both types of sensors, i.e. at least by one of the laser scanners (14, 16) and at least one of the CCTV stereo cameras (30a, 30b). The implementation of this principle is able to keep the rate of false alarms to a very low rate even under inclement weather.

This principle may be achieved with the use of charged-coupled device (CCD) which is a form of analog-to-digital converter that generates a digital signal output representing an analog image input. The transfer of stored charges in the CCD provides the method of operation so that each pixel may be assigned a coordinate corresponding to the grid which covers the train tracks along the platform edge. In this arrangement, both types of sensors, in particular the stereo cameras, are able to detect it at the same time and at the pixel position corresponding to each type of sensors.

Alternatively or complementarily, a scheme may be provided using the concept of image-ground registration to correlate the pixel position (x_i, y_i) on an image with the actual spatial coordinates (X_g, Y_g) on the ground. This is achieved by first selecting regions in the image that are recognised as the track area. By mapping the corners of this track-region (x_i, y_i) in the image with their actual ground distances (X_g, Y_g) from the camera, every pixel in the track-region is mapped to 2D coordinates in actual space. As a result of this mapping, the actual position (X_g, Y_g) of an object that occupies a position (x_i, y_i) in the track-region can be estimated.

Position sensors

With reference to Figure 1, apart from the two types of sensors, i.e. laser scanners (14, 16) and CCTV stereo cameras (30a, 30b), a third type of sensors may also be configured into the system as the most preferred embodiment of our invention. The third type of sensors is position sensors which are preferably inductive devices, i.e. devices that inductively produce electrical current as signal upon detecting a ferrous or non-ferrous metallic object which induces the signal about its inductive coils. Some of these sensors include TL-L series of long-range inductive proximity sensor made by Omron Electronics LLC (Schaumburg, IL, U.S.A.) which has effective long sensing distance of up to 100mm for both iron (ferrous) and aluminum (non-ferrous) targets. Another sensor model is the Osiprox inductive proximity sensor made by Schneider Electric Industries S.A. (Rueil-Malmaison, France) which has effective sensing distance of up to 60mm.

As shown in Figure 1, the most preferred embodiment comprises of three types of sensors, that is, apart from the laser scanners (14, 16) and CCTV stereo cameras (30a, 30b), position sensors (40a, 40b, 40c, 40d and 40e) are preferably placed spaced along the railway track for detecting the arriving, departing and berthing positions of the train.

Figure 1 shows five such position sensors (40a, 40b, 40c, 40d and 40e) being placed spaced apart along the railway track wherein 3 of them (40b, 40c and 40d) are placed to sense the position of a train berthing on the platform while one each (40a, 40e) is placed at each end of the track, preferably at 10 m away from each ends of the platform, leading out of the station to sense the train arriving at and departing from the station. Preferably, the position sensors are placed overhead (e.g. mounted on the track roof) spanning the railway tracks (20).

The number of the position sensors would depend on the length of the station as well as to adequately cover the length of the train which depends on the number of coaches. As shown in Figures 2B and 2C, one position
5 sensor (40) may adequately detect the position of a single-coach train (50) and two sensors (40b, 40c) for a two-coach train (52). The virtual wall (22) created by the laser scanners (14, 16) may be configured to ignore breaches along certain sections of the wall (22), or "open-up" window zones along the
10 wall (22) upon the position sensors (40, 40b, 40c) detected the train has berthed along the platform. Such window opening zones may correspond with the doors of the trains so that the movement of passengers boarding and alighting therefrom are not registered as intruding or breaching the virtual wall (22).

15 3D-scanning

In our implementation, the stereo cameras provide 3D scanning by using the established method of computing the stereo disparity maps. Such disparity maps are obtained by comparing two images taken of the same
20 scene through two different camera positions. Each map is composed of a matrix of values whereby each value represents the degree of position-disparity of each pixel. The value on each element is computed by first correlating the same point as seen by the two cameras, determining the relative positions of this same point in each of the two images, and obtaining
25 the depth information of this point through the use of basic geometry. Such stereo method allows the determination of the distance of objects from the cameras. As such, when this information is combined with the 2D spatial information provided by the image, the information is extended to 3D.

Signal processing and logic

Apart from the foregoing configuration of sensors, an essential component of the present intrusion detection system for train platform and tracks is a signal processing means for receiving and processing the signals from the various types of sensors afore-described so that background reference data may be collected and stored to be compared against with signals received from the sensors during the period of intrusion detection operation of the system. The signal processing means may preferably embody a logic flowchart or algorithm represented in Figure 3.

In Step (1) of the logic flowchart, both the laser scanner and the CCTV stereo cameras perform auto-calibration by allowing the sensors to receive data from the designated area to be protected, i.e. the platform edge and the railway tracks, when no passengers are allowed onto the platform yet. The data gathered are saved and retrievably stored as reference data. For the laser scanner, the profile of the platform edge as detected by the scanner is gathered and saved in memory. For the CCTV, the image of the railway track without train is also captured and stored.

In Step (2) the laser scanner scans the platform edge using its intrusion detection routine. It scans the scene at 40 Hz and for each frame captured, it is compared against the background profile as reference in Step (3). If there is no change in value or is within a predetermined threshold, the routine will revert to the beginning of Step (2). If there is a variance between the reference data and scanned data, or the difference in range values exceeds a predetermined threshold, the detected signal is regarded as a possible or potential intrusion.

In Steps (4), (5) and (6) upon the detection of a change in range profile by the laser scanners, the routine will check on the status of the position sensors. If the position sensors register a train being berthed, the possible or

potential intrusion signal is likely to be triggered by passengers breaching the virtual wall of the laser scanners in boarding or disembarking. The breach coordinates at the virtual wall is then checked to see if they correlate with the train's berthing positions. If they do correlate, the routine will revert to the beginning of Step (2).

Otherwise, it will proceed to the next step, i.e. if the breaches detected fall in the areas outside of the berthing train as determined by the position sensors, there is a possibility of intrusion, i.e. someone could have fallen onto the tracks, in front or behind the train. The next logical step is to compute the intruding object size.

In Steps (7) and (8), the intruding object's estimated size will be computed by analysing the number of angular segments that is being detected. If the estimated size exceeds a pre-determined or threshold size, the intrusion is taken as a valid scanner-level intrusion. The exact location of the intrusion is recorded for further analysis by the second type of sensors, i.e. the CCTV stereo camera in Step (9).

In Steps (9), (10) and (11), the routine resorts to using CCTV stereo cameras to see if the intrusion may similarly be detected at the same position on the railway track area. If the same position of intrusion is reported, the routine will proceed to determine if the object is the same one detected by the laser scanners and will proceed to determine the size of the object in Step (12). Otherwise, the detection event may be considered as due to noise and the routine will revert back to the beginning of Step (2).

In Step (11), if the CCTV has not detected any object, the routine will check with a timer on the laser scanner to see if the detection is transient or exceeding a predetermined time-frame. If it exceeds, for example, 2 seconds of time-frames, the intrusion is likely caused by tampering, interference or passengers standing too close to the platform edge and therefore constantly

trigger the scanner-level intrusion alert.

Accordingly, the routine will trigger an Alert Level 1 which may generate public warnings with audio and/or visual means such as automatic
5 voice broadcasts, flashing light, beeper warning sounds, etc. or alert the station's security personnel and notify the railway network's central command and control. If the CCTV fails to detect any object or if the time-frame of detection is not exceeded (e.g. the intruding passenger has moved away), the routine assumes that the detection by the laser scanner is due to transient
10 noise. The routine will then revert to the beginning of Step 2 and alternatively makes an event log.

Step (12) is executed upon confirmation of the presence of the intruding object by the CCTV. The routine will use the image capture by the
15 CCTV to compute the height and width of the object once it has settled down on the tracks. This is based on the assumption that it is more accurate to estimate a settled object's size than one that is still flying or falling, for example a newspaper. The size of the object is estimated using the registered pixel counts of the object image captured.

20 In Step 13, the object's size, as estimated from the CCTV image, is compared against a predetermined threshold and the number of time-frames the object remains captured. If the object size exceeds the threshold size and not transient, an Alert Level 2 is triggered. Depending on the responses
25 associated with this level of alert, which is deemed more serious than Level 1 alert, signals may be generated by the routine to override the train normal program from continuing to run, alerting the station's security and the railway network's central command and control, etc.

30 It will be appreciated that a number of the above-described features may be made modular, modified or adapted accordingly for other forms of utility or configuration. For example, the configuration of sensors may be

made modular so that two or more modules may be installed and configured to function integrally as a system to cover a large train station or an interchange. The signals from the sensors may be transmitted to the signal processing means by wireless means. The intrusion detected system may
5 also be made with supervisory control & data acquisition capabilities or SCADA-enabled or Internet Protocol-enabled so to enable centralised monitoring and control of multiple train stations of a rail service network.

It will further be appreciated that the above-described intrusion
10 detection system may be further added with other types of sensors to further enhance the false alarm prevention, e.g. by having infrared or heat detectors for confirming the presence of a large warm-blooded body on the railway tracks, etc.

15 It would also be obvious to a skilled person that some of the aforesaid sensors or scanner configuration and logic processes may be re-configured, modified or alternatively based on the same general concept, features and working principles of the present invention.

20 These variations and alternative embodiments may be used in substitution of the aforesaid parts, components, materials, steps or processes as alternative configurations or embodiments not specifically described herein but which may still be used to effectively work the concept and working principles of this invention. Accordingly, they are not to be considered as
25 departures from the present invention but shall be considered as falling within the letter and scope of the following claims.

While this invention has been described in connection with specific
embodiments thereof, it will be understood that it is capable of further
30 modification(s). This application is intended to cover any variations uses or adaptations of the invention following in general, the principles of the invention and including such departures from the present disclosure as come within

known or customary practice within the art to which the invention pertains and as may be applied to the essential features hereinbefore set forth.

As the present invention may be embodied in several forms without
5 departing from the spirit of the essential characteristics of the invention, it should be understood that the above described embodiments are not to limit the present invention unless otherwise specified, but rather should be construed broadly within the spirit and scope of the invention as defined in the appended claims. Various modifications and equivalent arrangements are
10 intended to be included within the spirit and scope of the invention and appended claims. Therefore, the specific embodiments are to be understood to be illustrative of the many ways in which the principles of the present invention may be practiced. In the following claims, means-plus-function clauses are intended to cover structures as performing the defined function
15 and not only structural equivalents, but also equivalent structures. For example, although a nail and a screw may not be structural equivalents in that a nail employs a cylindrical surface to secure wooden parts together, whereas a screw employs a helical surface to secure wooden parts together, in the environment of fastening wooden parts, a nail and a screw are equivalent
20 structures.

“Comprises/comprising” when used in this specification is taken to specify the presence of stated features, integers, steps or components but does not preclude the presence or addition of one or more other features,
25 integers, steps, components or groups thereof.”

CLAIMS

1. An intrusion detection system for a designated area comprising:
 - 5 - at least a first detector of a first electromagnetic spectrum range;
 - at least a second detector of a second electromagnetic spectrum range;
wherein the first and second detectors are disposed at different positions to receive respective electromagnetic waves from said designated area, such that
 - 10 - electromagnetic wave detected of said designated area's normal or lack-of-intrusion profile is assigned as background reference; and
 - electromagnetic wave detected of intrusion by objects into said designated area are compared against said background reference to determine if there exist variances, whereupon detecting a predetermined variance, generating a detected signal;
 - 15 - a signal processing means disposed to receive detected signals from said detectors, wherein the detected signals are integrally processed such that an intrusion-alert signal is only generated upon said signal processor validates that detected signals from both first and second detectors marking an intrusion detection at about the same location in said designated area being received at about the same time.
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2. An intrusion detection system according to Claim 1 wherein the designated area comprises at least one of rail tracks and platform edge of a train station.
- 30 3. An intrusion detection system according to Claim 1 wherein the first and second detectors include any one or combination of photoelectric point-to-point, multi-level beam detectors.

4. An intrusion detection system according to Claim 1 wherein the first and second detectors include any one or combination of microwave, radio wave, infrared, laser and visible light detectors.
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5. An intrusion detection system according to Claim 1 wherein the first detector is a laser scanner.
6. An intrusion detection system according to Claim 5 wherein the
- 10 scanner is a rectilinear scanner.
7. An intrusion detection system according to Claim 5 wherein the laser scanner is 2-dimensional (2D) laser scanner projecting a virtual wall parallel to and defining at least part of designated area's perimeter such that a breach of
- 15 this virtual wall triggers a detecting signal.
8. An intrusion detection system according to Claim 5 wherein the laser scanner is mounted overhead the platform edge projecting downwardly and sidewardly just about inside the platform edge.
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9. An intrusion detection system according to Claim 5 wherein sufficient numbers of the laser scanners are placed to project a virtual wall to span the length of a boarding area of train station platform.
- 25 10. An intrusion detection system according to Claim 1 wherein the second detector is a camera, including at least one of a still photographic camera and a video camera.
- 30 11. An intrusion detection system according to Claim 10 wherein the camera comprises a pair of stereo cameras.

12. An intrusion detection system according to Claim 10 wherein the camera is mounted above the platform edge at about roof level at least one end of the platform.

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13. An intrusion detection system according to Claim 11 wherein the stereo camera pair is trained with their optical axes parallel to the platform edge so that the stereo image receivable therewith show a composite image divided vertically into two parts, namely a platform part and a track part, such that the platform edge appears as a single line in the composite image.

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14. An intrusion detection system according to Claim 11 wherein a stereo camera pair is installed at each end of the platform.

15. An intrusion detection system according to any one of Claims 13 and 14 wherein the stereo composite image captured by at least one of the stereo camera pair is correlated on an array of pixels in the X- and Y-axes corresponding to a grid extending from along the platform edge spanning the train tracks along said platform.

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16. An intrusion detection system according to Claim 1 further including at least a position sensor for detecting the presence of a train in a position that is approaching, berthing or leaving the platform and generating a signal accordingly to be processed by said signal processing means.

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17. An intrusion detection system according to Claim 16 wherein the position sensor monitors the berthing position of the train so that berthing signal from the position sensor is sent to said signal processing means.

30 18. An intrusion detection system according to Claim 16 wherein the position sensor is an inductive device.

19. An intrusion detection system according to Claim 16 wherein a plurality of position sensors is placed overhead spanning the train track along the platform sufficient to monitor the train's length comprised of coaches with a further position sensors placed after and before the platform to detect arrival and departure of trains.

20. An intrusion detection system according to Claim 1 wherein the signal processing means collects background reference data from both the first and second detectors and stores said data for reference.

21. An intrusion detection system according to Claim 20 wherein the signal processing means receives detected signals from the first and second detectors, retrieves said background reference data, compares the detected signals against said background reference data to obtain variance data, compares said variance data against predetermined variance threshold and, upon detecting said variance data exceeding said predetermined variance threshold, triggers a first intrusion alert.

22. An intrusion detection system according to Claim 17 wherein the position sensors detects a train berthing along the platform and indicated to the signal processing means to ignore detected signals from the first and second detectors.

23. An intrusion detection system according to Claim 1 wherein upon the triggering of the first intrusion alert, the signal processing means

- initiates a routine in the signal processing means to analyse intrusion object size using 3-dimensional geometry function of second detector;
- compare object volume against a predetermined threshold volume; and/or
- validates if said object has been detected in at least 2 frames before triggering a second intrusion alert.

24. An intrusion detection system according to any one of the preceding claims which is modular and multiple modules is installed to cover the length of a platform or train comprising multiple coaches wherein the modules are integrated to function as a system unit for a train station.

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25. An intrusion detection system according to any one of the preceding claims wherein the signals are transmitting wirelessly to the signal processing means.

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26. An intrusion detection system according to any one of the preceding claims which is remotely-enabled for centralised monitoring and control of multiple train stations of a rail service network, including any one or combination of SCADA-enabled or Internet Protocol-enabled.

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27. A method for detecting an object intruding into a designated area comprising the steps of

- operating at least a first detector of a first electromagnetic spectrum range; and
- operating at least a second detector of a second electromagnetic spectrum range;

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wherein the first and second detectors are disposed at different positions to receive respective electromagnetic waves from said designated area, such that

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- electromagnetic wave detected of said designated area's normal or lack-of-intrusion profile is assigned as background reference; and

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- electromagnetic wave detected of intrusion by objects into said designated area are compared against said background reference to determine if there exist variances, whereupon detecting a predetermined variance, generating a detected signal;

- receiving and processing detected signals from said detectors, wherein

the detected signals are integrally processed such that an intrusion-alert signal is only generated upon said signal processor validates that detected signals from both first and second detectors marking an intrusion detection at about the same location in said designated area being received at about the same time.