

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

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 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 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 triggered and heavy rains or strong sunlight would confuse the sensor.

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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 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.

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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. 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.

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. 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.

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 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 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 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.

To achieve the foregoing objects, our intrusion detection system provides for a basic embodiment of our invention in the form of an intrusion detection apparatus for detecting intrusion of an object into a designated area, said apparatus comprising:

- at least a first detector of a first electromagnetic spectrum range;
 - at least a second detector of a second electromagnetic spectrum of a range substantially different from said first electromagnetic spectrum;
- wherein the first and second detectors are disposed at different positions to detect 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; and
 - electromagnetic wave currently detected of an intrusion by an object into said designated area is compared against said background reference to determine if there exist variances between said background reference and currently detected electromagnetic waves, whereupon detecting a predetermined variance, generating a detected signal;
 - a signal processing means disposed to receive detected signals from said detectors, wherein an intrusion-alert signal is generated upon said signal processor validating detected signals from both first and second detectors as detecting an intrusion at about the same location and at about the same time.

Preferably, our apparatus is implemented in a high human traffic area, such as an urban commuting train station wherein the designated area covers at least one of rail tracks and a platform edge of said train station. Preferably
5 still, the first and second detectors are each selected from photoelectric point-to-point, multi-level beam detectors or are each selected from microwave, radio wave, infrared, laser and visible light detectors.

In a preferred embodiment, the first detector is a laser scanner, including
10 a rectilinear scanner. The laser scanner may be a 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 this virtual wall triggers a detecting signal. The laser scanner is mounted overhead the platform edge projecting downwardly and sidewardly just about inside the platform edge. A
15 sufficient number of the laser scanners may be placed to project a virtual wall to span the length of a boarding area of train station platform.

The second detector may preferably be a camera selected from a still photographic camera and a video camera, including a pair of stereo cameras
20 which may be mounted overhead above the platform edge at at least one end, or preferably at each end of the platform. The stereo cameras pair may be trained with their optical axes parallel to the platform edge so that the stereo image receivable therewith show a composite image divided into two sides, namely a platform side and a track side, such that the platform edge appears as
25 a single perspective line in the composite image. 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 spanning the train tracks along said platform.

30 In a preferred embodiment, at least a position sensor capable of detecting a train that is approaching, berthing or leaving the platform and generating a signal accordingly to be processed by said signal processing

means is included. The position sensor may generate a berthing signal from the position sensor upon detecting a berthing train and sent to said signal processing means. The position sensor is preferably an inductive device. A plurality of position sensors may be placed overhead sufficiently to cover the length of a berthing train along the platform with a further position sensors placed after and before the platform to detect arrival and departure of the train.

In another aspect of our invention, a method is provided for detecting intrusion of an object into a designated area, wherein the method comprising the steps of

- detecting wavelength in a first electromagnetic spectrum range;
- detecting wavelength in a second electromagnetic spectrum of a range substantially different from said first electromagnetic spectrum range;
wherein the first and second electromagnetic spectrum ranges are detected at different positions of said designated area whereby
 - electromagnetic wave detected of said designated area's normal or lack-of-intrusion profile is assigned as background reference; and
 - electromagnetic wave currently detected of an object intruding into said designated area is compared against said background reference to determine if there exist variances between said background reference and currently detected electromagnetic waves; whereupon detecting a predetermined variance, generating a detected signal;
- validating the detected signal from both first and second electromagnetic spectrum as detecting an intrusion at about the same location in said designated area being received at about the same time before generating an intrusion-alert signal.

In a preferred embodiment, the method receives detected wavelengths of both first and second electromagnetic spectrums and stores said data for as background reference data. Preferably, our method receives currently detected

wavelengths of both first and second electromagnetic spectrum; compares said detected wavelengths against the background reference data to obtain variance data, compares said variance data against a predetermined variance threshold and, upon detecting said variance data exceeding said predetermined variance
5 threshold, triggers a first intrusion alert. Preferably, upon detecting at least a position of a train berthing along the platform, detected signals from the first and/or second electromagnetic spectrums are ignored.

In a preferred embodiment of the method, upon the triggering of the first
10 intrusion alert, a routine is initiated to estimate the intrusion object size that is detected with said first and/or second electromagnetic spectrums with a 3-dimensional geometry function; the estimated object size is compared against a predetermined threshold size; and/or validating whether object has been detected in at least 2 frames before triggering a second intrusion alert.

15 The entire length and/or position of the train may preferably be detected by multiple modular detecting means in an integrated manner and to operate as a single function. At least a position of the train berthing along the platform may be detected while detected signals from the first and/or second electromagnetic
20 spectrums are preferably ignored. The detected signals may be transmitted remotely to be processed and may therefore be implemented as remotely-enabled for centralised monitoring and control of multiple train stations of a rail service network, which may include any one or combination of SCADA-enabled or Internet Protocol-enabled.

25 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 indicating preferred embodiments of the invention, are given by way of illustration only,
30 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.

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 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 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.

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.

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).

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-
5 4, which provide a scanning field of view of about 180° and at a minimum rate of 25 Hz may be used.

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
10 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
15 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
20 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
25 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
30 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.

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
5 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
10 in the image displayed while dividing the image into two parts, namely, the platform part and the track part, in the composite image.

With such a configuration of the laser scanners and stereo CCTV, the protected or designated area will be fully covered by the intrusion detection
15 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.

Although the two types of detectors exemplarily described above are
20 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,
25 infrared, laser and visible light detectors.

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
30 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.

In a specific configuration, the CCTV stereo cameras (30a, 30b) are only
5 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 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
10 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
15 (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
20 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
25 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
30 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.

5 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.

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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.

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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

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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 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 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 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 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).

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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.

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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).

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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).

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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.

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Accordingly, the routine will trigger an Alert Level 1 which may generate public warnings with audio and/or visual means such as automatic 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 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 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.

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 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.

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 also be made with supervisory control & data acquisition capabilities or SCADA-enabled or Internet
5 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 detection system may be further added with other types of sensors to further enhance the
10 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.

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,
15 modified or alternatively based on the same general concept, features and working principles of the present invention.

These variations and alternative embodiments may be used in substitution of the aforesaid parts, components, materials, steps or processes
20 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 departures from the present invention but shall be considered as falling within the letter and scope of the following claims.

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While this invention has been described in connection with specific embodiments thereof, it will be understood that it is capable of further modification(s). This application is intended to cover any variations uses or adaptations of the invention following in general, the principles of the invention
30 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 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 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 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 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, integers, steps, components or groups thereof.”

CLAIMS

1. An intrusion detection apparatus for detecting intrusion of an object into a designated area, said apparatus comprising:

- 5 - at least a first detector of a first electromagnetic spectrum range;
 - at least a second detector of a second electromagnetic spectrum of a range substantially different from said first electromagnetic spectrum;

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

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

- electromagnetic wave currently detected of an intrusion by an
15 object into said designated area is compared against said background reference to determine if there exist variances between said background reference and currently detected electromagnetic waves, whereupon detecting a predetermined variance, generating a detected signal;

- 20 - a signal processing means disposed to receive detected signals from said detectors, wherein an intrusion-alert signal is generated upon said signal processor validating detected signals from both first and second detectors as detecting an intrusion at about the same location and at about the same time.

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2. An intrusion detection apparatus according to Claim 1 implemented in a high human traffic area, including an urban commuting train station wherein the designated area covers at least one of rail tracks and a platform edge of said train station.

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3. An intrusion detection apparatus according to Claim 1 wherein the first and second detectors are each selected from photoelectric point-to-point, multi-

level beam detectors.

4. An intrusion detection apparatus according to Claim 1 wherein the first
and second detectors are each selected from microwave, radio wave, infrared,
5 laser and visible light detectors.

5. An intrusion detection apparatus according to Claim 1 wherein the first
detector is a laser scanner.

10 6. An intrusion detection apparatus according to Claim 5 wherein the
scanner is a rectilinear scanner.

7. An intrusion detection apparatus according to Claim 6 wherein the laser
scanner is 2-dimensional (2D) laser scanner projecting a virtual wall parallel to
15 and defining at least part of designated area's perimeter such that a breach of
this virtual wall triggers a detecting signal.

8. An intrusion detection apparatus according to Claim 6 wherein the laser
scanner is mounted overhead the platform edge projecting downwardly and
20 sidewardly just about inside the platform edge.

9. An intrusion detection apparatus according to Claim 5 wherein sufficient
number of the laser scanners are placed to project a virtual wall to span the
length of a boarding area of train station platform.
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10. An intrusion detection apparatus according to Claim 1 wherein the
second detector comprises at least a camera selected from a still photographic
camera and a video camera.

30 11. An intrusion detection apparatus according to Claim 10 wherein the
camera comprises a pair of stereo cameras.

12. An intrusion detection apparatus according to Claim 10 wherein the camera is mounted overhead above the platform edge at at least one end of the platform.
- 5 13. An intrusion detection apparatus according to Claim 11 wherein the stereo cameras pair is trained with their optical axes parallel to the platform edge so that the stereo image receivable therewith show a composite image divided into two sides, namely a platform side and a track side, such that the platform edge appears as a single perspective line in the composite image.
- 10 14. An intrusion detection apparatus according to Claim 11 wherein a stereo camera pair is installed at each end of the platform.
- 15 15. An intrusion detection apparatus 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.
- 20 16. An intrusion detection apparatus according to Claim 1 further including at least a position sensor capable of detecting a train that is approaching, berthing or leaving the platform and generating a signal accordingly to be processed by said signal processing means.
- 25 17. An intrusion detection apparatus according to Claim 16 wherein the position sensor generates a berthing signal from the position sensor upon detecting a berthing train and sent to said signal processing means.
- 30 18. An intrusion detection apparatus according to Claim 16 wherein the position sensor is an inductive device.

19. An intrusion detection apparatus according to Claim 16 wherein a plurality of position sensors is placed overhead sufficiently to cover the length of a berthing train along the platform with a further position sensors placed after
5 and before the platform to detect arrival and departure of the train.

20. A method for detecting intrusion of an object into a designated area, said method comprising the steps of

- detecting wavelength in a first electromagnetic spectrum range;
- 10 - detecting wavelength in a second electromagnetic spectrum of a range substantially different from said first electromagnetic spectrum range;
wherein the first and second electromagnetic spectrum ranges are detected at different positions of said designated area whereby
- electromagnetic wave detected of said designated area's normal or lack-of-intrusion profile is assigned as background reference;
15 and
- electromagnetic wave currently detected of an object intruding into said designated area is compared against said background reference to determine if there exist variances between said
20 background reference and currently detected electromagnetic waves; whereupon detecting a predetermined variance, generating a detected signal;
- validating the detected signal from both first and second electromagnetic spectrum as detecting an intrusion at about the same location in said
25 designated area being received at about the same time before generating an intrusion-alert signal.

21. A method for detecting intrusion of an object according to Claim 20 comprising receiving detected wavelengths of both first and second electromagnetic spectrums and stores said data for as background reference data.

22. A method for detecting intrusion of an object according to Claim 21 comprising

- receiving currently detected wavelengths of both first and second electromagnetic spectrum,
- comparing said detected wavelengths against the background reference data to obtain variance data,
- comparing said variance data against a predetermined variance threshold and,
- upon detecting said variance data exceeding said predetermined variance threshold, triggering a first intrusion alert.

23. A method for detecting intrusion of an object according to Claim 20 including

- detecting at at least a position of a train berthing along the platform and
- ignoring detected signals from the first and/or second electromagnetic spectrums.

24. A method for detecting intrusion of an object according to Claim 20 wherein upon the triggering of the first intrusion alert,

- initiating a routine to estimate intrusion object size with a 3-dimensional geometry function detected with said first and/or second electromagnetic spectrums;
- comparing estimated object size against a predetermined threshold size; and/or
- validating whether object has been detected in at least 2 frames before triggering a second intrusion alert.

25. A method for detecting intrusion of an object according to Claim 23 wherein the entire length and/or position of the train is detected by multiple modular detecting means in an integrated manner and to operate as a single
5 function.

26. A method for detecting intrusion of an object according to Claim 20 including
- detecting at at least a position of a train berthing along the platform and
10 - ignoring detected signals from the first and/or second electromagnetic spectrums.

27. A method for detecting intrusion of an object according to any one of Claims 20 to 26 wherein the signals are transmitted remotely to be processed.
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28. A method for detecting intrusion of an object according to any one Claims 20 to 27 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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