

UNDER VEHICLE INSPECTION SHUTTLE SYSTEM

Field of the Invention

[0001] The present invention relates to inspection systems for vehicles.

[0002] In particular, this invention relates to a motorized deployable shuttle containing cameras and an image processing method to correct distortion in the images captured.

Background of the Invention

[0003] There exists the threat of terrorists or criminal elements attacking certain installations or buildings by placing bombs on the underside of vehicles entering these buildings. As such, security forces have to inspect the underside of all vehicles entering these areas to prevent such attacks.

[0004] The conventional method of doing so is to place mirrors under the vehicle to be inspected. These mirrors may be fixed on handheld booms or the mirrors may be mounted on trolleys that are pushed under the vehicle. Such products required the operator to manually move the mirror around the vehicle to visually inspect its underside.

[0005] A UK patent, now lapsed, GB 2258321A, teaches an inspection system comprising a wheeled trolley with cameras that can replace manually manipulated mirrors. The device has its own illumination means and the images captured by the line scan camera are then transferred to a computer monitor for viewing. The size of the housing has to be sufficiently large to accommodate the focal length of a camera that can scan the full width of the vehicle. GB 2258321A also has an alternative embodiment in which a system of mirrors to "fold" the light path for the camera, shortening the overall length of the trolley. However, this folding of the light path may also reduce the amount of light reaching the camera and reducing detail in the image captured.



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[0006] In addition, GB 2258321A requires the vehicle to be driven over the trolley and, because of the height of the trolley, a dedicated trough in the road or a specially-built ramp may be required. In addition to these limitations, variation in the speeds at which the vehicle is moved in relation to the trolley requires a speed monitor measure the speed of the vehicle so as to be able to control the scanning rate of the camera.

[0007] From a security point of view, this method and apparatus of GB 2258321A is dependent on several uncontrollable factors. An invention that addresses these deficiencies by speeding up the inspection process and by not introducing variation in the scanning speed of the underside of the car by the camera will be welcome.

Summary of the Invention

[0008] The present invention seeks to provide a system and method for inspecting the underside of vehicles.

[0009] Accordingly, in one aspect, the present invention provides a system comprising: a carrier, a shuttle with camera and illumination means deployable from said carrier, and a system control unit.

[0010] In another aspect, the present invention provides a method of inspecting vehicles by bringing vehicle and system into proximity, recording image of license plate of vehicle, activating shuttle to move under the vehicle, illuminating the underside of the vehicle, recording images of the underside of the vehicle, reversing shuttle to the start point, processing the recorded images, activating the shuttle for a detailed inspection of the underside of the vehicle if necessary, and saving images of the vehicle into a database.

Brief Description of the Drawings

[0011] A preferred embodiment of the present invention will now be more fully described, by way of example, with reference to the drawings of which:

[0012] FIG. 1 is a perspective, cutaway view of the present invention showing the main components;

[0013] FIG. 2 shows the positions of the carrier of the present invention during transportation (2A) by hand, at rest (2B), and the steps in the sequence of setting up the invention for use (2C to 2D);

[0014] FIG. 3 shows the deployment of the shuttle of the present invention (3A) in normal use and the deployment of the anti-vehicle spikes triggered by a vehicle attempting to escape inspection (3B and 3C).

[0015] FIG. 4 is a flowchart showing the method of inspecting vehicles under the present invention; and

[0016] FIG. 5 is a flowchart showing how the images captured are processed under the present invention.

Detailed Description of the Drawings

[0017] A detailed explanation of the present invention will now be given in accordance with a preferred embodiment of the invention. In the following description, details are provided to describe the preferred embodiment. It shall be apparent to one skilled in the art, however, that the invention may be practiced without such details. Some of these details may not be described at length so as not to obscure the invention.

[0018] The present invention, an under vehicle inspection system, comprises a wheeled carrier **100** with a housing to hold a deployable shuttle **200** with cameras, and a systems control unit (SCU) **300**. The handle **110** of the carrier also houses an anti-escape means to prevent vehicles from moving off before being allowed to leave.

[0019] The shuttle comprises several main component groups: the camera means **240**, and the lighting means **250**. The camera group **240** comprises at least one line scan camera **242** disposed in a substantially horizontal orientation and at least one pan-tilt-zoom (PTZ) camera **244** normally in a substantially vertical orientation. The preferred embodiment of the present invention has one horizontal line scan camera disposed along the center

line of the shuttle with two vertically oriented PTZ cameras on either side of the line scan camera.

[0020] The SCU **300** is a computer with a database of vehicle images matched with their respective license plate numbers. It is loaded with the appropriate software for interpreting vehicle license plate images, correcting image distortions, comparing images and has a screen to view the images. The SCU also has the means to allow the operator to remotely control the carrier and shuttle operations. The SCU may be a computer modified for this purpose as described above or it may be a purpose-built unit for this application.

[0021] In use, a suitable area of land with sufficient space for queuing and inspecting vehicles is set aside. This area may be marked out with traffic cones, traffic signs or road barriers. Vehicles in the queue are then directed to the location where the inspection system is set up.

[0022] To set up the present invention at the inspection area, the carrier with the shuttle inside is brought or wheeled (FIG. 2A) to the inspection area and laid flat (FIG. 2C). The handle **110** is then lifted upright to bring the carrier into the ready position (FIG. 2D). The carrier has suitable communication ports **140** through which it may be connected by one or more cables to the SCU **300**; or the carrier may communicate with the SCU via wireless means in other embodiments of the present invention.

[0023] Electrical power for the system may be supplied via batteries, an electric generator or an alternating current mains supply.

[0024] The carrier in its ready position can be brought to the vehicle to be inspected and positioned such that the centerline of the carrier is roughly aligned with the centerline of the vehicle. Alternatively, the vehicle may be driven to the carrier. In this case, the upright handle **110** helps to orientate the driver in positioning the vehicle in relation to the system. Neither exact alignment of the vehicle to the system, nor absolutely flat ground are necessary for the invention to work.

[0025] As the vehicle and the carrier are brought into close proximity, the operator can command one of the pan-tilt-zoom (PTZ) cameras **244** of the

shuttle to tilt and capture the image of the vehicle's license plate. A commercially-available vehicle license plate recognition program is then used to "read" or interpret the license plate image so as to derive the vehicle's license plate number. Thereafter, any previously stored images associated with that license plate number can be retrieved by the operator.

[0026] While the present invention may be position at either the front or rear end of the vehicle, it is preferable to position it at the front end of the vehicle for the anti-escape means of the invention to be fully utilized. This anti-escape feature is described in more detail below.

[0027] Once the carrier is in place near the vehicle, at the start point, the operator activates and deploys the shuttle **200** from the carrier **100** using the SCU. Wheels **210** driven by at least one electrical motor in the shuttle move the shuttle out of the carrier, under the vehicle and along the length of the vehicle. In the preferred embodiment of the present invention, the wheels of the shuttle are driven by direct drive electrical motors, with one motor driving each wheel.

[0028] A cable **130** connects the shuttle to the carrier. This cable is played out by a motorized reel **120** in the carrier. This cable has a number of functions in the present invention: providing electrical power to the shuttle, as a control cable for maneuvering the shuttle, and as a communications cable to transfer data between the SCU and the shuttle. The lines for these functions may be contained within the common sheath of the cable **130**.

[0029] In another embodiment of the present invention, the shuttle can be powered by internal batteries. Further, in this another embodiment, control of the shuttle and the transmission of the image data between the SCU may be performed wirelessly without need for the communications cable through a wireless communication means.

[0030] As the shuttle moves along the underside of the vehicle at a constant speed, the quality of the image built up from the line scans from the line scan camera is higher than that of the cited prior art.

[0031] Sufficient light for image capture of the vehicle's underside by the camera means **240** is provided by the illumination means **250**. The

illumination means comprises a source of light such as fluorescent or incandescent lamps **252** and a suitable lamp reflector **254** beamed through an illumination window **256** in the housing of the shuttle.

[0032] Alternatively, light-emitting diodes (LEDs) may be used; in which case, the light reflector may not be necessary as LEDs provide directional illumination. The lighting means are selected to provide even lighting for the camera means. These sources of light may be changed to provide the wavelength of light desired (infrared (IR), ultraviolet (UV) or visible ranges), together with appropriate filters (eg IR filters, UV-transparent windows, etc) to suit the cameras used. If desired, polarizing filters may be installed for the illumination and camera means to capture polarized images.

[0033] The camera means of the shuttle comprises a horizontally-oriented high resolution line scan camera **242** located along the centerline of the shuttle and two vertically-oriented pan-tilt-zoom (PTZ) cameras **244** located on either side of the line scan camera.

[0034] This arrangement is different from that used in the lapsed UK patent GB 2258321A where one or two horizontally oriented cameras are used. To obtain more detail from the images under the method of that invention, the image obtained has to be enlarged.

[0035] In the present invention, a camera reflector means **246** using mirrors or prisms, or both mirrors and prisms, allows the center line scan camera to capture images while the vertically-oriented PTZ cameras can capture images directly. Suitable camera windows **248** on the top surface of the shuttle housing allows the cameras to capture views of the underside of the vehicle.

[0036] In one embodiment of the present invention, the view captured by the center line scan camera **242** is planar to the orientation of the camera's horizontal orientation. In the preferred embodiment, varying the camera reflector means **246** allow other views at other angles to be captured. The advantage in this embodiment is that the camera windows **248** need not be positioned directly over the camera reflector means. This obviates the need for the window to be protected by a window glass. Without the need for a

window glass, there is no need to have a wiper mechanism to keep the glass clean, unlike that of the cited prior art.

[0037] In the present invention, distance from the lens of the center line scan camera to the reflector means is extremely short, typically less than 10 cm, to keep the shuttle compact. As such, the images captured by the line scan camera **242** through its wide angle lens will be distorted. This is where the vertically oriented PTZ cameras **244** come into play.

[0038] When the shuttle is approximately in the center (in the middle of both length and width) of the car, the two vertically oriented PTZ cameras will take a snapshot image each of the underside of the car. The image correction method of the present invention will use either one or both of these snapshot images to correct the distortion in the image formed by the center line scan camera.

[0039] Briefly, correction of the distorted image is achieved as follows. Prior to use, the system is calibrated. This is done by marking off linear intervals on straight meter rulers. Different intervals ranging from 10 cm to 100 cm in 10 cm-increments are marked on different rulers. Then distorted images taken of these rulers by the horizontal line scan camera **242** are compared with the non-distorted images of these same rulers captured by the PTZ cameras **244**.

[0040] From the table of data built-up from these comparisons, it will be possible to determine the adjustment needed to correct the distorted images captured by the center line scan camera.

[0041] In use, the undistorted image taken by the PTZ cameras is increasingly stretched or distorted at intervals using commercially available image processing software until the image corresponds closely to the distorted image captured by the line scan camera. Thus the amount or degree of distortion necessary to obtain the best match between these images from these two camera sources can be determined. Then the corresponding amount or degree of correction is applied to the image from the center line scan camera to obtain an undistorted image for viewing, analysis and comparison.

[0042] This is performed by programming the software to divide the image assembled by the line by line scanning of the line scan camera into several sections (typically six to ten sections). By comparing each of the distorted, sectioned images with the ones captured by the vertical PTZ cameras (which have little or no distortion), the system applies an appropriate degree or amount of correction to the images to remove the distortions.

[0043] While the shuttle can move at a constant speed while scanning, there may be circumstances under which the speed of the shuttle may not be constant. An example of such a situation is when the shuttle is running on internal batteries and the batteries are weak.

[0044] As a precaution against such situations, the shuttle has a speed sensing device to measure and record the speed at which the scanning of the underside of the car was done. If the speed is not constant within a predetermined, allowable range, a correction may be applied to the final image to improve it. Such techniques are well known to anyone skilled in the art.

[0045] As previously described, the vehicle license plate recognition software reads the license plate of the vehicle being examined. The operator can then retrieve previous images of the same vehicle stored in the database. A commercially-available image comparison software is then used to compare these two images. Any discrepancy will be highlighted as this may indicate a suspicious object.

[0046] Any raw or processed images of each vehicle may be saved in the database in one or more entries associated with its license plate number.

[0047] For detailed viewing of any suspicious objects, the operator may subsequently direct the shuttle to stop near or under the area of interest. He can then manipulate the two side PTZ cameras **244** via the SCU to zoom in on any suspicious objects for detailed inspection.

[0048] After the shuttle has run the length of the vehicle, the operator can issue a command for it to be retracted to the start point or into the carrier. Alternatively, the SCU can be programmed to do so automatically. In the daytime, the when the shuttle moves past the end of the vehicle and

encounter sunlight, the cameras will record a very high reading of light, signaling that the shuttle has move past the shadow formed by the vehicle. At night, the reverse situation is used as the signal. When the shuttle has moved past the vehicle and senses little or no light from the illumination means reflected off the underside of the vehicle, it can automatically retract itself. A manual signal from the operator can overcome ambiguities caused by lighting levels that are not sufficiently extreme to trigger this automatic function in the present invention such as when the inspection is performed under a shelter.

[0049] When the shuttle begins to retract, either automatically or on command, its motorized wheels will turn in the reverse direction. The motorized reel from which the communications cable (if used) is drawn, begins to wind the cable at a rate commensurate with the speed of the shuttle. The shuttle may be fully withdrawn into the carrier or remain just outside the carrier, at the start point, ready to be used for the next vehicle.

[0050] In yet another embodiment, as advancements in minaturisation of cameras are made in the future, use of a very compact center line scan camera will allow the line scan camera to be oriented vertically. This embodiment obviates the need for a camera reflector means while the PTZ cameras are still required for image correction.

[0051] The present invention has yet another feature, that of a means to stop a vehicle attempting to move off before being allowed to by the inspectors. The anti-escape means of the present invention comprises spring-loaded spikes **112** on two spring-loaded arms **114** normally hidden safely within the handle **100** (FIG. 3). In use, the upright handle is in front of the vehicle. A driver attempting to escape by driving off before being allowed to will knock down the handle (FIG. 3B). This will immediately trigger the deployment of the arms and the spikes as shown in the planar view of FIG 3C.

[0052] When knocked over, a mechanism in the handle will release the two arms containing the spring-loaded spikes. The spikes are of sufficient dimensions and characteristics to puncture the pneumatic tires of the

vehicle, rendering the vehicle inoperable or at least extremely difficult to control. The dimensions of the handle and arms are predetermined to cover the width range of most vehicles to be inspected.

[0053] This anti-escape feature is most effective when employed in conjunction with other means of preventing such incidents (eg road barriers). A variety of safety features may be incorporated to prevent accidental deployment of the spikes from injuring operators, especially during set up of the system.

[0054] The problem of using the system on uneven ground may be overcome by the use of a rail means. This rail means may be simply two parallel rails secured at the width and supported such that the shuttle may run smoothly under the vehicle to be inspected.

[0055] There are many advantages of the preferred embodiment of the invention. One advantage of the preferred embodiment is that under vehicle inspections may be carried out quickly and efficiently without the need for a trough or recess to accommodate the system.

[0056] In addition, the use of a motorized shuttle allows a constant speed when scanning the vehicle so as to obtain a high-quality image. By using the present invention, inspection of vehicles may be done with fewer personnel.

[0057] Yet another advantage is the correction of the distorted images captured by the center line scan camera **242** by the processing method used, in conjunction with the paired PTZ cameras. The arrangement of camera, lighting and reflector means allow a very compact system to be made. In fact, a working model of the present invention is only 40 cm wide x 55 cm long x 9 cm tall. Further reduction in these dimensions is envisaged with advances in the illumination, camera and control means. However, it is also possible to scale up the present invention to accommodate wider vehicles.

[0058] In another embodiment of the present invention for inspecting wide vehicles such as railway cars or tractor trailers, two line scan cameras disposed side-by-side in the shuttle with a single PTZ camera between

them may be used. The images captured by the line scan cameras may be "stitched" or merged together by a suitable image processing programme to form a whole, undistorted image for analysis and examination.

[0059] Such an embodiment using two or more line scan cameras may also be applied to inspecting vehicles such as sedan or saloon cars from side to side rather than from one end to the other.

[0060] It can be appreciated by anyone skilled in the art that the present invention, being remotely controlled either by wire or by wireless means, is advantageous from a security point of view. The operators may safely inspect the vehicle from a distance or from behind a blast shelter, protected from detonation of any bombs or weapons in the vehicle.

[0061] In addition, the present invention can be easily adapted for inspecting rail tracks by using an appropriately sized shuttle in an inverted position after installing appropriate wheels and an appropriate wireless control and communication means.

[0062] The present invention therefore provides a vehicle inspection system and a method for correcting distortions in captured images that allow users to overcome, or at least alleviate, the problems of the prior art.

[0063] It will be appreciated that although one preferred embodiment has been described in detail, various modifications and improvements can be made by a person skilled in the art without departing from the scope of the present invention.

Claims

1. A system of inspecting a vehicle using cameras, said system comprises:
a carrier;
a shuttle deployable from said carrier; and
a system control unit.
2. The system according to Claim 1, wherein said carrier comprises:
a plurality of wheels;
a housing;
at least one communications port; and
a handle.
3. The carrier according to Claim 2, wherein said handle further houses spring loaded arms and spikes to puncture pneumatic tires of said vehicle if said handle is knocked over by said vehicle.
4. The system according to Claim 1, wherein said shuttle comprises:
a camera means;
an illumination means;
a shuttle housing; and
a plurality of motorized wheels.
5. The shuttle according to Claim 4, wherein said shuttle further comprises a wireless control means.
6. The shuttle according to Claim 4, wherein said camera means comprises:
at least one line scan camera, and
at least one vertically-oriented pan-tilt-zoom camera.
7. The shuttle according to Claim 4, wherein camera means further comprises:
a camera reflector means; and

said at least one line scan camera is oriented horizontally.

8. The shuttle according to Claim 5, wherein said at least one line scan camera is oriented vertically.
9. The shuttle according to Claim 7, wherein said camera reflector means comprises prisms.
10. The shuttle according to Claim 7, wherein said camera reflector means comprises mirrors.
11. The shuttle according to Claim 7, wherein said camera reflector means comprises prisms and mirrors.
12. The system according to Claim 1, wherein said system may be adaptable for inspecting rail tracks by installing appropriate wheels and a wireless command and communications means.
13. A method of inspecting the underside of a vehicle using an under vehicle inspection system, said method comprises:
bringing vehicle and carrier and shuttle of said system into proximity at a start point;
recording image of license plate of said vehicle with at least one pan-tilt-zoom camera housed in said shuttle;
activating shuttle to move under said vehicle approximately along the approximate centerline of said vehicle;
illuminating underside of said vehicle with an illumination means housed in said shuttle;
recording line images of said underside of said vehicle with a line scan camera housed in said shuttle;
recording at least one image of said underside of said vehicle with said at least one pan-tilt-zoom camera housed in said vehicle;

reversing said shuttle to said start point when said shuttle passes end of said vehicle;
processing said images recorded by said cameras to obtain processed images;
activating said shuttle to move to any position under said vehicle for detailed examination if necessary;
associating said images with said license plate number of said vehicle; and
saving said association, said license plate number and said images in at least one database of said system.

14. The method according to Claim 11, said processing of said images further comprises:

interpreting license plate number of said license plate from said image of license plate of said vehicle;
retrieving said saved images associated with said license plate number from said at least one database of said vehicle, if any;
assembling at least one assembled image from said line images recorded by said line scan camera;
distorting at least one image recorded by said at least one pan-tilt-zoom camera at intervals until at least one best match with said at least one assembled image is obtained;
applying corresponding correction to said at least one assembled image to obtain a processed image;
comparing said processed image with said saved image associated with said vehicle, if any; and
highlighting any differences between said processed image and said save image.

15. A method of inspecting a vehicle from one side of said vehicle to the other side of said vehicle by use of a deployable shuttle having two line scan cameras, mounted side by side, said method comprises:

activating said shuttle to move under said vehicle from said one side of said vehicle to the said other side;
illuminating underside of said vehicle;
capturing line scan images of said underside of said vehicle;
correcting distorted images obtained by said line scan cameras; and
merging said images to form a whole processed image.