

ASSET MONITORING SYSTEM

FIELD

This invention relates to an asset monitoring system to monitor assets stored in a warehouse for real-time monitoring of asset count and location.

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BACKGROUND

Cargo or asset fraud has been an ever-present issue in trade financing. Examples include phantom trade with no cargo, incompliant cargo, cargo loss from collusion between borrowing & warehouseman, and multiple financing for the same cargo. More lately, documentation fraud is forcing the trade financing business into the digital age. Examples include fake bills of lading, fake invoices, fake warehouse receipts, fake certificates, fake financial instruments such as letters of credit or stand-by letters of credit, and multiple financing for the same document. To reduce occurrences of fraud, it is thus important to have means to validate the physical state and quantity of the cargo with the shipping, commercial and financial documents. In a supply chain, cargo or assets typically spends most of its time in warehouses, while transit time is significantly lower by comparison. Thus, it is important that assets in warehouses should be monitored for security reasons. However, in a trade or financing transaction, there are currently no good ways to verify that an asset in a particular documentation is in the warehouse as it should be because there are presently no good solutions to track assets real-time in a warehouse. Although many warehouses today deploy off-the-shelf CCTV surveillance, many warehouses also concurrently store assets belonging to different entities, and in many cases, it is impossible to visually distinguish or confirm from the CCTV footage which assets belong to which entities. For example, as can be seen in FIG. 1 (prior art) which shows a warehouse in which aluminium alloy is being stored for different entities, if any of the stored alloy is stolen, CCTV surveillance can show the alloy being removed but will not be able to tell whose alloy has been taken. In existing warehouse monitoring systems, tags with printed barcodes or other forms of visual or machine-readable identification (for example, tags that use Bluetooth Low Energy (BLE) or RFID beacons as signal emitting devices), may be affixed to each asset in the warehouse. However, this still does not allow CCTV surveillance to determine whose asset has been removed as the identity of each asset can only be determined when its tag is scanned or visually read, and even then, using signal emitting tags cannot guarantee perfect reads of their emitted signals. There is thus a need for an asset monitoring system that overcomes the shortfalls of CCTV surveillance and using asset tagging as a security measure.

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SUMMARY

According to a first aspect, there is provided an asset monitoring system for real-time monitoring of assets in a warehouse, the system comprising: at least one camera provided in the warehouse to obtain images of assets in the warehouse; an image processing software module provided in connection with the at least one camera and configured to automatically assign a unique identification to every asset imaged for a first time by the at least one camera and subsequently continuously detect, recognize and track assets assigned with unique identification in the warehouse from the images obtained by the at least one camera; a location determination software module configured to generate, from the images obtained of the assets, spatial coordinates of the assets corresponding to physical locations of the assets in the warehouse; and a digital inventory stored in a database, the digital inventory comprising the generated spatial coordinates and status information of the assets, the digital inventory configured to be accessible via at least one computing device to allow viewing and updating of the status information of the assets.

The system may further comprise a monitoring software module configured to continuously monitor data in the digital inventory and continuously monitor detection, recognition and tracking of the assets by the imaging processing software module in order to determine occurrence of events including:

- (i) movement of an asset within the warehouse;
- (ii) removal of an asset from the warehouse;
- (iii) item movement, item removal and/or asset separation for an asset comprising multiple items; and
- (iv) tampering with an asset.

The monitoring software module is further configured to perform image comparison to detect any change in geometry of each asset in the obtained images and conclude that item removal or asset separation has occurred when a change in geometry has been detected for an asset at different times.

The monitoring software module is further configured to check status information of an asset for which any one of events (i) to (iv) has occurred to determine if authorization has been given for the event to occur and to trigger an alert if it is determined that any one of events (i) to (iv) has occurred without authorization having been given.

The system may further comprise an alarm configured to be triggered when the monitoring software module determines that any one of events (i) to (iv) has occurred for any asset without authorization having been given

5 The system may further comprise a modelling software module configured to generate, for each asset, a digital asset comprising a 3D digital model of the asset, and to show all generated digital assets in a 3D digital space corresponding to the warehouse on a display screen of at least one computing device.

10 A 3D geometry and virtual location of each digital asset in the 3D digital space may correspond to 3D geometry and actual physical location of its corresponding asset in the warehouse.

Each digital asset shown on the display screen may be configured to be selectable using an input device of the at least one computing device for at least one of: viewing status information of the
15 selected digital asset and unencumbered viewing of the selected digital asset in the 3D digital space.

Each digital asset shown on the display screen may be further configured to allow only an authorized user of the at least one computing device to update status information of the selected
20 digital asset.

The system may further comprise an inventory updating software module provided in association with the digital inventory and configured to allow status information of assets in the warehouse to be input in the digital inventory by only an authorized user via a computing device.

25 The at least one camera may comprise multiple cameras provided at different locations in the warehouse to obtain images of the assets from different viewing angles.

At least one of the multiple cameras may comprise a mobile camera.

30 According to a second exemplary aspect, there is provided a method of real-time monitoring assets in a warehouse, the method comprising:

- (a) obtaining images of assets in the warehouse via at least one camera provided in the warehouse;
- 35 (b) automatically assigning a unique identification to every asset imaged for a first time by the at least one camera via an image processing software module provided in connection with the at least one camera;

- (c) the image processing software module continuously detecting, recognizing and tracking assets assigned with unique identification in the warehouse from the images obtained by the at least one camera;
- 5 (d) generating, from the images obtained of the assets, spatial coordinates of the assets corresponding to physical locations of the assets in the warehouse via a location determination software module;
- (e) storing a digital inventory comprising the generated spatial coordinates and status information of the assets in a database; and
- 10 (f) viewing and updating the status information of the assets via at least one computing device provided with access to the digital inventory.

The method may further comprise:

- 15 (g) a monitoring software module continuously monitoring data in the digital inventory and continuously monitoring detection, recognition and tracking of the assets by the imaging processing software module; and
- (h) the monitoring software module determining occurrence of events including:
- (I) movement of an asset within the warehouse;
- (II) removal of an asset from the warehouse;
- 20 (III) item movement, item removal and/or asset separation for an asset comprising multiple items; and
- (IV) tampering with an asset.

The method may further comprise:

- 25 (i) the monitoring software module performing image comparison to detect any change in geometry of each asset in the obtained images and concluding that item removal or asset separation has occurred when a change in geometry has been detected for an asset at different times.

The method may further comprise:

- 30 (j) the monitoring software module checking status information of an asset for which any one of events (I) to (IV) has occurred to determine if authorization has been given for the event to occur and triggering an alert if it is determined that any one of events (I) to (IV) has occurred without authorization having been given.

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The method may further comprise:

- (k) an alarm triggering when the monitoring software module determines that any one of events (I) to (IV) has occurred for any asset without authorization having been given

5 The method may further comprise:

- (l) a modelling software module generating, for each asset, a digital asset comprising a 3D digital model of the asset, and showing all generated digital assets in a 3D digital space corresponding to the warehouse on a display screen of at least one computing device.

10 The method may further comprise:

- (m) selecting a digital asset shown on the display screen using an input device of the at least one computing device for at least one of: viewing status information of the selected digital asset and unencumbered viewing of the selected digital asset in the 3D digital space.

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The method may further comprise:

- (n) only an authorized user of the at least one computing device updating status information of the selected digital asset.

20 The method may further comprise:

- (o) only an authorized user inputting status information of assets in the warehouse via a computing device provided with an inventory updating software module provided in association with the digital inventory.

25 **BRIEF DESCRIPTION OF FIGURES**

In order that the invention may be fully understood and readily put into practical effect, there shall now be described by way of non-limitative example only exemplary embodiments of the present invention, the description being with reference to the accompanying illustrative drawings.

FIG. 1 (prior art) is a still image of CCTV footage of assets being stored in a warehouse.

30 FIG. 2 is an architecture diagram of an asset monitoring system.

FIG. 3 is a fisheye view still image of a video obtained by a camera in the system of FIG. 2.

FIG. 4 is a regular perspective view still image generated by an image processing software module of the system of FIG. 2 from the image of FIG. 3.

FIG. 5 is a screen capture of digital assets in a 3D digital space showing a specific digital asset
35 being selected.

FIG. 6 is multiple screen captures of the digital assets of FIG. 5 viewed from different angles.

DETAILED DESCRIPTION

Exemplary embodiments of an asset monitoring system 100 will be described below with reference to FIGS. 2 to 6 wherein the same reference numerals refer to the same or similar parts.

5 In general, as can be seen in FIG. 2, an asset monitoring system 100 is provided for real-time monitoring of asset count and location in a warehouse 10 where assets 20 are stored. An asset 20 in the warehouse 10 may comprise a single item or multiple items. An asset 20 comprising multiple items may be stored in one or more packages, boxes, bundles, crates, pallets, stacks, or any other collective storage forms in the warehouse 10. Where an asset 20 comprises multiple
10 items, the multiple items may be stored together as a group at one location in the warehouse 10, or the multiple items may be stored separately at different locations in the warehouse 10. Assets 20 in the warehouse 10 may comprise anything ranging from raw materials to food, production parts to finished goods and so on.

15 The system 100 includes at least one camera 30 provided in the warehouse 10 to continuously obtain images 22 of the assets 20 in the warehouse 10. In this application, the word “image” is used to refer to photographs and/or videos 22 of the assets 20. For example, FIG. 3 is a still image 22 of a moment in time of an exemplary video obtained by a camera 30. In FIG. 3, a specific asset 20 has been indicated for ease of reference.

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The system 100 further comprises an image processing software module 33 provided in connection with the at least one camera 30. The image processing software module 33 is configured to automatically assign a unique identification to every asset 20 imaged for a first time by the at least one camera 30 and subsequently continuously detect, recognize and track
25 assets 20 assigned with unique identification in the warehouse 10 from the images 22 obtained by the at least one camera 30. As can be seen in FIG. 4, the asset 20 indicated in FIG. 3 has been detected from the image 22 of FIG. 3, and is shown surrounded by a rectangle generated by the image processing software module 33. The image processing software module 33 is preferably able to correct for distortions, as can be seen in the difference between the fisheye view image
30 22 shown in FIG. 3 and the regular perspective view image 22P generated by the image processing software module 33 as shown in FIG. 4.

As shown in FIG. 2, the system 100 further comprises a location determination software module 40 configured to generate, from the images 22 obtained of the assets 20 and processed by the
35 image processing software module 33, spatial coordinates 42 of each asset 20 corresponding to

the three dimensional (3D) geometry and the physical location of each asset 20 in the warehouse 10. The spatial coordinates 42 comprise coordinates in a 3D coordinate system that takes reference from the actual storage space in the warehouse 10. The system 100 preferably comprises multiple cameras 30 provided at different locations in the warehouse to obtain images 22 of the assets 20 from different viewing angles so that the spatial coordinates 42 of each asset 20 can be more accurately generated from multiple images 22 of different views of the same asset 20. In an exemplary embodiment, the 3D coordinate system may comprise the Cartesian coordinate system so that the spatial coordinates 42 of an asset 20 in the warehouse 10 comprise a set of multiple x, y and z numerical values corresponding to multiple surface points of the asset 20 along three mutually perpendicular predetermined axes with reference to a predetermined origin location point in the warehouse 10. Other known 3D coordinate systems, such as the cylindrical coordinate system or the spherical coordinate system, for example, may alternatively be used for establishing the spatial coordinates 42 of the assets 20 in the warehouse 10.

From the generated spatial coordinates 42, therefore, the 3D geometry and location of each asset 20 in the warehouse 10 are obtained without requiring any location sensors to be attached to each asset in the warehouse for asset location tracking, and without requiring the warehouse to be divided into physically demarcated storage spaces that require keeping a register of which specific demarcated storage space each asset is located at in the warehouse. In an exemplary embodiment, the spatial coordinates 42 of every asset 20 may comprise a point cloud comprising a set of data points in space that define the asset 20. From the generated spatial coordinates 42, a 3D render of every asset 20 in its specific location in a 3D space corresponding to the warehouse 10 may be generated, as will be described in greater detail below.

The system 100 also further comprises a digital inventory 50 stored in a database 60 that is provided on a server (not shown). The digital inventory 50 comprises the generated spatial coordinates 42 as well as status information of the assets 20 in the warehouse 10, and is configured to be accessible via at least one computing device 90 to allow viewing and updating of the status information of the assets 20. Status information of an asset 20 may comprise information such as: the unique identification of the asset 20 as assigned by the image processing software module 33, asset owner identity, asset description, storage dates of the asset 20, whether or not the asset 20 is presently authorized for events such as movement or removal of the asset 20, and so on. Appreciably, asset description may be supplemented with additional data from other sources such as weighing scale data when the asset 20 is weighed, or data from quality or sampling checks whereby such reports can be matched to the asset 20 being checked. Preferably,

status information of the assets 20 in the warehouse 10 may be input or updated in the digital inventory 50 only by an authorized person.

The system 100 may further comprise an inventory updating software module 55 provided in association with the digital inventory 50. The inventory updating software module 55 is configured to allow the status information of assets 20 to be viewed and updated in the digital inventory 50 via the at least one computing device 90, which may be a computer, smart phone, tablet, scanner and so on. More details on updating the status information of assets 20 in the digital inventory 50 will be described below.

The at least one computing device 90 is preferably provided with barcode and QR code scanning functionality for reading information stored in barcodes and/or QR codes provided on the assets 20. For example, the at least one computing device 90 may additionally or alternatively be provided with Bluetooth Low Energy (BLE), RFID and other signal scanning capability to read BLE, RFID or other signal-emitting tags that may be affixed to the assets 20. In this way, information provided in the BLE/RFID/signal-emitting tags may be used by the asset identification functionality of the system 100 to assign digital identification to new incoming assets 20 that are added to the warehouse 10 inventory, thereby allowing the system 100 to connect the physical world of the warehouse 10 and assets 20 with the digital world of shipping, commercial, and financial documentation and interactions related to the assets 20. In an alternative configuration, the system 100 may comprise one or more dedicated special tag readers (not shown) configured to automatically detect and assign identity to incoming new assets 20 by automatically scanning and reading BLE/RFID/signal-emitting tags that are already attached to the incoming assets 20.

The images 22 obtained by the at least one camera 30 may also be stored in the database 60, preferably separately from the digital inventory 50, to serve as raw data that may be used for review, analysis or verification purposes, for example.

To enhance functionality of the system 100, the system 100 preferably further comprises a monitoring software module 70. The monitoring software module 70 is configured to continuously monitor data in the digital inventory 50 and also continuously monitor detection, recognition and tracking of the assets 20 by the imaging processing software module 33 in order to determine occurrence of at least the following events:

- (i) movement of an asset 20 within the warehouse 10;

- (ii) removal of an asset 20 from the warehouse 10;
- (iii) item movement, item removal and/or asset separation for an asset 20 comprising multiple items; and
- (iv) tampering with an asset 20.

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To determine if any asset 20 has been moved, the at least one camera 30 is provided with currently available motion detection capability. Event (i) above (i.e. movement of an asset 20 within the warehouse 10) can then be determined as having occurred if the monitoring software module 70 determines that motion has been detected by the at least one camera 30 and that an
10 asset 20 has been tracked from one location to another location in the warehouse 10 by the imaging processing software module 33. Object tracking may include the image processing software module 33 determining that an object has appeared at a new location and recognising that the object at the new location is actually an asset 20 that was previously at another location. By utilizing the motion detecting capability of the at least one camera 30 and the object tracking
15 capability of the image processing software module 33, the monitoring software module 70 can thus determine that an asset 20 has been moved within the warehouse 10.

As a secondary confirmation of movement of an asset 20 within the warehouse, by comparing currently generated spatial coordinates 42 (generated from currently obtained images 22 of an
20 asset 20 in the warehouse 10) with previously generated spatial coordinates 42 of the same asset 20, if the currently generated spatial coordinates 42 are found not to match the previously generated spatial coordinates 42, it can also be determined that the location of the asset 20 has changed and therefore movement of the asset 20 has occurred.

25 Event (ii) above (i.e. removal of an asset 20 from the warehouse 10) can be determined as having occurred if the monitoring software module 70 determines that an asset 20 is no longer detected by the imaging processing software module 33. As a secondary confirmation of removal of an asset 20, event (ii) can also be determined as having occurred if spatial coordinates can no longer be generated from images 22 currently obtained by the at least one camera 30 for an asset 20
30 having previously generated spatial coordinates. This means that the asset 20 cannot be found in the images 22 currently obtained by the at least one camera 30 and the asset 20 has therefore been removed from the warehouse 10.

Event (iii) above (i.e. item movement, item removal and/or asset separation for an asset 20
35 comprising multiple items) can be determined as having occurred by comparing geometries of

the assets 20 from the obtained images 22 at different time stamps. For example, a geometry of a pallet containing nine boxes would be different from a geometry of the same pallet containing only eight boxes after one of the nine boxes has been removed or separated from the pallet. Accordingly, the monitoring software module 70 is preferably configured to perform image
5 comparison to detect any change in geometry of each asset 20 in the obtained images 22 and conclude that item movement/removal or asset separation has occurred when a change in geometry has been detected for the same asset 20 at different times.

Such change in asset geometry can also be monitored and applied to single item assets 20 to
10 determine event (iv) above (i.e. tampering with an asset 20). For example, where an asset 20 comprises a bag of coffee beans, removal of some of the beans would lead to the bag flattening and such change in geometry and volume of the bag can similarly be detected to conclude that theft from the single bag has occurred.

15 To further better identify the nature of event (iv) above (i.e. tampering with an asset 20) that has been determined to have occurred, the monitoring software module 70 may be further configured to receive input from a secondary source such as a person or a detecting device (which may comprise a camera provided on a forklift) who was present at the time the event (iv) occurred and who can provide input as to the nature of the event (iv), for example, whether the event (iv)
20 was an accident. For example, an asset 20 comprising a pile of bags on a pallet may experience one or more of the bags spontaneously falling off due to poor placement at the time of placing the asset 20 in its storage location in the warehouse 10. Such an event would give rise to change in geometry of the asset 20, and this would be detected and determined by the monitoring software module 70 as event (iv) having occurred. A person or detecting device present at the
25 time of the event occurring would thus be able to provide secondary input identifying that this event (iv) was accidental and not a tamper.

The monitoring software module 70 is preferably further configured to check the status information of an asset 20 for which any one of events (i) to (iv) has occurred to determine if
30 authorization has been given for the event to occur. If an event occurs for which authorization has not been given, the monitoring software module 70 is accordingly preferably further configured to trigger an alert. The system 100 may accordingly further comprise an alarm (not shown) that is configured to be triggered when the monitoring software module 70 determines that any one of events (i) to (iv) has occurred for any asset 20 without authorization having been
35 given, so that an investigation into the unauthorized event may be launched.

The system 100 preferably further comprises a modelling software module 80 configured to generate a 3D digital model 88 of the warehouse 10 and the assets 20 therein. The modelling software module 80 is configured to generate, for each asset 20, a digital asset 82 comprising a 3D digital model of the asset 20 and to show all generated digital assets 82 in a 3D digital space 81 corresponding to the warehouse 10 on a display screen 99 of at least one computing device 90. 3D geometry and virtual location of each generated digital asset 82 in the 3D digital space 81 correspond to actual 3D geometry and physical location of its corresponding asset 20 in the warehouse 10. A digital asset 82 corresponding to an asset 20 in the warehouse 10 may be generated from at least the generated spatial coordinates 42 of the asset 20. The images 22 obtained by multiple cameras 30 provided in the system 100 may also be used to perform 3D reconstruction and image render of the digital assets 82 and digital warehouse 81 during generation of the digital model 88, using known 3D reconstruction and image rendering techniques.

On the display screen 99, each digital asset 82 is preferably configured to be selectable using an input device (not shown; typically a pointing device such as a touch screen, mouse, touch pad, track pad, pointing stick, joystick, and so on). Selecting a digital asset 20 may be for the purpose of viewing status information 82-I of the selected digital asset 82 and/or unencumbered viewing of the geometry and virtual location of the selected digital asset 82 in the 3D digital space 81, as shown in FIG. 5 that comprises an exemplary screenshot where a specific digital asset 82-S has been selected and status information 82-I corresponding to the specific digital asset 82-S appears on the display screen 99. In one embodiment, the modelling software module 80 may be configured to highlight or show only the selected digital asset 82 on the display screen 99 after a digital asset 82 has been selected. The other digital assets 82 corresponding to other assets in the warehouse 10 may optionally be dimmed or hidden. In this way, the virtual location of the selected digital asset 82 in the 3D digital space 81 may be more clearly viewed on the display screen 99.

As mentioned above, each asset 20 may comprise multiple items that may be stored together at one location or stored separately at different locations in the warehouse 10. Thus, for an asset 20 that comprises multiple items of specific geometries stored in different locations in the warehouse 10, its corresponding digital asset 82 shown on the display screen 99 would also be shown as multiple digital items having the same specific geometries at corresponding different virtual locations in the 3D digital space 81 (not depicted in the figures). In this way, by selecting its digital asset 82, determination of the actual multiple physical locations of an asset 20

comprising multiple items stored separately in the warehouse 10 may be more easily made by viewing the specific multiple geometries and virtual locations of the multiple digital items comprised in one digital asset 82 in the 3D digital space 81 on the display screen 99.

5 In a preferable exemplary embodiment, the system 100 is provided with multiple cameras 30 as mentioned above so that multiple concurrent images 22 obtained by the multiple cameras 30 from different viewing angles may be used to generate the spatial coordinates 42 and the 3D renders of the digital assets 82 in the 3D digital space 81, thus providing a 3D digital model 88 of all the assets 20 in the warehouse 10 with corresponding length, breadth, depth/height and
10 volume information. This allows the whole warehouse 10 to be viewed as a virtual totality in 3D from different angles, as can be seen in the exemplary screenshots in FIG. 6.

In embodiments of the system 100 where multiple cameras 30 are provided, one or more of the multiple cameras 30 may be mobile, such as by mounting a camera 30 on a forklift (not shown)
15 that is free to move about the warehouse 10 to obtain more and closer images of the assets 20 in the warehouse 10. Providing the system 100 with one or more mobile cameras 30 is particularly useful for high-density warehouses so that increased resolution of the assets 20 (and storage structures if desired, such as pallet racks, not shown) can be used to generate a more detailed render of the digital assets 82 and storage structures (if desired) in the 3D digital space 81.

20 Each digital asset 82 is preferably further configured to allow only an authorized user of the at least one computing device to update the status information of a selected digital asset 82 and to store status information updates for its corresponding asset 20 in the digital inventory 50. In this way, only an authorized person may change the status information of assets 20 so that assets 20
25 in the warehouse 10 may not be moved or removed from the warehouse 10 without permission having been given by only an authorized person. It should be noted that status information updates on assets 20 in the digital inventory 50 may be made via their corresponding digital assets 82 in addition to or in place of updating the status information of assets 20 via the inventory updating software module 55 provided with the digital inventory 50 as described
30 above.

In an exemplary embodiment of the system 100, the various software modules 33, 40, 55, 70, 80 described above are installed and run on a same server (not shown) as the one in which the database 60 is stored, while the at least one computational device 90 interfaces with the server
35 as a client. In alternative embodiments, the software modules 33, 40, 55, 70, 80 may be installed

and run separately on two or more servers. In yet other embodiments, one or more of the software modules 33, 40, 55, 70, 80 (for example the modelling software module 80) may be installed and run on one or more client computing devices 90 instead, depending on the processing and computational requirements available and the desired operating speed. For example, the various software modules 33, 40, 55, 70, 80 may be run on one or more of: an on-site server provided in the warehouse 10, a public cloud, and an on-premise private cloud. The image processing software module 33 may alternatively be run on hardware provided in the at least one camera 30.

Using the above described asset monitoring system 100, all assets 20 can thus be tracked and monitored in real-time and preferably have real-time X,Y,Z positions in the 3D digital model 88 of the warehouse 10 and assets 20. Showing their corresponding digital assets 82 on a display screen 99 allows the assets 20 in the warehouse 10 to be virtually viewed, identified and monitored in real-time without requiring staff to be deployed at the warehouse 10 to inspect/scan and confirm the locations of specific assets 20 in the warehouse 10. In an exemplary embodiment of the system 100, any tamper or unauthorized events occurring for the assets 20 will trigger an alert while also identifying which assets 20 experienced the unauthorized event. The system 100 thus not only provides real-time and continuous viewing of the assets 20 in the warehouse 10, the system 100 may also identify each and every asset 20 in the warehouse through their corresponding digital assets 82 in the 3D digital model 88. The system 100 therefore allows assets 20 in warehouses 10 to be closely and meticulously monitored while lowering reliance on the dependability of human guards, strength of physical barrier structures and onerous physical tagging and scanning of individual asset items.

Whilst there has been described in the foregoing description exemplary embodiments of the present invention, it will be understood by those skilled in the technology concerned that many variations and combination in details of design, construction and/or operation may be made without departing from the present invention. For example, while the embodiments described above have been in relation to assets or cargo in the warehouse, the same system may be used to monitor persons as well as machinery in the warehouse to enhance asset monitoring with reference to what is done by such persons and machinery to the assets in the warehouse.

CLAIMS

1. An asset monitoring system for real-time monitoring of assets in a warehouse, the system comprising:

5 at least one camera provided in the warehouse to obtain images of assets in the warehouse;
an image processing software module provided in connection with the at least one
camera and configured to automatically assign a unique identification to every
asset imaged for a first time by the at least one camera and subsequently
continuously detect, recognize and track assets assigned with unique identification
10 in the warehouse from the images obtained by the at least one camera;
a location determination software module configured to generate, from the images
obtained of the assets, spatial coordinates of the assets corresponding to physical
locations of the assets in the warehouse, the spatial coordinates comprising
coordinates in a 3D coordinate system that takes reference from actual storage
15 space in the warehouse; and
a digital inventory stored in a database, the digital inventory comprising the generated
spatial coordinates and status information of the assets, the digital inventory
configured to be accessible via at least one computing device to allow viewing and
updating of the status information of the assets.

2. The system of claim 1, further comprising a monitoring software module configured to continuously monitor data in the digital inventory and continuously monitor detection, recognition and tracking of the assets by the imaging processing software module in order to determine occurrence of events including:

25 (i) movement of an asset within the warehouse;
 (ii) removal of an asset from the warehouse;
 (iii) item movement, item removal and/or asset separation for an asset comprising multiple
 items; and
 (iv) tampering with an asset.

3. The system of claim 2, wherein the monitoring software module is further configured to perform image comparison to detect any change in geometry of each asset in the obtained images and conclude that item removal or asset separation has occurred when a change in geometry has been detected for an asset at different times.

4. The system of claim 2 or claim 3, wherein the monitoring software module is further configured to check status information of an asset for which any one of events (i) to (iv) has occurred to determine if authorization has been given for the event to occur and to trigger an alert if it is determined that any one of events (i) to (iv) has occurred without authorization having been given.
5. The system of claim 4, further comprising an alarm configured to be triggered when the monitoring software module determines that any one of events (i) to (iv) has occurred for any asset without authorization having been given
6. The system of any one of the preceding claims, further comprising a modelling software module configured to generate, for each asset, a digital asset comprising a 3D digital model of the asset, and to show all generated digital assets in a 3D digital space corresponding to the warehouse on a display screen of at least one computing device.
7. The system of claim 6, wherein a 3D geometry and virtual location of each digital asset in the 3D digital space corresponds to 3D geometry and actual physical location of its corresponding asset in the warehouse.
8. The system of claim 7, wherein each digital asset shown on the display screen is configured to be selectable using an input device of the at least one computing device for at least one of: viewing status information of the selected digital asset and unencumbered viewing of the selected digital asset in the 3D digital space.
9. The system of claim 8, wherein each digital asset shown on the display screen is further configured to allow only an authorized user of the at least one computing device to update status information of the selected digital asset.
10. The system of any one of the preceding claims, further comprising an inventory updating software module provided in association with the digital inventory and configured to allow status information of assets in the warehouse to be input in the digital inventory by only an authorized user via a computing device.
11. The system of any one of the preceding claims, wherein the at least one camera comprises multiple cameras provided at different locations in the warehouse to obtain images of the assets from different viewing angles.

12. The system of claim 11, wherein at least one of the multiple cameras comprises a mobile camera.

13. A method of real-time monitoring assets in a warehouse, the method comprising:

- (a) obtaining images of assets in the warehouse via at least one camera provided in the warehouse;
- (b) automatically assigning a unique identification to every asset imaged for a first time by the at least one camera via an image processing software module provided in connection with the at least one camera;
- (c) the image processing software module continuously detecting, recognizing and tracking assets assigned with unique identification in the warehouse from the images obtained by the at least one camera;
- (d) generating, from the images obtained of the assets, spatial coordinates of the assets corresponding to physical locations of the assets in the warehouse via a location determination software module, wherein the spatial coordinates comprise coordinates in a 3D coordinate system that takes reference from the actual storage space in the warehouse;
- (e) storing a digital inventory comprising the generated spatial coordinates and status information of the assets in a database; and
- (f) viewing and updating the status information of the assets via at least one computing device provided with access to the digital inventory.

14. The method of claim 13, further comprising:

- (g) a monitoring software module continuously monitoring data in the digital inventory and continuously monitoring detection, recognition and tracking of the assets by the imaging processing software module; and
- (h) the monitoring software module determining occurrence of events including:
 - (i) movement of an asset within the warehouse;
 - (ii) removal of an asset from the warehouse;
 - (iii) item movement, item removal and/or asset separation for an asset comprising multiple items; and
 - (iv) tampering with an asset.

15. The method of claim 14, further comprising:

- (i) the monitoring software module performing image comparison to detect any change in geometry of each asset in the obtained images and concluding that item removal or asset separation has occurred when a change in geometry has been detected for an asset at different times.

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16. The method of claim 14 or claim 15, further comprising:

- (j) wherein the monitoring software module checking status information of an asset for which any one of events (i) to (iv) has occurred to determine if authorization has been given for the event to occur and triggering an alert if it is determined that any one of events (i) to (iv) has occurred without authorization having been given.

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17. The method of claim 16, further comprising:

- (k) an alarm triggering when the monitoring software module determines that any one of events (i) to (iv) has occurred for any asset without authorization having been given

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18. The method of any one of claims 13 to 17, further comprising:

- (l) a modelling software module generating, for each asset, a digital asset comprising a 3D digital model of the asset, and showing all generated digital assets in a 3D digital space corresponding to the warehouse on a display screen of at least one computing device.

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19. The method of claim 18, wherein a 3D geometry and virtual location of each digital asset in the 3D digital space corresponds to 3D geometry and actual physical location of its corresponding asset in the warehouse.

25 20. The method of claim 19, further comprising:

- (m) selecting a digital asset shown on the display screen using an input device of the at least one computing device for at least one of: viewing status information of the selected digital asset and unencumbered viewing of the selected digital asset in the 3D digital space.

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21. The method of claim 20, further comprising:

- (n) only an authorized user of the at least one computing device updating status information of the selected digital asset.

35 22. The method of any one of the claims 13 to 21, further comprising:

- (o) only an authorized user inputting status information of assets in the warehouse via a

computing device provided with an inventory updating software module provided in association with the digital inventory.