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Morton

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(54) **SCANNING SYSTEMS**

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This patent is subject to a terminal disclaimer.

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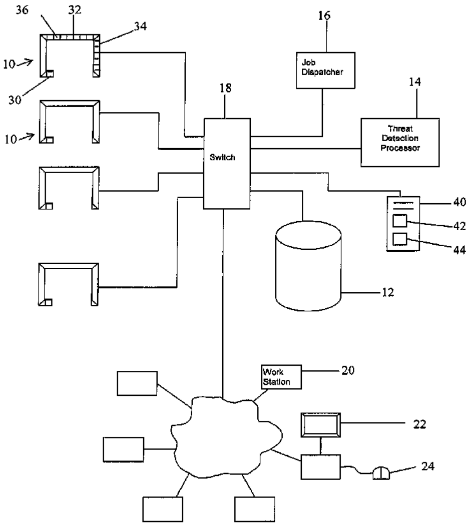
(57) **ABSTRACT**

The present application is directed toward cargo scanning systems having scanners, each arranged to scan a respective object and generate a set of scan data, processors arranged to process each set of scan data to determine whether it meets a predetermined threat condition, workstations, and data management system arranged to direct data that meets the threat condition to one of the workstations for analysis.

28 Claims, 3 Drawing Sheets



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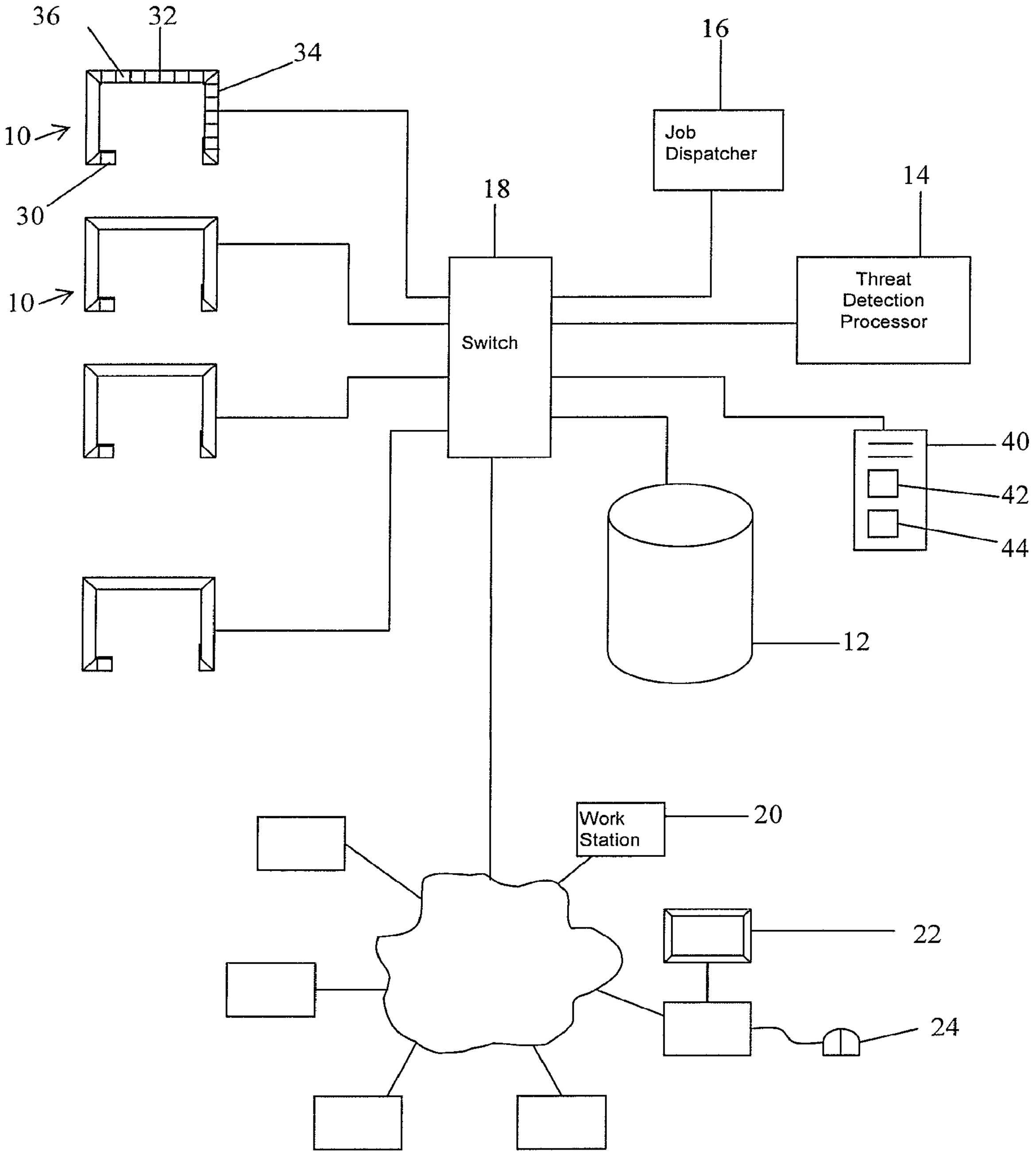
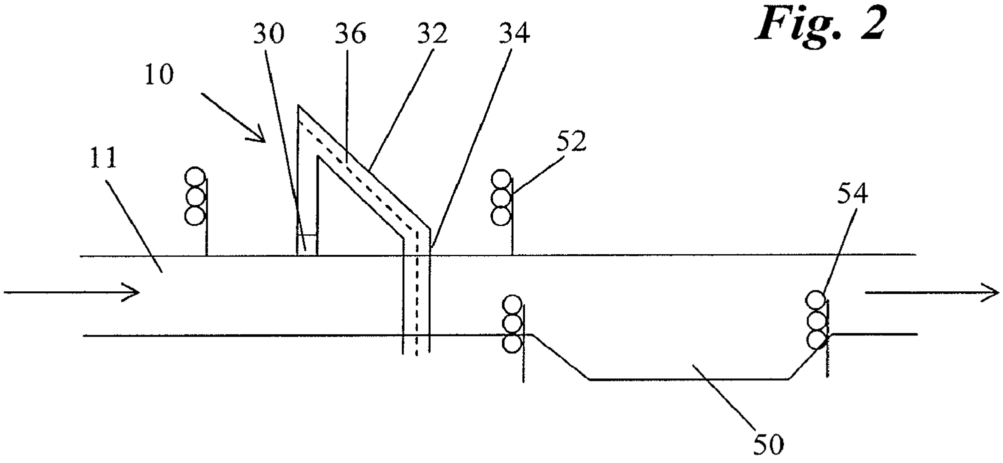

36
32
34
10
30
10
16
Job Dispatcher
18
14
Switch
Threat Detection Processor
40
42
44
12
Work Station
20
22
24

Fig. 1

Fig. 2



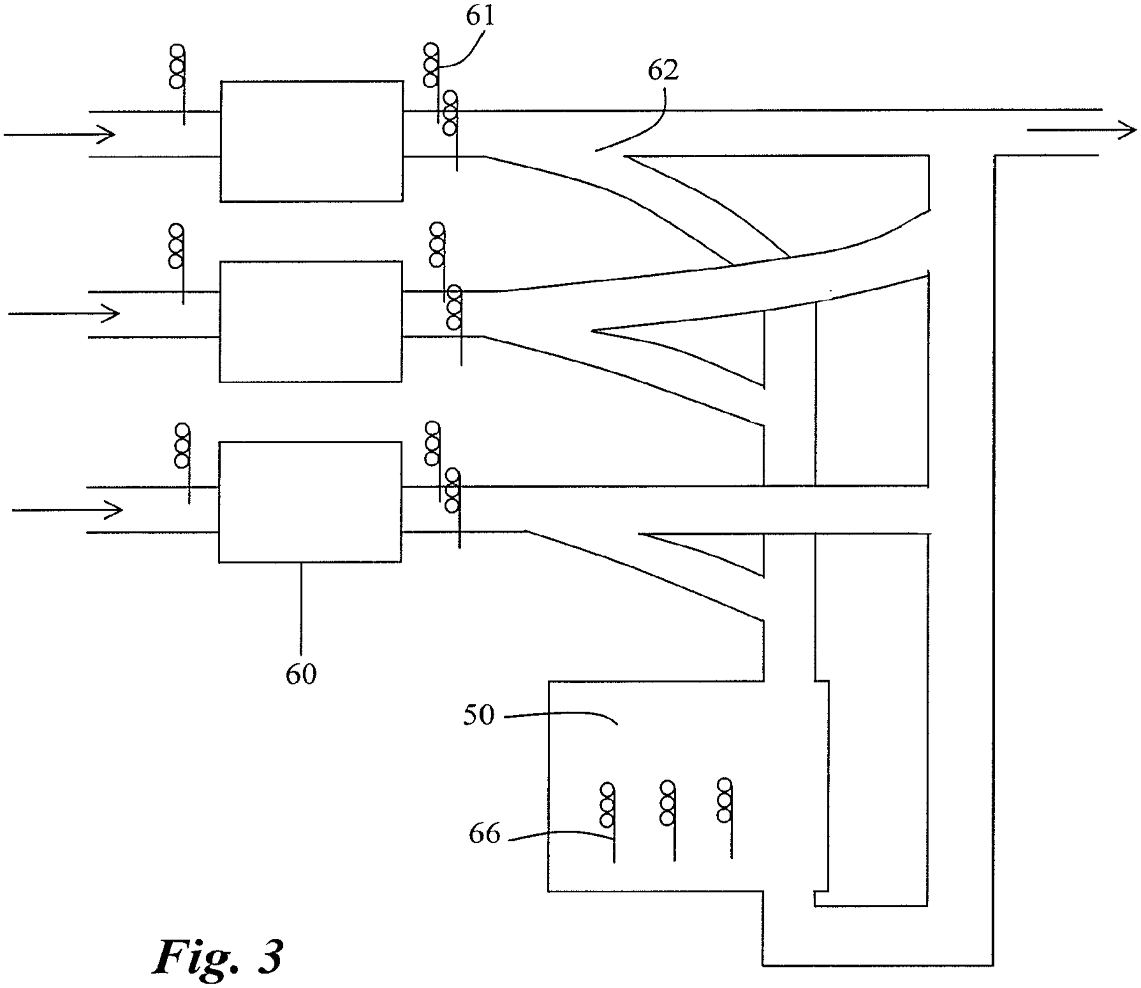


Fig. 3

Fig. 4

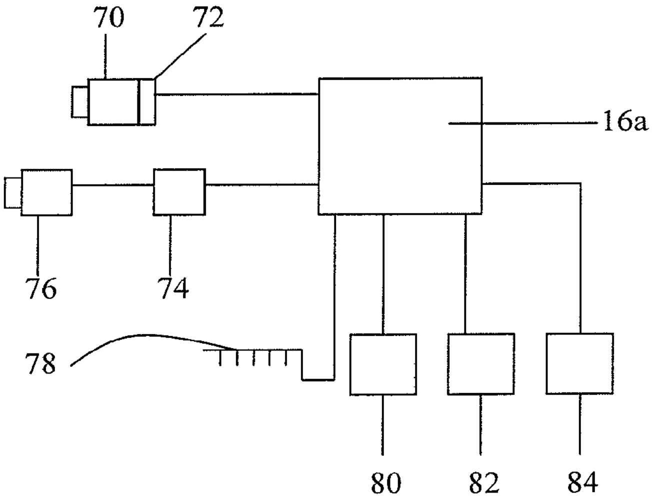
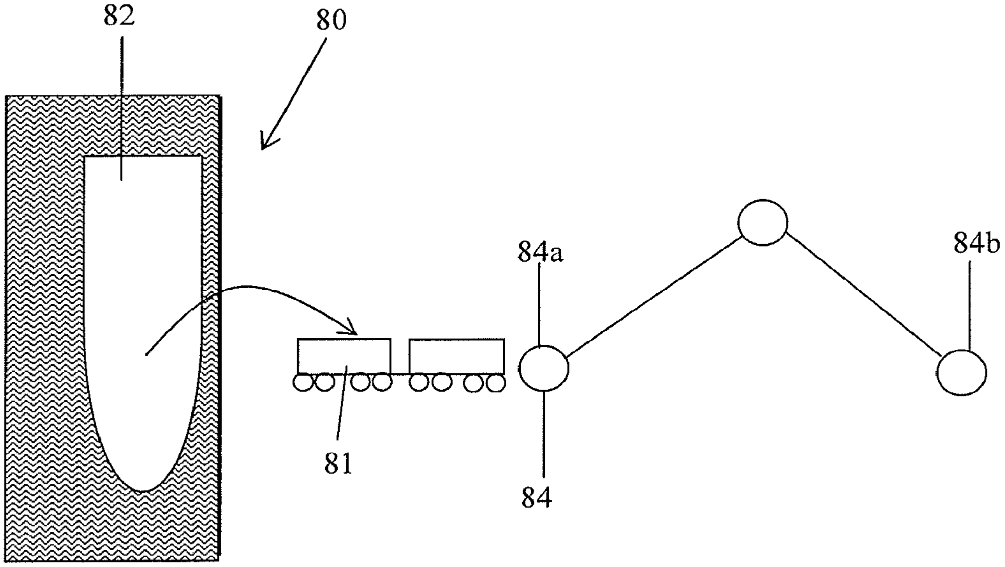


Fig. 5



SCANNING SYSTEMS

CROSS REFERENCE

The present application is a national stage application of PCT/GB2009/000575, filed on Feb. 27, 2009, which further relies on Great Britain Patent Application Number 0803644.4, filed on Feb. 28, 2008, for priority. The applications are incorporated herein by reference in their entirety.

FIELD OF THE INVENTION

The present invention relates to scanning systems. It has particular application in scanning systems for cargo.

BACKGROUND

There is a requirement to be able to screen cargo items for the presence of illicit materials and devices for the protection of the public.

Currently, such inspection may be undertaken using X-ray based screening apparatus. In these systems, an X-ray image of the object under inspection is taken and an operator reviews this image to resolve, in their experience, whether the cargo is clear for onwards travel or whether the cargo requires a further level of inspection. However greater volumes of cargo traffic and greater desire and need for security scanning have lead to an increasing need to increase the throughput of scanning systems.

SUMMARY OF THE INVENTION

The present invention provides a cargo scanning system comprising a plurality of scanners each arranged to scan a respective object and generate a set of scan data, processing means arranged to process each set of scan data to determine whether it meets a predetermined threat condition, and data management means arranged to direct data that meets the threat condition to a workstation, or one of a plurality of workstations, for analysis.

The present application is directed toward cargo scanning systems having scanners, each arranged to scan a respective object and generate a set of scan data, processors arranged to process each set of scan data to determine whether it meets a predetermined threat condition, workstations, and data management system arranged to direct data that meets the threat condition to one of the workstations for analysis.

The data management means may comprise a job dispatcher. The job dispatcher may be arranged to coordinate the tasks which are directed to each of the workstations. The data management means may further comprise a threat detection processor, which may be arranged to process image data to allocate the data to a threat category automatically, for example using one or more image processing algorithms. The data management means may also comprise a threat injector, which may be arranged to input test image data defining an image of a threat item. These different functions of the data management system can be provided as separate processors, or can be provided as different functions of a single processor.

The system may further comprise a cargo movement control means arranged to control movement of the objects through the scanners. Where the system is arranged to scan cargo carried on road-going vehicles the movement control means may include traffic lights and other signs and indicators for the driver of the vehicle. Where the system is arranged to scan rail cargo, the movement control means may include points on the railway. Where the system is arranged to scan cargo on a conveyor, the movement control means can include the conveyor.

The system may further comprise a holding bay and the movement control means may be arranged to hold one of the objects in the holding bay in response to the object meeting the threat condition. The movement control means may be arranged to cause the object to bypass the holding bay if it does not meet the threat condition.

According to some embodiments of the invention, a multi-level inspection process is provided which seeks to automate the scanning process to allow higher throughput and lower screening cost per cargo item.

The present invention further provides a method of scanning cargo comprising providing a plurality of scanners, scanning a respective object with each of the scanners to generate a respective set of scan data, processing each set of scan data to determine whether it meets a predetermined threat condition, and directing data that meets the threat condition to a workstation for analysis.

Preferred embodiments of the present invention will now be described by way of example only with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of a scanning system according to an embodiment of the invention;

FIG. **2** is a schematic view of part of the scanning system of FIG. **1**;

FIG. **3** is a schematic plan view of a scanning system according to a further embodiment of the invention;

FIG. **4** is a schematic diagram of a threat detection system forming part of a scanning system according to a further embodiment of the invention; and;

FIG. **5** is a schematic diagram of a cargo security system according to a further embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. **1**, a scanning system according to one embodiment of the invention comprises a number of scanners **10**, which can be for example static, moving gantry or mobile scanners, each of which is arranged to scan a cargo container to generate image data. In this case the scanners **10** are arranged over a roadway **11** so that they can scan road-going cargo trucks. A storage array **12**, threat detection processor **14** and job dispatcher **16**, which generally includes a computer with a processor, are all connected to the scanners **10** and to each other by a data switch **18** or other suitable data transmission system. The data switch is also connected to a network of workstations **20**. Each of the workstations **20** includes a display **22** arranged to display the image data in the form of an image for viewing by an operator, and a user input **24**, in this case in the form of a mouse, which enables the operator to allocate one of a number of threat categories to each image.

The scanners **10** are able to operate independently and at high throughput. A typical scanner comprises an X-ray generator **30**, a set of X-ray detector arrays **32**, **34** each comprising a number of individual detectors **36** each arranged to generate an output signal. The scanner may be a drive-through scanner, or it may include means, such as a movable gantry, to scan the cargo item through an X-ray beam which fires from the X-ray generator **30** through the cargo item and onto the set of X-ray detectors **36**. A two-dimensional image data set is formed by the scanner from the detector output signals. That data set contains information about the cargo item under inspection. In some embodiments more than one X-ray beam is used. In this case the beams may be used to generate two-dimensional image data sets, or three dimensional image data sets. In either case the image data from a series of scans is typically in a form that can be used to build up a three-dimensional image of the cargo item. The scanners **10** pass the image information through the data switch **18** which is able to route the information directly from the scanners **10** to the other nodes **12**, **14**, **16**, **20**. Typically, a scan will generate data in the form of Ethernet packets and the data switch **18** is therefore simply an Ethernet switch.

In the embodiment described here, data from the scanners **10** is passed directly to the central storage array **12** and the job dispatcher node **16** which is therefore arranged to receive from the generating scanner **10** the new cargo image data.

The job dispatcher **16** is then arranged, on receipt of any new image data set, to allocate time on the threat detection processor **14** for automated analysis of the new image data. Advantageously, the image data produced by the scanner **10** will have multi-energy attributes such that a detailed materials discrimination algorithm can be executed first by the threat detection processor **14**, followed by an automated detection algorithm. Once the threat detection processor has analysed the image data produced by the scanner **10**, it is arranged to notify the job dispatcher **16** of its conclusions.

If a threat item (e.g. a material or device) has been detected by the threat detection processor **14**, the job dispatcher **16** is arranged to allocate an operator to review the image data produced by the scanner to resolve the severity of the threat item(s) that were detected by the threat detection processor **14**, and to transmit the image data to one of the workstations **20**, or simply make the data available for retrieval and analysis by the operator. The operator will utilise one of the networked operator workstations **20** that has the capability to manipulate the image data for optimal display.

Once the operator has made their decision, and input it as an operator decision input to the workstation using the input device **24**, the result (either that the cargo is in fact clear for onwards travel or that it does indeed contain threat materials or devices) is forwarded to the job dispatcher **16** by the operator workstation. This can be done by sending the image data back with the decision attached to it in the form of a threat categorization, or by sending the decision, again for example as a threat categorization, with an identifier which uniquely identifies the image data set. The job dispatcher **16** is then arranged to notify the scanner **10** of the result.

In the event that a cargo item is flagged or categorized by the operator at the workstation **20** as containing a threat material or device, the facility manager is also notified, and a traffic management system controlled as described in more detail below to direct the cargo items appropriately, such that the threat cargo item can be quarantined until such time as an operative is available for manual search of the cargo item.

Typically, the threat detection processor **14** can be optimised to deliver a low false alarm rate to minimise the congestion and process delays that are caused when a threat cargo item is detected. The corollary of this is that the true detection rate will also be low. In this situation, very few operators are required in order to inspect image data from large numbers of scanning devices. This ensures a low screening cost per cargo item.

In this low false alarm rate scenario, it is reasonable to send a fraction of all the scanned images to the network of operators using random scheduling of cargo items which were cleared by the threat detection processor **14**.

This ensures that good inspection coverage of all the cargo items that are passing through the facility is achieved.

In a further mode of operation of the system, the balance between false alarm rate and detection probability is adjusted such that a higher detection rate is achieved but with a consequent increase in false alarm rate. In this scenario, more operators will be required in order to confirm or reject the cargo items following automated threat detection processing. At this higher false alarm rate level, it is unlikely that additional random inspection of automatically cleared containers will be required. The use of more operators pushes up the cost of screening containers but this comes at the benefit of an enhanced detection probability.

The threat detection processor **14** can be set to any particular sensitivity to suit the environment in which the system is to be used. However in this embodiment the sensitivity of the threat detection processor **14** is adjustable so that the operation of the system can be adjusted to suit the prevailing conditions. This means that where the threat detection processor is arranged to allocate each item to one of a number of threat categories, corresponding to different levels of threat, the category to which any particular images will be allocated can be adjusted so as to adjust the proportion of items that will be allocated to each of the categories. The threat detection processor can be arranged to adjust this allocation on the basis of one or more inputs, for example inputs indicative of an overall threat level, the volume of traffic which needs to be scanned, or the number of operators available to review the images. In a modification to this arrangement, the threat detection processor **14** can be arranged to allocate the items in the same way at all times, and the job dispatcher **16** can be made adjustable so that it allocates jobs to the workstations, and controls the flow of traffic in a way which is variable and adjustable in response to the same variables.

In a further embodiment of this invention, a further network node is added in the form of a threat injector **40**. The threat injector node **40** comprises a computer **42** having a processor **44** and memory **46**, with a library, stored in the memory **46**, of images of threat items that have been collected under controlled conditions using scanners identical to those 10 in use in the installation. Using a scheduling algorithm that is controlled by the job dispatcher **16**, image data that has been cleared by the threat detection processor **14** is passed to the threat injector **40**. The threat injector **40** superimposes a threat object image from its library of stored images into the true cargo image in order to create a hybrid image that now contains a known threat in an otherwise clear image.

This hybrid image is then dispatched by the job dispatcher **16** to one of the workstations **20** for an operator review. The operator will be expected to find and mark the threat object. When the operator threat categorization decision is input at the workstation **20** and returned to the job dispatcher **16**, the job dispatcher will send a notification to the workstation **20** to notify the operator that a known threat had been inserted into the image and will confirm whether the operator located the threat correctly. This information is then stored in a database of records, as part of one of the records which is relevant to the particular operator, in order to build up a picture of the individual operator's performance standard.

In a practical realisation of this invention, each workstation **20** can be arranged to display to an operator approximately 10% hybrid threat images, and 90% pure scanned images, in order to keep them occupied and well trained. The nature and complexity of the threat images that are injected are arranged to be variable and dependent on the identity of the operator, so that the testing can be balanced against the performance ability of the observer. This allows targeted training programmes to be established by the facility managers to ensure optimal human operation of the screening system.

In a modification to this system, instead of a hybrid image being generated as described above, a test image representing a threat object is simply selected from a library of test images and sent to one of the work stations **20**, and the response of the operator monitored to see whether their categorization of the image is correct.

The job dispatcher **16** can be arranged to allocate jobs to individual workstations or workstation operators on the basis simply of the current workload of each operator, which the job dispatcher can determine from the tasks it has already allocated, and results it is waiting for from each operator, and the threat category to which the threat detection processor has allocated the item. However where the system has a record or profile associated with each operator, the allocation of tasks to operators can also be made on the basis of the profile. For example in some case the threat detection processor may allocate items to different categories not just on the basis of a level of threat that it associates with the item, but also on the basis of the type of threat, for example the type of threat object that has been detected or the category of threat material that has been detected. Where the operator profile includes types of threat that each operator is able to analyse, or a degree of proficiency of each operator at analysing each type of threat, the job dispatcher can allocate each task to an operator at least on the basis of this information to match each task to an operator suitable to perform it.

Each operator workstation **20** has the facility to annotate the displayed image, in response to inputs from the user input **24**, in order to mark up an image to indicate the presence and type of threat objects and materials that have been detected in the cargo item.

In a further modification to this embodiment of this invention, to facilitate the smooth operation of each scanning device **10**, the job dispatcher **16** is able to cause the scanning system to route the passage of cargo items at its exit depending on the results of the automated detection processor and of any subsequent human inspection of the image data. For example, as shown in FIG. **2**, each of the scanners **10** can have a holding bay **50** which a vehicle can enter after passing through the scanner, with a traffic control system, such as traffic lights **52**, arranged to direct vehicles that have passed through the scanner **10** into the holding bay, or past the holding bay **50**. If the automated threat detection processor **14** detected the presence of a threat item or material, of the traffic lights **52** adjacent to the scanner **10** will be controlled by the job dispatcher **16** to direct the load to the holding bay **50** until such time as the operator has input their response. When the operator response has been received by the job dispatcher **14** it is arranged to control further traffic controls, such as a further set of traffic lights **54**, to indicate that the cargo is free to leave the scanning site, or that it needs to move on to another area for example for manual searching.

To maximise throughput of the installation, the automated threat detection processor **14** is arranged to generate a decision relating to a cargo item in a time period which is short compared to the overall scanning time for the cargo item. The job dispatcher **16** is arranged to be capable of allowing a scanner **10** to continue scanning new cargo items even if a cargo item is located in the associated holding bay **50** awaiting an operator decision.

The embodiments of FIGS. **1** and **2** are arranged to scan and control cargo carried on road vehicles, and the traffic management systems therefore rely on traffic lights and other suitable indicators or signs to direct the driver of the vehicle where to drive. However in another embodiment the system is arranged to scan cargo transported by rail. In this case the traffic management systems comprise traffic lights and also points on the rail tracks, for example at the exits **62** from the scanners in FIG. **3**, that can be switched to determine the route which the cargo takes.

The job dispatcher **16** is also arranged to control queuing of multiple suspect cargo items in the holding bay in order to maximise throughput of the screening installation.

Referring to FIG. **3**, in a further embodiment, a security installation is similar to that of FIG. **2** but comprises a number of scanners **60**, each with an associated traffic control system **61**, and arranged to scan cargo items in parallel. The exits **62** from all of the scanners **60** lead to a shared quarantine area **64** that serves all of the scanning systems **60**. The traffic control systems **61** which comprise traffic lights or equivalent traffic management systems, are arranged to direct traffic either straight through scanners **60** to the exit of the scanning installation or, in the event of a threat being detected, to direct the load to the quarantine area **64** where further traffic management systems **66** are provided and arranged to route cargo loads to the exit of the installation following manual search as required.

Referring to FIG. **4**, in further embodiments of the invention, which can be otherwise similar to those of FIGS. **1** to **3**, the job dispatcher **16*a*** is similar to that of FIG. **1**, but is also arranged to receive, use and manage one or more different forms of information in addition to X-ray image data. This could typically include video images of the cargo load, which the job dispatcher **16*a*** is arranged to receive from one or more video cameras **70**. It can also include optical character recognition data related to container numbering, which can either be obtained by an image processor **72** arranged to process images from the video cameras, or a separate processor **74** arranged to receive and process images from an imaging device **76** specifically arranged to image a part of the container that carries the numbering. The information can also include scanned images of manifest information that may be provided with the cargo item. It may include data from secondary sensors such as weighbridge data from a weighbridge **78** indicative of the weight of the container, data from chemical detectors or 'sniffers' **80** indicative of the presence of one or more chemical compounds in the container, passive gamma ray data from a gamma ray detector **82** or neutron sensing data from a neutron sensor **84**. The secondary sensors are shown here is present at the scanner site and part of the installation, but any of them can equally be at a separate location, and arranged to store the data they provide on a data carrier so that it can be input to the job dispatcher, or to transmit the data to the job dispatcher with some form of identification of the container it relates to. Where this ancillary data is available, the job dispatcher **16*a*** is typically arranged to pass the data to the automated threat detection processor which is arranged to use it as an input to the threat detection algorithm that it uses in order to assist it in making the best possible threat categorization decision.

Referring to FIG. **5**, in a further embodiment of the invention a cargo security system is similar to that of FIGS.

3 and **4**, but the system is arranged to scan cargo carried by rail on a rail train **81**. The parts of the system are distributed over larger distances so as to enable an efficient flow of cargo traffic. The system is arranged to scan and categorize cargo arriving at a port **80** on a vessel **82**. The system includes a number of scanners, and all of the sources of secondary data described above with reference to FIG. **4**, but these are distributed at a number of locations **84** along the rail route between the port **80** and a final quarantine or checking area. In particular the scanners **60** are at one location **84***a* close to the port **80** where they can be used to scan the cargo shortly after it has been loaded onto the rail vehicle **81**, and the final checking area is provided at another location **84***b* further away from the port which may be at a destination of the cargo where it is removed from the rail vehicle **81** carrying it, and any individual cargo items or containers which are identified as a possible threat can be checked without delaying the progress of containers which are not identified as a threat. A traffic management system similar to that of FIG. **3** including rail points and traffic lights is used to control the route of each item of cargo, into or past the checking area **86**, dependent on the analysis of the scan data and other secondary data by the threat detection processor. This arrangement means that the cargo items do not need to be delayed close to the port **80**, and can be moving away from the port, and towards their final destination, while the threat detection analysis is being performed.

I claim:

1. A non-transient computer readable medium comprising a plurality of programmatic instructions that, when executed by at least one processor:

- receive scan data, wherein the scan data are representative of contents positioned within one or more containers;
- perform an automated detection process on the scan data;
- receive descriptive information of the contents of the one or more containers;
- assess the scan data based on the automated detection process;
- for a first portion of the assessed scan data, acquire a threat object image from a library of images representative of known threats and combine the threat object image with the first portion of the assessed scan data to generate hybrid scan data; and
- send the hybrid scan data and a second portion of the assessed scan data to an operator workstation, wherein the second portion of the assessed scan data does not have a threat object image from the library of images representative of known threats and wherein an amount of the second portion of the assessed scan data is greater than an amount of the hybrid scan data.

2. The non-transient computer readable medium of claim **1**, wherein, when executed by the at least one processor, the plurality of programmatic instructions automatically allocate the hybrid scan data and the second portion of the assessed scan data to at least one operator workstation for analysis.

3. The non-transient computer readable medium of claim **1**, wherein, when executed by the at least one processor, the plurality of programmatic instructions generate optical character recognition data indicative of characters associated with the one or more containers.

4. The non-transient computer readable medium of claim **1**, wherein, when executed by the at least one processor, the plurality of programmatic instructions execute a material discrimination process on the scan data.

5. The non-transient computer readable medium of claim **4**, wherein, when executed by the at least one processor, the plurality of programmatic instructions first executes the material discrimination process on the scan data and then subsequently executes the automated detection process on the scan data.

6. The non-transient computer readable medium of claim **5**, wherein, when executed by the at least one processor, the plurality of programmatic instructions is configured to display the hybrid scan data and the second portion of the assessed scan data on an operator workstation after the material discrimination process and the automated detection process is performed on the scan data.

7. The non-transient computer readable medium of claim **1**, wherein, when executed by the at least one processor, the plurality of programmatic instructions combines the threat object image with the first portion of the assessed scan data by superimposing the threat object image onto an image corresponding to the first portion of the assessed scan data.

8. The non-transient computer readable medium of claim **7**, wherein the first portion of the assessed scan data combined with the threat object image corresponds to an image of contents without a threat.

9. The non-transient computer readable medium of claim **1**, wherein, when executed by the at least one processor, the plurality of programmatic instructions determines a severity of a threat item based on the scan data.

10. The non-transient computer readable medium of claim **1**, wherein, when executed by the at least one processor, the plurality of programmatic instructions receives decision data from an operator workstation, wherein the decision data comprises a categorization of the threat item.

11. The non-transient computer readable medium of claim **1**, wherein, when executed by the at least one processor, the plurality of programmatic instructions generates and transmits a notification based on the decision data.

12. The non-transient computer readable medium of claim **1**, wherein, when executed by the at least one processor, the plurality of programmatic instructions allocates each threat item to one of a number of threat categories and wherein each of the threat categories corresponds to a different level of threat.

13. The non-transient computer readable medium of claim **1**, wherein, when executed by the at least one processor, the plurality of programmatic instructions allocates the hybrid scan data and the second portion of the assessed scan data to one or more operator workstations based on an overall threat level.

14. The non-transient computer readable medium of claim **1**, wherein, when executed by the at least one processor, the plurality of programmatic instructions allocates the hybrid scan data and the second portion of the assessed scan data to one or more operator workstations based on a volume of traffic.

15. A method implemented by at least one processor configured to execute a plurality of programmatic instructions in a non-transient computer readable medium, the method comprising:

- receiving scan data, wherein the scan data are representative of contents positioned within one or more containers;
- performing an automated detection process on the scan data;
- receiving descriptive information of the contents of the one or more containers;
- assessing the scan data based on the automated detection process;
- for a first portion of the assessed scan data, acquiring a threat object image from a library of images represen-

tative of known threats and combining the threat object image with the first portion of the assessed scan data to generate hybrid scan data; and

sending the hybrid scan data and a second portion of the assessed scan data to an operator workstation, wherein the second portion of the assessed scan data does not have a threat object image from the library of images representative of known threats and wherein an amount of the second portion of the assessed scan data is greater than an amount of the hybrid scan data.

16. The method of claim **15**, comprising automatically allocating the hybrid scan data and the second portion of the assessed scan data to at least one operator workstation for analysis.

17. The method of claim **15**, comprising generating optical character recognition data indicative of characters associated with the one or more containers.

18. The method of claim **15**, comprising executing a material discrimination process on the scan data.

19. The method of claim **18**, comprising first executing the material discrimination process on the scan data and then subsequently executing the automated detection process on the scan data.

20. The method of claim **19**, comprising displaying the hybrid scan data and the second portion of the assessed scan data on an operator workstation after the material discrimination process and the automated detection process is performed on the scan data.

21. The method of claim **15**, comprising combining the threat object image with the first portion of the assessed scan data by superimposing the threat object image onto an image corresponding to the first portion of the assessed scan data.

22. The method of claim **21**, wherein the first portion of the assessed scan data combined with the threat object image corresponds to an image of contents without a threat.

23. The method of claim **15**, comprising determining a severity of a threat item based on the scan data.

24. The method of claim **15**, comprising receiving decision data from an operator workstation, wherein the decision data comprises a categorization of the threat item.

25. The method of claim **15**, comprising generating and transmitting a notification based on the decision data.

26. The method of claim **15**, comprising allocating each threat item to one of a number of threat categories and wherein each of the threat categories corresponds to a different level of threat.

27. The method of claim **15**, comprising allocating the hybrid scan data and the second portion of the assessed scan data to one or more operator workstations based on an overall threat level.

28. The method of claim **15**, comprising allocating the hybrid scan data and the second portion of the assessed scan data to one or more operator workstations based on a volume of traffic.

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