INSPECTION DEVICES AND INSPECTION METHODS

TECHNICAL FIELD

[0001] The present disclosure relates to radiation detection technology, and in particular to devices and methods for inspecting an object being inspected, such as a container truck.

BACKGROUND

[0002] With development of world economy and international trade, container/vehicle cargo transportation is becoming widely used in national economy. Meanwhile, it also brings convenience for terrorists to transport contraband and dangerous goods, such as nuclear materials, explosives or drugs etc. which leads to serious threat to the lives of people around the world. For example, if nuclear material such as raw material uranium 235 or plutonium 239 reaches a certain amount (e.g., uranium 12-16kg, plutonium 6-9kg), it is possible to cause weapons-level nuclear explosion. In addition, criminal and economic losses caused by illegal proliferation of explosives and drugs have also brought great harm to individuals, families and a whole society. Therefore, it is necessary to strengthen non-destructive inspection on the container/vehicle cargo transportation, and strictly control and manage the illegal proliferation of the above materials.

[0003] There is a problem with the prior art that the current technique of inspecting the nuclear material and/or the drugs has a lower detection accuracy or a lower efficiency.

SUMMARY

[0004] In view of one or more of problems in the prior art, an inspection device and an inspection method for inspecting an object being inspected such as a container are provided.

[0004a] Aspects of the invention are defined in the independent claims. Some optional features of the invention are defined in the dependent claims.

[0005] According to one example, an inspection method is provided, including: performing X-ray scanning on an object being inspected to generate an image of the object being inspected; dividing the image of the object being inspected to determine at least one region of interest; detecting interaction between a cosmic ray and the region of interest to obtain a detection value; calculating a scattering characteristic value and/or an absorption characteristic value of the cosmic ray in the region of interest based on size information of the region of interest and the detection value; and discriminating a material attribute of the region of interest by means of the scattering characteristic value and/or the absorption characteristic value.

[0006] According to some examples, the image of the object being inspected includes at least one of following images: a single-energy transmission image, an attenuation coefficient image, a CT value image, an electron density image, and an atomic number image.

[0007] According to some examples, the material attribute of one region of interest is discriminated by means of the scattering characteristic value, and the material attribute of another region of interest is discriminated by means of the absorption characteristic value.

[0008] According to some examples, the inspection method further includes: judging whether nuclear material is contained in the region of interest by performing a nonparametric test.

[0009] According to some examples, the inspection method further includes: reconstructing a 3D image of the object being inspected by means of parameters.

[0010] According to some examples, an alarm signal is issued when the material attribute of the object being inspected satisfies a predetermined condition.

[0011] According to some examples, the step of discriminating the material attribute of the region of interest by means of the scattering characteristic value and/or the absorption characteristic value includes: determining an atomic number value of the material in the region of interest based on the scattering characteristic value and/or the

absorption characteristic value by means of a previously created classification curve or lookup table.

[0012] According to some examples, the inspection method further includes: monitoring a trajectory of the object being inspected; and calculating, based on the trajectory, the detection value indicating a result of the interaction between the cosmic ray and the object being inspected.

[0013] According to some examples, performing the scanning on the object being inspected includes at least one of: performing backscattering scanning on the object being inspected; performing single-energy transmission scanning on the object being inspected; performing single-energy CT scanning on the object being inspected; performing double-energy X-ray transmission scanning on the object being inspected; performing double-energy CT scanning on the object being inspected.

[0014] According to some examples, the step of calculating the scattering characteristic value and/or the absorption characteristic value of the cosmic ray in the region of interest based on the size information of the region of interest and the detection value includes:

[0015] calculating the scattering characteristic value by a formula of:

$$R_{scatter} = \frac{\sigma_\theta^{\,2} \cdot p^2}{L}$$

[0016] wherein σ_θ denotes a Root Mean Square of a scattering angle, p denotes an average momentum of incident particles, and L denotes the size information, particularly, a thickness of the material obtained by the X-ray scanning;

[0017] calculating a stopping power value as the absorption characteristic value by a formula of:

$$R_{stop} = \frac{N_{stop} \Big/ \left(a_{stop} \cdot t_{stop}\right)}{N_{scatter} \Big/ \left(a_{scatter} \cdot t_{scatter}\right)} \cdot \frac{p}{L}$$

[0018] wherein $N_{scatter}/(a_{scatter} \cdot t_{scatter})$ represents a number $N_{scatter}$ of particles detected on an imaging area or volume $a_{scatter}$ within a time $t_{scatter}$ which are subjected to a scattering effect by substances, $N_{stop}/(a_{stop} \cdot t_{stop})$ represents a number N_{stop} of particles detected on an imaging area or volume a_{stop} within a time t_{stop} which are subjected to a stopping effect by substances, p denotes the average momentum of the incident particles, and L denotes the size information, particularly, the thickness of the material obtained by the X-ray scanning.

[0019] According to another aspect of the present disclosure, an inspection device is provided, including: an X-ray source configured to emit an X-ray to perform scanning on an object being inspected; a detection and collection apparatus configured to detect and collect the X-ray penetrating the object being inspected to obtain detection data; a data processing apparatus configured to generate an image of the object being inspected based on the detection data and divide the image of the object being inspected to determine at least one region of interest; a cosmic ray detection apparatus configured to detect interaction between a cosmic ray and the region of interest to obtain a detection value and calculate a scattering characteristic value and/or an absorption characteristic value of the cosmic ray in the region of interest based on size information of the region of interest and the detection value, wherein the data processing apparatus is further configured to discriminate a material attribute of the region of interest by means of the scattering characteristic value and/or the absorption characteristic value.

[0020] According to some examples, the inspection device further includes: a positioning apparatus configured to determine a trajectory of the object being inspected, wherein the detection value obtained by the cosmic ray detection apparatus is matched with the trajectory to obtain the detection value of the region of interest.

[0021] With the above technical solutions, inspection accuracy and inspection efficiency may be improved.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] In order to better understand the present disclosure, examples of the present disclosure will be described according to the accompanying drawings, in which:

[0023] Fig. 1 shows a schematic structure diagram of an inspection device according to an example of the present disclosure;

[0024] Fig. 2 shows a schematic structure diagram of the computing apparatus as shown in Fig. 1;

[0025] Fig. 3A shows a side view of an inspection device according to an example of the present disclosure;

[0026] Fig. 3B shows a top view of an inspection device according to an example of the present disclosure;

[0027] Fig. 3C shows a schematic diagram of an X-ray scanning subsystem in an inspection device according to an example of the present disclosure;

[0028] Fig. 4A shows a schematic structure diagram of a cosmic ray detector in an inspection device according to an example of the present disclosure;

[0029] Fig. 4B shows a side view depicting a cosmic ray detector according to another example of the present disclosure;

[0030] Fig. 4C is a left side view depicting a cosmic ray detector according to another example of the present disclosure;

[0031] Fig. 4D is another left side view depicting a cosmic ray detector according to another example of the present disclosure;

[0032] Fig. 5 is a schematic flow chart depicting an inspection method according to an example of the present disclosure; and

[0033] Fig. 6 is a schematic flow chart depicting another inspection method according to an example of the present disclosure.

I/We claim:

1. An inspection method comprising:

performing X-ray scanning on an object being inspected to generate an image of the object being inspected;

dividing the image of the object being inspected to determine at least one region of interest;

detecting interaction between a cosmic ray and the region of interest to obtain a detection value;

calculating a scattering characteristic value and/or an absorption characteristic value of the cosmic ray in the region of interest based on size information of the region of interest and the detection value; and

discriminating a material attribute of the region of interest by means of the scattering characteristic value and/or the absorption characteristic value,

wherein the material attribute of one region of interest is discriminated by means of the scattering characteristic value, and the material attribute of another region of interest is discriminated by means of the absorption characteristic value.

2. The inspection method according to claim 1, wherein the image of the object being inspected includes at least one of following images:

a single-energy transmission image, an attenuation coefficient image, a CT value image, an electron density image, and an atomic number image.

3. The inspection method according to claim 1, further comprising:

judging whether nuclear material is contained in the region of interest by performing a nonparametric test.

4. The inspection method according to claim 1, further comprising:

reconstructing a 3D image of the object being inspected by means of parameters.

5. The inspection method according to claim 1, wherein an alarm signal is issued when the material attribute of the object being inspected satisfies a predetermined condition.

6. The inspection method according to claim 1, wherein the step of discriminating the material attribute of the region of interest by means of the scattering characteristic value and/or the absorption characteristic value comprises:

determining an atomic number value of the material in the region of interest based on the scattering characteristic value and/or the absorption characteristic value by means of a previously created classification curve or lookup table.

7. The inspection method according to claim 1, further comprising:

monitoring a trajectory of the object being inspected; and

calculating, based on the trajectory, the detection value indicating a result of the interaction between the cosmic ray and the object being inspected.

8. The inspection method according to claim 1, wherein performing the scanning on the object being inspected comprises at least one of:

performing backscattering scanning on the object being inspected;

performing single-energy transmission scanning on the object being inspected;

performing single-energy CT scanning on the object being inspected;

performing double-energy X-ray transmission scanning on the object being inspected;

performing double-energy CT scanning on the object being inspected.

9. The inspection method according to claim 1, wherein the step of calculating the scattering characteristic value and/or the absorption characteristic value of the cosmic ray in the region of interest based on the size information of the region of interest and the detection value comprises:

calculating the scattering characteristic value by a formula of:

$$R_{scatter} = \frac{\sigma_\theta^{\,2} \cdot p^2}{L}$$

wherein σ_θ denotes a Root Mean Square of a scattering angle, p denotes an average momentum of incident particles, and L denotes the size information, particularly, a thickness of the material obtained by the X-ray scanning;

calculating a stopping power value as the absorption characteristic value by a formula of:

$$R_{stop} = \frac{N_{stop} / \left(a_{stop} \cdot t_{stop}\right)}{N_{scatter} / \left(a_{scatter} \cdot t_{scatter}\right)} \cdot \frac{p}{L}$$

wherein $N_{scatter} / \left(a_{scatter} \cdot t_{scatter}\right)$ represents a number $N_{scatter}$ of particles detected on an imaging area or volume $a_{scatter}$ within a time $t_{scatter}$ which are subjected to a scattering effect by substances, $N_{stop} / \left(a_{stop} \cdot t_{stop}\right)$ represents a number N_{stop} of particles detected on an imaging area or volume a_{stop} within a time t_{stop} which are subjected to a stopping effect by substances, p denotes the average momentum of the incident particles, and L denotes the size information, particularly, the thickness of the material obtained by the X-ray scanning.

10. An inspection method comprising:

dividing an image of an object being inspected, the image having been generated after an X-ray scan of the object, to determine at least one region of interest;

detecting interaction between a cosmic ray and the region of interest to obtain a detection value;

calculating a scattering characteristic value and/or an absorption characteristic value of the cosmic ray in the region of interest based on size information of the region of interest and the detection value; and

discriminating a material attribute of the region of interest by means of the scattering characteristic value and/or the absorption characteristic value,

wherein the material attribute of one region of interest is discriminated by means of the scattering characteristic value, and the material attribute of another region of interest is discriminated by means of the absorption characteristic value.

11. An inspection device, comprising:

an X-ray source configured to emit an X-ray to perform scanning on an object being inspected;

a detection and collection apparatus configured to detect and collect the X-ray penetrating the object being inspected to obtain detection data;

a data processing apparatus configured to generate an image of the object being inspected based on the detection data and divide the image of the object being inspected to determine at least one region of interest;

a cosmic ray detection apparatus configured to detect interaction between a cosmic ray and the region of interest to obtain a detection value and calculate a scattering characteristic value and/or an absorption characteristic value of the cosmic ray in the region of interest based on size information of the region of interest and the detection value,

wherein the data processing apparatus is further configured to discriminate a material attribute of the region of interest by means of the scattering characteristic value and/or the absorption characteristic value, and

wherein the data processing apparatus is configured to discriminate the material attribute of one region of interest by means of the scattering characteristic value, and discriminate the material attribute of another region of interest by means of the absorption characteristic value.

12. The inspection device according to claim 11, further comprising:

a positioning apparatus configured to determine a trajectory of the object being inspected, wherein the inspection device is configured to match the detection value obtained by the cosmic ray detection apparatus with the trajectory to obtain the detection value of the region of interest.

13. The inspection device according to claim 11, wherein the data processing apparatus is configured to determine an atomic number value of the material in the region of interest based on the scattering characteristic value and/or the absorption characteristic value by means of a previously created classification curve or lookup table.

14. The inspection device according to claim 11, wherein the data processing apparatus is configured to:

calculate the scattering characteristic value by a formula of:

$$R_{scatter} = \frac{\sigma_\theta^{\,2} \cdot p^2}{L}$$

wherein σ_θ denotes a Root Mean Square of a scattering angle, p denotes an average momentum of incident particles, and L denotes the size information, particularly, a thickness of the material obtained by the X-ray scanning;

calculate a stopping power value as the absorption characteristic value by a formula of:

$$R_{stop} = \frac{N_{stop} / \left(a_{stop} \cdot t_{stop}\right)}{N_{scatter} / \left(a_{scatter} \cdot t_{scatter}\right)} \cdot \frac{p}{L}$$

wherein $N_{scatter} / \left(a_{scatter} \cdot t_{scatter}\right)$ represents a number $N_{scatter}$ of particles detected on an imaging area or volume $a_{scatter}$ within a time $t_{scatter}$ which are subjected to a scattering effect by substances, $N_{stop} / \left(a_{stop} \cdot t_{stop}\right)$ represents a number N_{stop} of particles detected on an imaging area or volume a_{stop} within a time t_{stop} which are subjected to a stopping effect by substances, p denotes the average momentum of the incident particles, and L denotes the size information, particularly, the thickness of the material obtained by the X-ray scanning.

15. An inspection device, comprising:

a data processing apparatus configured to generate an image of an object being inspected based on detection data and to divide the image of the object being inspected to determine at least one region of interest, the detection data having been detected and collected by a detection and collection apparatus from an X-ray penetrating the object;

a cosmic ray detection apparatus configured to detect interaction between a cosmic ray and the region of interest to obtain a detection value and calculate a scattering characteristic value and/or an absorption characteristic value of the cosmic ray in the region of interest based on size information of the region of interest and the detection value,

wherein the data processing apparatus is further configured to discriminate a material attribute of the region of interest by means of the scattering characteristic value and/or the absorption characteristic value, and

wherein the data processing apparatus is configured to discriminate the material attribute of one region of interest by means of the scattering characteristic value, and discriminate the material attribute of another region of interest by means of the absorption characteristic value.