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(54) TERAHERTZ WAVE SECURITY INSPECTION SYSTEM AND METHOD

(57) A terahertz wave security inspection system (100) and a method thereof are provided. The terahertz wave security inspection system includes: an information acquisition device including a terahertz wave imaging mechanism (10) configured to generate a terahertz wave image of an object to be detected, and a visible light imaging mechanism (20) configured to generate a visible light image of the object to be detected, where the visible light image generated by the visible light imaging mechanism matches the terahertz wave image generated by the terahertz wave imaging mechanism within a range of depth of field of the terahertz wave imaging mechanism; and a data processing device (30) in data communication with the information acquisition device and configured to acquire the terahertz wave image of the object to be detected provided by the terahertz wave imaging mechanism and the visible light image provided by the visible light imaging mechanism, determine whether a suspected item exists in the object to be detected or not based on the terahertz wave image and the visible light image, and if it is determined that a suspected item exists in the object to be detected, determine whether the suspected item is a prohibited item or not based on the visible light image and the terahertz wave image.

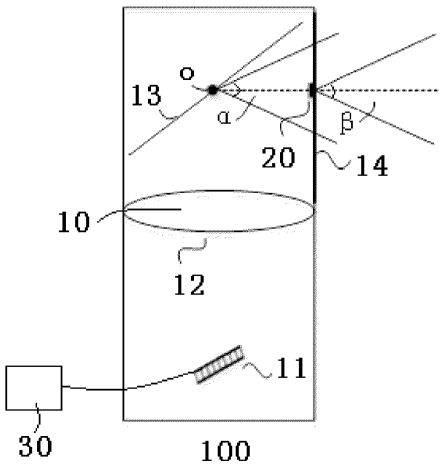

FIG. 1

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Description

TECHNICAL FIELD

[0001] The present disclosure relates to a field of security inspection technology, and in particular to a terahertz wave security inspection system and a terahertz wave security inspection method.

BACKGROUND

[0002] A terahertz wave security inspection system performs scanning and imaging by receiving a terahertz wave signal emitted by an object to be detected (such as a human body). After the terahertz wave emitted by the object to be detected is reflected by a speculum, the terahertz wave is focused by a lens on a detector array at a focal position, and the detector array converts the terahertz wave signal into an electrical signal to generate a terahertz wave image. However, the terahertz wave image generated by current passive terahertz wave security inspection system is prone to background interference, false alarms, etc., resulting in low security inspection efficiency and low inspection accuracy.

SUMMARY

[0003] According to an embodiment of an aspect of the present disclosure, there is provided a terahertz wave security inspection system, comprising: an information acquisition device comprising a terahertz wave imaging mechanism configured to generate a terahertz wave image of an object to be detected and a visible light imaging mechanism configured to generate a visible light image of the object to be detected; and a data processing device in data communication with the information acquisition device and configured to: acquire the terahertz wave image of the object to be detected provided by the terahertz wave imaging mechanism and the visible light image of the object to be detected provided by the visible light imaging mechanism, determine whether a suspected item exists in the object to be detected or not based on the terahertz wave image and the visible light image, and if it is determined that a suspected item exists in the object to be detected, determine whether the suspected item is a prohibited item or not based on the visible light image and the terahertz wave image.

[0004] In some embodiments, the visible light image generated by the visible light imaging mechanism matches the terahertz wave image generated by the terahertz wave imaging mechanism within a range of depth of field of the terahertz wave imaging mechanism.

[0005] In some embodiments, the visible light image generated by the visible light imaging mechanism matching the terahertz wave image generated by the terahertz wave imaging mechanism within a range of depth of field of the terahertz wave imaging mechanism comprises: the visible light image generated by the visible light imaging mechanism, after being cropped, matches the terahertz wave image generated by the terahertz wave imaging mechanism within the range of depth of field of the terahertz wave imaging mechanism.

[0006] In some embodiments, the visible light imaging mechanism is located at an inner side of a virtual cone with a center of rotation of a speculum of the terahertz wave imaging mechanism as a vertex, a normal direction of field of view as a centerline, and a vertex angle of view of $\alpha/3$, wherein α is a field of view of the terahertz wave imaging mechanism.

[0007] In some embodiments, the terahertz wave security inspection system comprises a housing in which the terahertz wave imaging mechanism is located, and the housing is provided with a window, a terahertz wave emitted by the object to be detected is transmitted through the window and received by the terahertz wave imaging mechanism to generate the terahertz wave image, and the visible light imaging mechanism is located on the window.

[0008] In some embodiments, an extension line of an optical axis of the visible light imaging mechanism passes through the center of rotation of the speculum of the terahertz wave imaging mechanism.

[0009] In some embodiments, the data processing device is further configured to that: when it is determined that a suspected item exists in the object to be detected based on the terahertz wave image, marking one or more areas of the terahertz wave image as a suspected area in which the suspected item is located, identifying an area in which the object to be detected is located based on the visible light image, and if the suspected area corresponds to an area of the visible light image outside the area in which the object to be detected is located, removing the suspected area.

[0010] In some embodiments, the data processing device is further configured to that: if the suspected area corresponds to an area of the visible light image within the area in which the object to be detected is located, identifying whether an item in the area of the visible light image corresponding to the suspected area is a non-hidden item or not, if the item is a non-hidden item, determining that the suspected area does not contain a prohibited item, and if the item is not a non-hidden item, determining that the suspected area contains a prohibited item.

[0011] In some embodiments, the terahertz wave security inspection system further comprises an image display device in data communication with the data processing device and configured to display the terahertz wave image and/or the visible light image generated by the information acquisition device.

[0012] In some embodiments, the terahertz wave imaging mechanism is a terahertz wave human body security instrument, and the visible light imaging mechanism is an optical camera.

[0013] In some embodiments, the optical camera is a pinhole camera or an infrared camera.

[0014] According to an embodiment of another aspect of the present disclosure, there is further provided a terahertz wave security inspection method implemented by the terahertz wave security inspection system described above, comprising: an information acquisition step of generating a terahertz wave image of an object to be detected by using a terahertz wave imaging mechanism and generating a visible light image of the object to be detected by using a visible light imaging mechanism; a prohibited item initial-determination step of processing the terahertz wave image and determining whether a suspected item exists in the object to be detected or not by using a data processing device; and if the data processing device determines that a suspected item exists in the object to be detected, performing a prohibited item secondary-determination step of determining whether the suspected item is a prohibited item or not based on the visible light image and the terahertz wave image by using the data processing device.

[0015] In some embodiments, in the prohibited item initial-determination step, the data processing device further marks one or more areas of the terahertz wave image as a suspected area in which the suspected item is located.

[0016] In some embodiments, in the prohibited item secondary-determination step, the data processing device identifies an area in which the object to be detected is located based on the visible light image, and if the suspected area corresponds to an area of the visible light image outside the area in which the object to be detected is located, the data processing device removes the suspected area.

[0017] In some embodiments, identifying an area in which the object to be detected is located based on the visible light image comprises: framing the area of the visible light image in which the object to be detected is located by using a specific color; or performing a pixel-level segmentation on the object to be detected in the visible light image, and obtaining the area in which the object to be detected is located by using a pixel-level segmentation result.

[0018] In some embodiments, subsequent to the identifying an area in which the object to be detected is located based on the visible light image, a pixel value of an area outside the area of the terahertz wave image corresponding to the area in which the object to be detected is located in the visible light image is set to zero to remove background interference.

[0019] In some embodiments, the prohibited item secondary-determination step comprises: if the suspected area corresponds to an area of the visible light image within the area in which the object to be detected is located, identifying whether an item in the area of the visible light image corresponding to the suspected area is a non-hidden item or not, if the item is a non-hidden item, determining that the suspected area does not contain a prohibited item, and if the item is not a non-hidden item, determining that the suspected area contains a prohibited item.

[0020] In some embodiments, if it is determined in the prohibited item secondary-determination step that the suspected area contains a prohibited item, the method further comprises: a displaying step of displaying the terahertz wave image and/or the visible light image by an image display device.

[0021] In some embodiments, the displaying step further includes: displaying a terahertz wave dynamic video and a visible light dynamic video simultaneously through the image display device, and displaying the suspected area determined to contain a prohibited item, in a form of an alarm frame, simultaneously in the terahertz wave image and the visible light image.

[0022] In some embodiments, the displaying step further comprises: replacing the suspected area determined to contain a prohibited item in the visible light image with a corresponding terahertz wave image.

[0023] In some embodiments, the displaying step further comprises: displaying a visible light dynamic video through the image display device, and displaying the suspected area determined to contain a prohibited item in the visible light image in a form of an alarm frame.

[0024] In some embodiments, the displaying step further comprises: replacing the suspected area determined to contain a prohibited item in the visible light image with a corresponding terahertz wave image.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025]

FIG. 1 shows a schematic structural diagram of a terahertz wave security inspection system according to an exemplary embodiment of the present disclosure;

FIG. 2 shows a schematic structural diagram of a terahertz wave security inspection system according to another exemplary embodiment of the present disclosure;

FIG. 3 shows a schematic diagram of a terahertz wave security inspection method according to an exemplary embodiment of the present disclosure; and

FIG. 4 shows a flowchart of a terahertz wave security inspection method according to an exemplary embodiment of the present disclosure.

DETAILED DESCRIPTION OF EMBODIMENTS

[0026] Although the present disclosure will be fully described with reference to the drawings containing the preferred embodiments of the present disclosure, it should be understood that those skilled in the art may modify the content described herein while obtaining the technical effects of the present disclosure. Therefore, it should be understood that the above description is a broad disclosure for those ordinary skilled in the art, and its content is not intended to limit the exemplary embodiments de-

scribed in the present disclosure.

[0027] In the following detailed description, for ease of interpretation, many specific details are set forth to provide a comprehensive understanding of the embodiments of the present disclosure. Obviously, however, one or more embodiments may also be implemented without these specific details. In other cases, well-known structures and devices are shown in diagrammatic form to simplify the drawings.

[0028] According to a general inventive concept of the present disclosure, there is provided a terahertz wave security inspection system, including: an information acquisition device including a terahertz wave imaging mechanism configured to generate a terahertz wave image of an object to be detected and a visible light imaging mechanism configured to generate a visible light image of the object to be detected, where the visible light image generated by the visible light imaging mechanism matches the terahertz wave image generated by the terahertz wave imaging mechanism within a range of depth of field of the terahertz wave imaging mechanism; and a data processing device in data communication with the information acquisition device and configured to: acquire the terahertz wave image of the object to be detected provided by the terahertz wave imaging mechanism and the visible light image of the object to be detected provided by the visible light imaging mechanism, determine whether a suspected item exists in the object to be detected or not based on the terahertz wave image and the visible light image, and if it is determined that a suspected item exists in the object to be detected, determine whether the suspected item is a prohibited item or not based on the visible light image and the terahertz wave image.

[0029] According to another general inventive concept of the present disclosure, there is provided a terahertz wave security inspection method using the terahertz wave security inspection system described above, including: an information acquisition step of generating a terahertz wave image of an object to be detected by using a terahertz wave imaging mechanism and generating a visible light image of the object to be detected by using a visible light imaging mechanism; a prohibited item initial-determination step of processing the terahertz wave image by using a data processing device and determining whether a suspected item exists in the object to be detected or not; and if the data processing device determines that a suspected item exists in the object to be detected , performing a prohibited item secondary-determination step of determining whether the suspected item is a prohibited item or not based on the visible light image and the terahertz wave image by using the data processing device.

[0030] FIG. 1 shows a schematic structural diagram of a terahertz wave security inspection system according to an exemplary embodiment of the present disclosure. FIG. 2 shows a schematic structural diagram of a terahertz wave security inspection system according to another exemplary embodiment of the present disclosure.

[0031] As shown in FIG. 1, a terahertz wave security inspection system 100 according to the present disclosure includes: an information acquisition device including a terahertz wave imaging mechanism 10 configured to generate a terahertz wave image of an object to be detected and a visible light imaging mechanism 20 configured to generate a visible light image of the object to be detected, where the visible light image generated by the visible light imaging mechanism 20 matches the terahertz wave image generated by the terahertz wave imaging mechanism 10 within a range of depth of field of the terahertz wave imaging mechanism 10. Here, the visible light image generated by the visible light imaging mechanism 20 matching the terahertz wave image generated by the terahertz wave imaging mechanism 10 within a range of depth of field of the terahertz wave imaging mechanism 10 refers to that within the range of depth of field (for example, 0.5 m-5 m) of the terahertz wave imaging mechanism 10, the visible light image generated by the visible light imaging mechanism 20 substantially corresponds to the terahertz wave image generated by the terahertz wave imaging mechanism 10 in spatial position, that is, a position and a size of the object to be detected in the visible light image substantially correspond to a position and a size of the object to be detected in the terahertz wave image.

[0032] In an exemplary embodiment, as shown in FIG. 1, a field of view β of the visible light imaging mechanism 20 is generally greater than a field of view α of the terahertz wave imaging mechanism 10. In this case, the visible light image generated by the visible light imaging mechanism 20 matching the terahertz wave image generated by the terahertz wave imaging mechanism 10 within the range of depth of field of the terahertz wave imaging mechanism 10 includes: the visible light image generated by the visible light imaging mechanism 20, after being cropped, matches the terahertz wave image generated by the terahertz wave imaging mechanism 10 within the range of depth of field of the terahertz wave imaging mechanism 10.

[0033] In an exemplary embodiment, as shown in FIG. 1, the terahertz wave imaging mechanism 10 includes a detector array 11, a focusing lens 12 and a speculum 13. The terahertz wave emitted by a human body is reflected by the speculum 13 to the focusing lens 12 for focusing. The focused terahertz wave is received by the detector array 11 at the focal position, and the detector array 11 converts a terahertz wave signal into an electrical signal. The speculum 13 reciprocates around a center of rotation, thereby realizing terahertz imaging within the field of view.

[0034] In an exemplary embodiment, as shown in FIG. 1, the visible light imaging mechanism 20 may be, for example, a pinhole camera, so as to avoid affecting the imaging of the object to be detected by the terahertz wave imaging mechanism 10. Of course, those skilled in the art should understand that in some other embodiments of the present disclosure, the visible light imaging mech-

anism 20 may also be an infrared camera or other depth cameras with depth detection capabilities.

[0035] In an exemplary embodiment, as shown in FIG. 1, in order to ensure that the visible light image generated by the visible light imaging mechanism 20 matches the terahertz wave image generated by the terahertz wave imaging mechanism 10 within the range of depth of field of the terahertz wave imaging mechanism 10, the visible light imaging mechanism 20 is positioned so that an extension line of an optical axis of the visible light imaging mechanism 20 passes through the center of rotation of the speculum 13 of the terahertz wave imaging mechanism 10.

[0036] However, those skilled in the art should understand that, in some other embodiments of the present disclosure, the visible light imaging mechanism 20 may also be located at an inner side of a virtual cone with the center of rotation of the speculum 13 of the terahertz wave imaging mechanism 10 as a vertex, a normal direction of field of view as a centerline, and a vertex angle of view of $\alpha/3$, where α is the field of view of the terahertz wave imaging mechanism 10. By arranging the visible light imaging mechanism 20 inside the virtual cone described above, the visible light image generated by the visible light imaging mechanism 20 may also match the terahertz wave image generated by the terahertz wave imaging mechanism 10 within the range of depth of field of the terahertz wave imaging mechanism 10.

[0037] In an exemplary embodiment, as shown in FIG. 1, the terahertz wave security inspection system 100 includes a housing 14, the terahertz wave imaging mechanism 10 is located inside the housing 14. The housing 14 is provided with a window which may be formed of, for example, materials such as polytetrafluoroethylene, polyethylene, etc. The terahertz wave emitted by the object to be detected may be transmitted through the window and received by the terahertz wave imaging mechanism 10 to generate the terahertz wave image. The visible light imaging mechanism 20 is located on the window and faces an area used to wait for detecting, so as to take an optical image of the object to be detected.

[0038] In an exemplary embodiment, as shown in FIG. 1, the speculum 13 of the terahertz wave imaging mechanism 10 is a flat speculum and reciprocates around the center of rotation of the speculum 13. However, those skilled in the art should understand that in some other embodiments of the present disclosure, the speculum 13 of the terahertz wave imaging mechanism 10 may also be other forms of speculums, such as a curved speculum. A scanning mode of the terahertz wave imaging mechanism 10 may also be a two-dimensional scanning mode. In addition, the speculum 13 of the terahertz wave imaging mechanism 10 may also be replaced by a polyhedron speculum (as shown in FIG. 2). In this case, the polyhedron speculum rotates around the center of rotation of the speculum 13, and the extension line of the optical axis of the visible light imaging mechanism 20 passes through an axis of rotation of the polyhedron speculum and is perpendicular to the axis of rotation of the polyhedron speculum.

[0039] According to an embodiment of the present disclosure, the terahertz wave imaging mechanism 10 may be, for example, a terahertz wave human body security instrument. Of course, those skilled in the art should understand that, in some other embodiments of the present disclosure, the terahertz wave imaging mechanism 10 may also take other forms.

[0040] In an exemplary embodiment, as shown in FIG. 1, the data processing device 30 is in data communication with the information acquisition device, in a wired or wireless manner. Specifically, the data processing device 30 may obtain the terahertz wave image and visible light image described above. The data processing device 30 may also transmit instructions or other information to the information acquisition device, for example, to instruct the information acquisition device to start collecting the terahertz wave image and/or the visible light image.

[0041] In an exemplary embodiment, as shown in FIG. 1, the data processing device 30 may determine, based on the terahertz wave image and the visible light image, whether a prohibited item exists in the object to be detected or not. Specifically, the data processing device 30 may determine whether a suspected item exist in the object to be detected or not based on the terahertz wave image. If the data processing device 30 determines that the suspected item exists, then further determining whether the suspected item is a prohibited item or not based on the visible light image and the terahertz wave image.

[0042] In an exemplary embodiment, as shown in FIG. 1, the data processing device 30 may be configured such that: when the data processing device 30 determines whether a suspected item exists in the object to be detected or not based on the terahertz wave image, the data processing device 30 marks one or more areas of the terahertz wave image as suspected areas in which the suspected items are located by using a deep learning algorithm. Further, the data processing device 30 may be configured such that: when the data processing device 30 determines whether a prohibited item exists in the suspected area or not based on the visible light image and the terahertz wave image, first identifying an area in which the object to be detected is located based on the visible light image by using the deep learning algorithm. If the above-mentioned suspected area corresponds to an area of the visible light image outside the area in which the object to be detected is located, removing the suspected area.

[0043] In an exemplary embodiment, as shown in FIG. 1, the data processing device 30 is further configured such that: if the suspected area corresponds to an area of the visible light image within the area in which the object to be detected is located, identifying whether an item in the area of the visible light image corresponding to the suspected area is a non-hidden item or not by using, for example, the deep learning algorithm, and if so, deter-

mining that no prohibited items exist in the suspected area; or determining that a prohibited item exists in the suspected area.

[0044] In the terahertz wave image, outer packaging materials such as plastic, paper, textiles, and leather may be transmitted by terahertz waves. Therefore, when a human body carries an item that may not be penetrated by a terahertz wave, the terahertz wave is reflected by the item, and thus an outline of the item appears in the terahertz wave image. Although the outline of the item is displayed, whether the item is a prohibited item or not may not be accurately determined from the terahertz wave image, and it may only be determined that the item is a suspected item. In this embodiment, the visible light imaging mechanism 20 is also provided to capture the visible light image of the object to be detected, and the visible light image generated by the visible light imaging mechanism 20 matches the terahertz wave image generated by the terahertz wave imaging mechanism 10 within the range of depth of field of the terahertz wave imaging mechanism 10, so as to determine whether the suspected item in the terahertz wave image is a prohibited item or not more easily and accurately.

[0045] In an exemplary embodiment, the terahertz wave security inspection system 100 further includes an image display device in data communication with the data processing device 30. The image display device may display the terahertz wave image and/or the visible light image generated by the information acquisition device. In an exemplary embodiment, the image display device may also display a terahertz wave dynamic video and a visible light dynamic video. The suspected area determined to contain the prohibited item is displayed in both the terahertz wave image and the visible light image in a form of an alarm frame. In an exemplary embodiment, the image display device may also replace the suspected area determined to contain the prohibited item in the visible light image with a corresponding terahertz wave image.

[0046] In an exemplary embodiment, the image display device only displays the visible light dynamic video and does not display the terahertz wave image, and the suspected area determined to contain the prohibited item is displayed in the visible light image in a form of an alarm frame. In an exemplary embodiment, the image display device may also replace the suspected area determined to contain the prohibited item in the visible light image with a corresponding terahertz wave image.

[0047] In an exemplary embodiment, the data processing device 30 may be configured to frame a suspected area in which a suspected item and/or a prohibited item is located in the terahertz wave image and/or the visible light image by using a specific color. The image display device may display the visible light image and the terahertz wave image of the suspected area in which the suspected item and/or the prohibited item is located has been framed, so that the inspector may make a comparison.

[0048] In an exemplary embodiment, the terahertz wave security inspection system 100 further includes a voice prompt device that may prompt whether the object to be detected carries a prohibited item or not according to an identification result. The voice prompt device is advantageous. For example, when items such as backpacks, handbags, etc., are needed to be removed from the object to be detected, the voice prompt device may prompt the object to be detected to remove the items himself/herself, thereby improving operation efficiency. The voice prompt device may also prompt the object to be detected the inspection is over, and thus the object to be detected is allowed to leave. The image display device and/or the voice prompt device may be configured to prompt whether the object to be detected is allowed to pass or not.

[0049] FIG. 3 shows a schematic diagram of a terahertz wave security inspection method according to an exemplary embodiment of the present disclosure. FIG. 4 shows a flowchart of a terahertz wave security inspection method according to an exemplary embodiment of the present disclosure.

[0050] As shown in FIG. 3, a human body target segmentation algorithm and a human body target recognition algorithm are used to identify an area in which the human body is located in the visible light image, and a suspected item recognition algorithm is used to identify a suspected area in which the suspected item is located in the terahertz wave image. It is determined whether the suspected area in which the suspected item is located in the terahertz wave image corresponds to an area of the visible light image within the area in which the human body is located or not. If so, a pixel value of an area outside the area of the terahertz wave image corresponding to the area in which the object to be detected is located in the visible light image is set to zero, so as to remove background interference. A non-hidden item recognition algorithm is used to identify whether the suspected item in the area in which the human body is located is a non-hidden item or not. This security inspection method may effectively eliminate false alarms.

[0051] According to another aspect of the present disclosure, there is further provided a terahertz wave security inspection method that performs security inspection by using the terahertz wave security inspection system 100 described above.

[0052] The terahertz wave security inspection method according to an embodiment of the present disclosure includes: an information acquisition step of generating a terahertz wave image of an object to be detected by using a terahertz wave imaging mechanism 10 and generating a visible light image of the object to be detected by using a visible light imaging mechanism 20; a prohibited item initial-determination step of processing the terahertz wave image by using the data processing device 30 and determining whether a suspected item exists in the object to be detected or not; and if the data processing device 30 determines that the object to be detected has a sus-

pected item, performing a prohibited item secondary-determination step of determining whether the suspected item is a prohibited item or not based on the visible light image and the terahertz wave image by using the data processing device 30.

[0053] In an exemplary embodiment, the terahertz security inspection method includes: in the prohibited item initial-determination step, the data processing device 30 marks one or more areas in the terahertz wave image as suspected areas in which the suspected items may be located; and in the prohibited item secondary-determination step, the data processing device 30 identifies an area in which the object to be detected is located based on the visible light image, and if a suspected area corresponds to an area of the visible light image outside the area in which the object to be detected is located, removes the suspected area.

[0054] In an exemplary embodiment, identifying an area in which the object to be detected is located based on the visible light image includes: framing an area in which the object to be detected is located in the visible light image by using a specific color. In some other embodiments of the present disclosure, the identifying an area in which the object to be detected is located based on the visible light image may include: performing a pixel-level segmentation on the object to be detected in the visible light image, and obtaining an area in which the object to be detected is located by using a pixel-level segmentation result, so as to determine the area in which the object to be detected is located more accurately.

[0055] In an exemplary embodiment, if the suspected area corresponds to an area of the visible light image within the area in which the object to be detected is located, the method further includes: identifying whether an item in an area of the visible light image corresponding to the suspected area is a non-hidden item or not, and if it is identified that the item is a non-hidden item, determining that no prohibited items exist in the suspected area; or if it is identified that the item is not a non-hidden item, determining that a prohibited item exists in the suspected area.

[0056] In an exemplary embodiment, subsequent to the identifying an area in which the object to be detected is located based on the visible light image, a pixel value of an area outside the area of the terahertz wave image corresponding to the area in which the object to be detected is located in the visible light image is set to zero, so as to remove background interference.

[0057] In an exemplary embodiment, if it is determined in the prohibited item secondary-determination step that a prohibited item exists in the object to be detected, the method further includes: a displaying step of displaying the terahertz wave image and/or visible light image described above by using the image display device. It should be noted that in some other embodiments of the present disclosure, the displaying step may also be performed when it is determined in the prohibited item secondary-determination step that the object to be detected does not have a prohibited item.

[0058] In an exemplary embodiment, the displaying step further includes: displaying a terahertz wave dynamic video and a visible light dynamic video simultaneously on the image display device, and displaying the suspected area determined to contain the prohibited item simultaneously in the terahertz wave image and the visible light image in a form of an alarm frame. In an exemplary embodiment, the displaying step further includes: replacing the suspected area determined to contain the prohibited item in the visible light image with a corresponding terahertz wave image.

[0059] In an exemplary embodiment, the displaying step further includes: displaying the visible light dynamic video through the image display device and not displaying the terahertz wave dynamic video, and displaying the suspected area determined to contain the prohibited item in the visible light image in a form of an alarm frame. In an exemplary embodiment, the displaying step further includes: replacing the suspected area determined to contain the prohibited item in the visible light image with a corresponding terahertz wave image.

[0060] In order to enable the present disclosure to be more fully understood, the present disclosure is described below through a specific security inspection process shown in FIG. 4.

S1: The visible light imaging mechanism 20 captures a visible light image of a human body and transmits the visible light image to the data processing device 30, while the terahertz wave imaging mechanism 10 collects a terahertz wave image of the human body and transmits the terahertz wave image to the data processing device 30.

S2: The data processing device 30 processes the terahertz wave image to determine whether an object to be detected carries a suspected item or not. 1) If it is determined based on the terahertz wave image that the object to be detected carries a suspected item, proceed to S3; 2) if it is determined based on the terahertz wave image that the object to be detected does not carry the suspected item, transmitting an inspection result to the image display device, and prompting the object to be detected to pass, for example, through the voice prompt device.

S3: The data processing device 30 processes the visible light image of the human body, identifies an area in which the human body is located, and determines whether a suspected area in which a suspected item is located in the terahertz wave image corresponds to an area of the visible light image within the area in which the human body is located or not. 1) If it is determined that the suspected area in which the suspected item is located in the terahertz wave image corresponds to an area of the visible light image within the area in which the human body is located, proceed to S4; 2) if it is determined that the suspected area in which the suspected item is locat-

ed in the terahertz wave image corresponds to an area of the visible light image outside the area in which the human body is located, removing the suspected area, transmitting an inspection result to the image display device, and prompting the object to be detected to pass, for example, through the voice prompt device.

S4: A deep learning algorithm is used to identify an item in an area of the visible light image corresponding to the suspected area, and determine whether the item is a non-hidden item or not. 1) If the item is a non-hidden item, transmitting an inspection result to the image display device, and prompting the object to be detected to pass, for example, through the voice prompt device; 2) if the item is not a non-hidden item, transmitting an inspection result to the image display device, and then proceed to step S5.

S5: A location of the prohibited item is framed with a specific color on the terahertz wave image and visible light image of the object to be detected, and a result is transmitted to the image display device. The image display device displays an inspection result, and the voice prompt device, for example, prompts that the object to be detected carries a prohibited item and gives an alarm.

[0061] The present disclosure aims at a problem that the suspected area of the terahertz wave image may not be accurately determined in a security inspection, and proposes a security inspection system and method combining the terahertz wave imaging and the visible light imaging, so as to improve an inspection accuracy of prohibited items, reduce false alarms, and improve security inspection efficiency.

[0062] Those skilled in the art may understand that the embodiments described above are exemplary, and those skilled in the art may make improvements. The structures described in the various embodiments may be combined freely without conflicts in structure or principle.

[0063] Although the present disclosure is described with reference to the drawings, the embodiments disclosed in the drawings are for illustrative purposes only and are not to be construed as limiting the present disclosure.

[0064] Although some embodiments of the general concept of the present disclosure have been illustrated and described, it should be understood by those ordinary skilled in the art that these embodiments may be changed without departing from the principle and spirit of the general concept of the present disclosure. The scope of the present disclosure is defined by the claims and their equivalents.

[0065] It should be noted that the word "comprising" or "including" does not exclude other elements or steps, and the word "a", "an" or "one" does not exclude a plurality. In addition, any reference signs in the claims should not be construed as limiting the scope of the present disclosure.

Claims

1. A terahertz wave security inspection system (100), comprising:

   an information acquisition device comprising a terahertz wave imaging mechanism (10) configured to generate a terahertz wave image of an object to be detected and a visible light imaging mechanism (20) configured to generate a visible light image of the object to be detected; and
   a data processing device (30) in data communication with the information acquisition device and configured to: acquire the terahertz wave image of the object to be detected provided by the terahertz wave imaging mechanism (10) and the visible light image of the object to be detected provided by the visible light imaging mechanism (20), determine whether a suspected item exists in the object to be detected or not based on the terahertz wave image and the visible light image, and if it is determined that a suspected item exists in the object to be detected, determine whether the suspected item is a prohibited item or not based on the visible light image and the terahertz wave image.

2. The terahertz wave security inspection system (100) according to claim 1, wherein the visible light image generated by the visible light imaging mechanism (20) matches the terahertz wave image generated by the terahertz wave imaging mechanism (10) within a range of depth of field of the terahertz wave imaging mechanism (10).

3. The terahertz wave security inspection system (100) according to claim 2, wherein the visible light image generated by the visible light imaging mechanism (20) matching the terahertz wave image generated by the terahertz wave imaging mechanism (10) within a range of depth of field of the terahertz wave imaging mechanism (10) comprises: the visible light image generated by the visible light imaging mechanism (20), after being cropped, matches the terahertz wave image generated by the terahertz wave imaging mechanism (10) within the range of depth of field of the terahertz wave imaging mechanism (10).

4. The terahertz wave security inspection system (100) according to any one of claims 1 to 3, wherein the visible light imaging mechanism (20) is located at an inner side of a virtual cone with a center of rotation of a speculum (13) of the terahertz wave imaging mechanism (10) as a vertex, a normal direction of field of view as a centerline, and a vertex angle of view of $\alpha/3$, wherein α is a field of view of the terahertz wave imaging mechanism (10).

5. The terahertz wave security inspection system (100) according to any one of claims 1 to 4,
wherein the terahertz wave security inspection system (100) comprises a housing (14) in which the terahertz wave imaging mechanism (10) is located, and the housing (14) is provided with a window, a terahertz wave emitted by the object to be detected is transmitted through the window and received by the terahertz wave imaging mechanism (10) to generate the terahertz wave image, and the visible light imaging mechanism (20) is located on the window.

6. The terahertz wave security inspection system (100) according to claim 4, wherein an extension line of an optical axis of the visible light imaging mechanism (20) passes through the center of rotation of the speculum (13) of the terahertz wave imaging mechanism (10).

7. The terahertz wave security inspection system (100) according to any one of claims 1 to 6,

wherein the data processing device (30) is further configured to that: when it is determined that a suspected item exists in the object to be detected based on the terahertz wave image, marking one or more areas of the terahertz wave image as a suspected area in which the suspected item is located, identifying an area in which the object to be detected is located based on the visible light image, and if the suspected area corresponds to an area of the visible light image outside the area in which the object to be detected is located, removing the suspected area; and
wherein the data processing device (30) is further configured to that: if the suspected area corresponds to an area of the visible light image within the area in which the object to be detected is located, identifying whether an item in the area of the visible light image corresponding to the suspected area is a non-hidden item or not, if the item is a non-hidden item, determining that the suspected area does not contain a prohibited item, and if the item is not a non-hidden item, determining that the suspected area contains a prohibited item.

8. The terahertz wave security inspection system (100) according to any one of claims 1 to 7, wherein the terahertz wave security inspection system (100) further comprises an image display device in data communication with the data processing device (30) and configured to display the terahertz wave image and/or the visible light image generated by the information acquisition device.

9. The terahertz wave security inspection system (100) according to any one of claims 1 to 8,

wherein the terahertz wave imaging mechanism (10) is a terahertz wave human body security instrument, and the visible light imaging mechanism (20) is an optical camera; and
wherein the optical camera is a pinhole camera or an infrared camera.

10. A terahertz wave security inspection method implemented by the terahertz wave security inspection system (100) according to any one of claims 1 to 9, comprising:

an information acquisition step of generating a terahertz wave image of an object to be detected by using a terahertz wave imaging mechanism (10) and generating a visible light image of the object to be detected by using a visible light imaging mechanism (20);
a prohibited item initial-determination step of processing the terahertz wave image and determining whether a suspected item exists in the object to be detected or not by using a data processing device (30); and
if the data processing device (30) determines that a suspected item exists in the object to be detected, performing a prohibited item secondary-determination step of determining whether the suspected item is a prohibited item or not based on the visible light image and the terahertz wave image by using the data processing device (30).

11. The terahertz wave security inspection method according to claim 10,

wherein in the prohibited item initial-determination step, the data processing device (30) further marks one or more areas of the terahertz wave image as a suspected area in which the suspected item is located; and
in the prohibited item secondary-determination step, the data processing device (30) identifies an area in which the object to be detected is located based on the visible light image, and if the suspected area corresponds to an area of the visible light image outside the area in which the object to be detected is located, the data processing device (30) removes the suspected area; and
wherein identifying an area in which the object to be detected is located based on the visible light image comprises:

framing the area of the visible light image in which the object to be detected is located by using a specific color; or

performing a pixel-level segmentation on the object to be detected in the visible light image, and obtaining the area in which the object to be detected is located by using a pixel-level segmentation result; and

wherein subsequent to the identifying an area in which the object to be detected is located based on the visible light image, a pixel value of an area outside the area of the terahertz wave image corresponding to the area in which the object to be detected is located in the visible light image is set to zero to remove background interference.

12. The terahertz wave security inspection method according to claim 11, wherein the prohibited item secondary-determination step comprises: if the suspected area corresponds to an area of the visible light image within the area in which the object to be detected is located, identifying whether an item in the area of the visible light image corresponding to the suspected area is a non-hidden item or not, if the item is a non-hidden item, determining that the suspected area does not contain a prohibited item, and if the item is not a non-hidden item, determining that the suspected area contains a prohibited item.

13. The terahertz wave security inspection method according to claim 12, wherein if it is determined in the prohibited item secondary-determination step that the suspected area contains a prohibited item, the method further comprises:
a displaying step of displaying the terahertz wave image and/or the visible light image by an image display device.

14. The terahertz wave security inspection method according to claim 13,

wherein the displaying step further comprises: displaying a terahertz wave dynamic video and a visible light dynamic video simultaneously through the image display device, and displaying the suspected area determined to contain a prohibited item, in a form of an alarm frame, simultaneously in the terahertz wave image and the visible light image; and
wherein the displaying step further comprises: replacing the suspected area determined to contain a prohibited item in the visible light image with a corresponding terahertz wave image.

15. The terahertz wave security inspection method according to claim 13,

wherein the displaying step further comprises: displaying a visible light dynamic video through the image display device, and displaying the suspected area determined to contain a prohibited item in the visible light image in a form of an alarm frame; and
wherein the displaying step further comprises: replacing the suspected area determined to contain a prohibited item in the visible light image with a corresponding terahertz wave image.

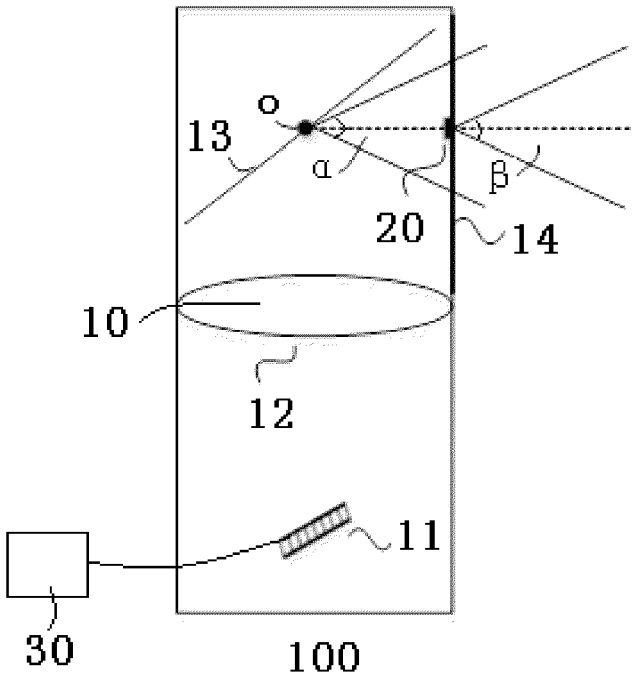

FIG. 1

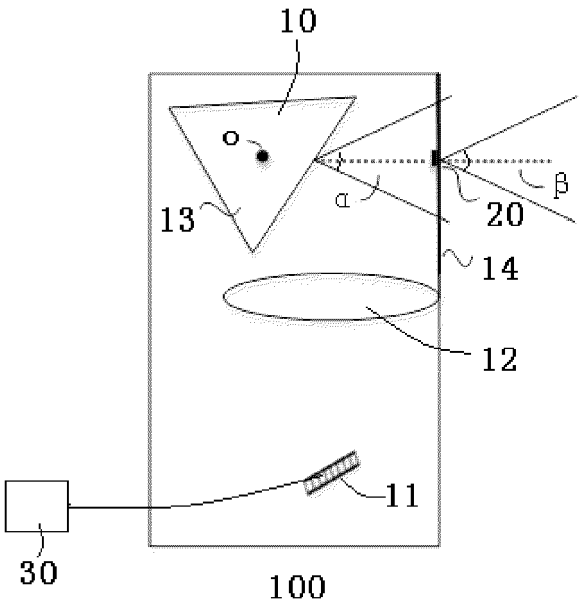

FIG. 2

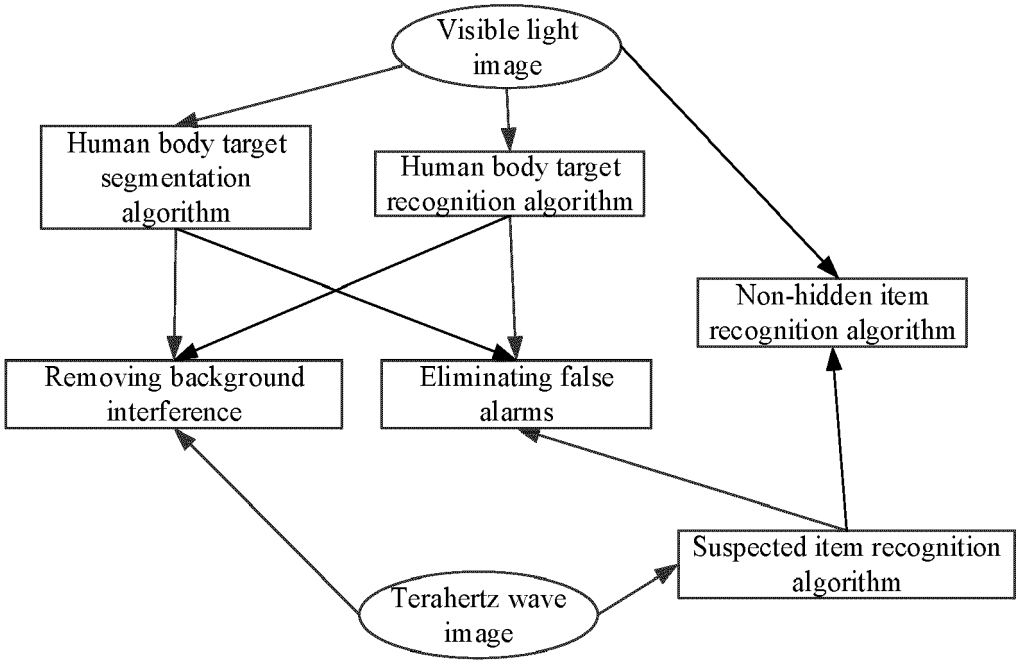
Visible light image
Human body target segmentation algorithm
Human body target recognition algorithm
Non-hidden item recognition algorithm
Removing background interference
Eliminating false alarms
Suspected item recognition algorithm
Terahertz wave image

FIG. 3

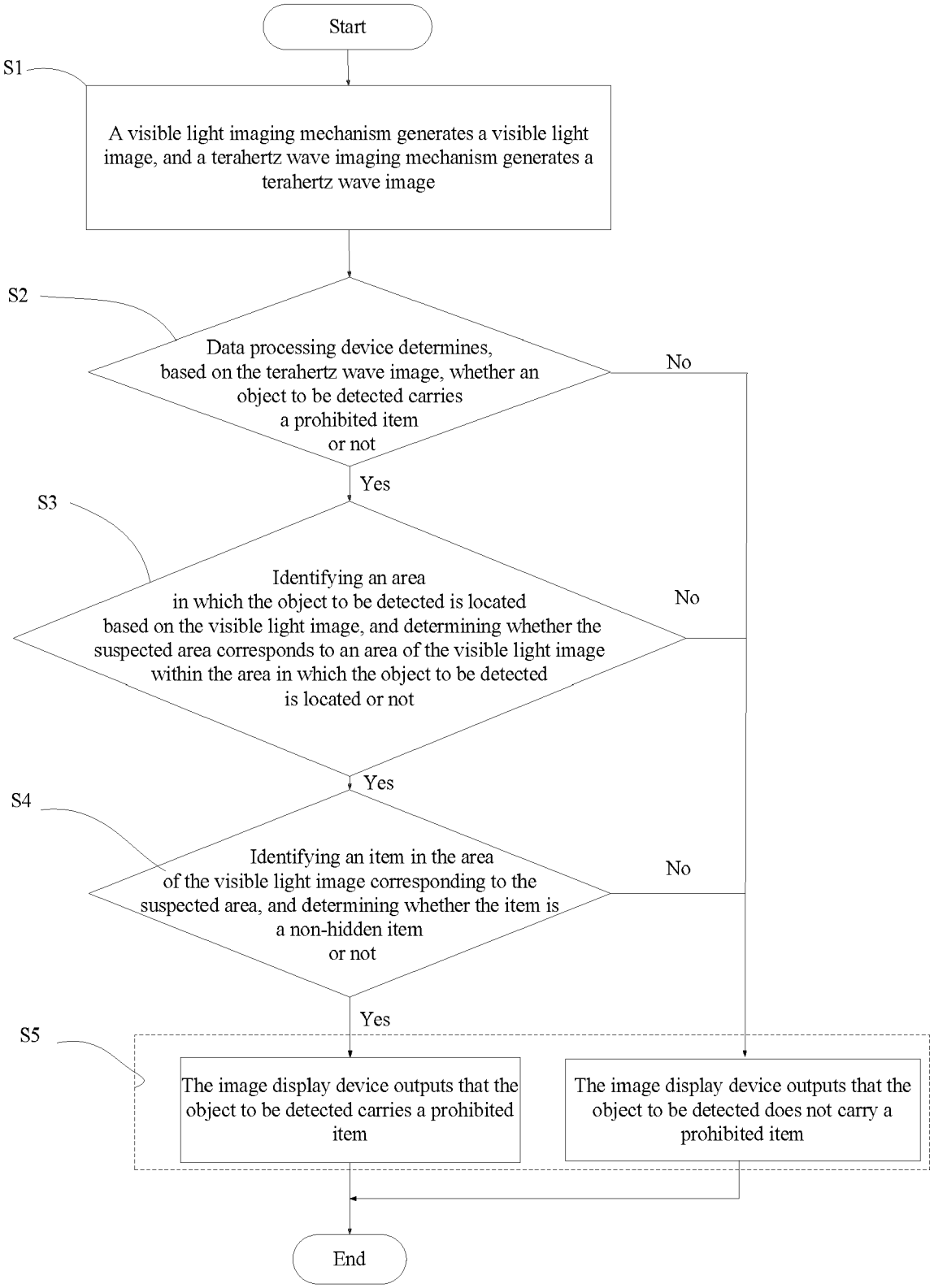
Start
S1
A visible light imaging mechanism generates a visible light image, and a terahertz wave imaging mechanism generates a terahertz wave image
S2
Data processing device determines, based on the terahertz wave image, whether an object to be detected carries a prohibited item or not
No
Yes
S3
Identifying an area in which the object to be detected is located based on the visible light image, and determining whether the suspected area corresponds to an area of the visible light image within the area in which the object to be detected is located or not
No
Yes
S4
Identifying an item in the area of the visible light image corresponding to the suspected area, and determining whether the item is a non-hidden item or not
No
Yes
S5
The image display device outputs that the object to be detected carries a prohibited item
The image display device outputs that the object to be detected does not carry a prohibited item
End

FIG. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 20 21 6032

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X	M. KOWALSKI ET AL: "Hidden Object Detection System Based on Fusion of THz and VIS Images", ACTA PHYSICA POLONICA: SERIES A, vol. 124, no. 3, 1 September 2013 (2013-09-01), pages 490-493, XP055662050, PL ISSN: 0587-4246, DOI: 10.12693/APhysPolA.124.490	4,6,8, 11,13-15	
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	3 May 2021	Meacher, David

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03-05-2021

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