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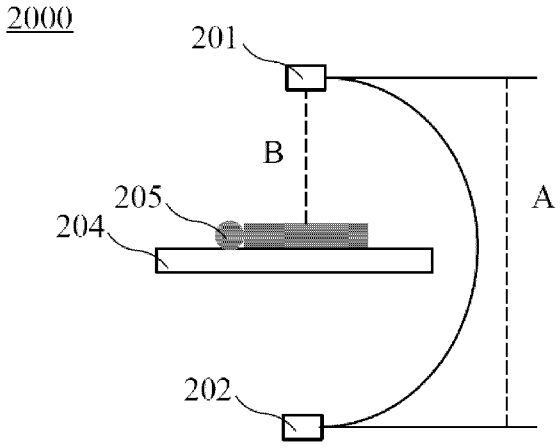

Fig. 2

(57) Abstract: The present disclosure relates to a parameter optimization method, an apparatus, a medical device, a medium and a product. The parameter optimization method comprises: obtaining a distance from a radiation source of the medical device to a test target; obtaining an initial exposure parameter used for initial exposure performed by the medical device; according to a first association, determining an initial incident dose that is associated with the initial exposure parameter and the distance; according to a second association, determining an initial image parameter that is associated with the initial exposure parameter and the initial incident dose; and on the basis of at least two of the initial incident dose, the initial image parameter and the initial exposure parameter, determining at least one optimized exposure parameter for the medical device according to the first association and the second association. Embodiments of the present disclosure can save on the time for adjusting an exposure parameter, and improve an operation procedure and efficiency.

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PARAMETER OPTIMIZATION METHOD, APPARATUS, MEDICAL DEVICE, MEDIUM AND PRODUCT

TECHNICAL FIELD

The present disclosure relates to the technical field of medical equipment, in particular a parameter optimization method and a parameter optimization apparatus for a medical device, a medical device, a computer-readable storage medium and a computer program product.

BACKGROUND ART

Adjustment of an exposure parameter is one of the important stages of a workflow of a medical device such as a medical X-ray imaging device. This is because the exposure parameter affects the radiation dose and image quality of the medical X-ray imaging device for example. Choosing a suitable exposure parameter is not only beneficial for optimizing image quality to facilitate diagnosis, but can also prevent a test target from coming into contact with excessive X-ray radiation.

However, in certain situations and for certain test targets, a medical device cannot be adjusted according to a preset exposure curve to an exposure parameter that can achieve a diagnostic objective. Here, an operator must manually re-adjust the exposure parameter to obtain the required image quality for diagnosis; this results in a longer and time-consuming workflow, and causes the test target to come into excessive contact with X-ray radiation.

The method described in this section is not necessarily a previously envisaged or used method. Unless otherwise stated, it should not be assumed that any method described in this section is regarded as prior art simply because it is included in this section. Similarly, unless otherwise stated, problems mentioned in this section should not be regarded as having been generally acknowledged in any prior art.

SUMMARY OF THE INVENTION

According to a first aspect of the present disclosure, a parameter optimization method for a medical device is provided, wherein the medical device comprises a tube and a detector, and the parameter optimization method comprises: obtaining a distance from a radiation source of the medical device to a test target; obtaining an initial exposure parameter used for initial exposure performed by the medical device; on the basis of the initial exposure parameter and the distance from the radiation source to the test target, according to a first association, determining an initial incident dose that is associated with the initial exposure parameter and the

distance from the radiation source to the test target, wherein the first association is used for indicating a relationship of an exposure parameter used for exposure performed by the medical device and the distance from the radiation source to the test target with the corresponding obtained incident dose; according to a second association, determining an initial image parameter that is associated with the initial exposure parameter and the initial incident dose, wherein the second association is used for indicating, with the exposure parameter used for exposure performed by the medical device being applied, a relationship between the corresponding obtained incident dose and the image parameter of a corresponding generated medical image; and on the basis of at least two of the initial incident dose, the initial image parameter and the initial exposure parameter, determining at least one optimized exposure parameter for the medical device according to the first association and the second association.

According to a second aspect of the present disclosure, a parameter optimization apparatus for a medical device is provided, wherein the medical device comprises a tube and a detector, and the parameter optimization apparatus comprises: a first acquisition module, the first acquisition module being configured to acquire a distance from a radiation source of the medical device to a test target; a second acquisition module, the second acquisition module being configured to acquire an initial exposure parameter used for initial exposure performed by the medical device; a first determination module, the first determination module being configured to determine an initial incident dose that is associated with the initial exposure parameter and the distance from the radiation source to the test target, on the basis of the initial exposure parameter and the distance from the radiation source to the test target, according to a first association, wherein the first association is used for indicating a relationship of an exposure parameter used for exposure performed by the medical device and the distance from the radiation source to the test target with the corresponding obtained incident dose; a second determination module, the second determination module being configured to determine an initial image parameter that is associated with the initial exposure parameter and the initial incident dose according to a second association, wherein the second association is used for indicating, with the exposure parameter used for exposure performed by the medical device being applied, a relationship between the corresponding obtained incident dose and the image parameter of a corresponding generated medical image; and a third determination module, the third determination module being configured to determine at least one optimized exposure parameter for the medical device, according to the first association and the second association, on the basis of at least two of the initial incident dose, the initial

image parameter and the initial exposure parameter.

According to a third aspect of the present disclosure, a medical device is provided, comprising: at least one processor; and a memory in communicative connection with the at least one processor, wherein the memory stores a computer program which, when executed by the at least one processor, implements the parameter optimization method according to the present disclosure.

According to a fourth aspect of the present disclosure, a non-transitory computer-readable storage medium storing a computer program is provided, wherein the computer program, when executed by a processor, implements the parameter optimization method according to the present disclosure.

According to a fifth aspect of the present disclosure, a computer program product is provided, comprising a computer program, wherein the computer program, when executed by a processor, implements the parameter optimization method of the present disclosure.

According to one or multiple embodiments of the present disclosure, an initial incident dose and an initial image parameter are calculated by means of the initial exposure parameter used in the initial exposure, and an optimized exposure parameter is determined on the basis of the initial exposure parameter and the calculated parameter, according to a relationship of the exposure parameter of the medical device with the incident dose and the image parameter. Firstly, the time of an operator adjusting the exposure parameter can be saved on during actual use of the medical device, and the operation procedure and efficiency of operating the medical device are improved; additionally, the probability of patients re-performing radiological examinations can be reduced, to prevent excessive exposure of patients to radioactive radiation.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present disclosure are described in detail below with reference to the accompanying drawings, to give those skilled in the art a clearer understanding of the above-mentioned and other features and advantages of the present disclosure. In the drawings:

Fig. 1 is a flowchart of a parameter optimization method for a medical device according to some exemplary embodiments of the present disclosure;

Fig. 2 is a schematic diagram of a distance from a focus of a tube to a surface of a detector, and a distance from the focus of the tube to a test target, according to some exemplary embodiments of the present disclosure;

Fig. 3 is a schematic diagram of a relationship between an exposure parameter and an incident dose of a medical device according to some exemplary embodiments of the present disclosure;

Fig. 4 is a schematic diagram of a relationship between an exposure voltage and a contrast-to-noise ratio of a medical device according to some exemplary embodiments of the present disclosure;

Fig. 5 is a schematic diagram of exposure curves related to optimized exposure parameters that are determined on the basis of an initial incident dose and a target image parameter, according to some exemplary embodiments of the present disclosure;

Fig. 6 is a schematic diagram of exposure curves related to optimized exposure parameters that are determined on the basis of an initial image parameter and a target incident dose, according to some exemplary embodiments of the present disclosure;

Fig. 7 is a schematic block diagram of a parameter optimization apparatus for a medical device according to some exemplary embodiments of the present disclosure; and

Fig. 8 shows an exemplary configuration of an electronic device that may be used to implement the methods described herein.

DETAILED DESCRIPTION OF THE INVENTION

To enable a clearer understanding of the technical features, objectives and effects of the present disclosure, particular embodiments of the present disclosure are now explained with reference to the accompanying drawings, in which identical labels indicate identical parts.

As used herein, "schematic" means "serving as an instance, example or illustration". No drawing or embodiment described herein as "schematic" should be interpreted as a more preferred or more advantageous technical solution.

To make the drawings appear uncluttered, only those parts relevant to the present disclosure are shown schematically in the drawings; they do not represent the actual structure thereof as a product. Furthermore, to make the drawings appear uncluttered for ease of understanding, in the case of components having the same structure or function in certain drawings, only one of these is drawn schematically, or only one is marked.

In this text, "a" does not only mean "just this one"; it may also mean "more than one". As used herein, "first" and "second" etc. are merely used to differentiate between parts, not to indicate their order or degree of importance, or any precondition of mutual existence, etc.

An X-ray imaging device acts as a type of medical device, and uses an X-ray generator to emit X-rays, the X-ray generator comprising an X-ray tube (such as a tube) and a high-voltage generator. The X-ray tube generally comprises an anode target and a cathode. When energized, a filament of the cathode can produce thermal electrons, and under the driving action of a high voltage between the cathodeand the anode, the electrons move at high speed and strike the surface of the anode target, generating X-ray radiation, and the X-rays are emitted through a window. When the X-ray tube rotates, the test target is exposed to X-rays. Using the X-rays, an operator can irradiate any part that it is necessary to inspect, and then generate an image by means of film or an imaging apparatus. The X-rays penetrate a target or human body and attenuate throughout the process. "Dose" is a measure of an amount of relevant radiation at a certain measurement point in units of Gy (gray) or uGy (micro-gray). "Incident dose" refers to a dose reaching a surface of an object. Regarding the test target, "incident dose" refers to a dose reaching the surface of the test target. Herein, unless especially stated, "incident dose" refers to the incident dose of the test target.

Whether an image generated by an X-ray imaging device is suitable for performing diagnosis can be assessed by means of multiple image indexes, such as image contrast resolution, image noise level, degree of artifact suppression, image signal uniformity, etc. Parameters for assessing image contrast resolution may comprise contrast-to-noise ratio (CNR), signal-to-noise ratio (SNR), etc. "CNR" refers to a ratio of a contrast between a region of interest and background in an image. SNR is a ratio of image signal to background in a given region.

An exposure parameter, for example, may comprise: a filter parameter (wherein a filter is used for attenuating or changing a spectral component of X-ray radiation), a

tube voltage (alternatively called exposure voltage, with units kV), a tube current (alternatively called exposure current, with units mA), an exposure time (with units s or ms) and exposure milliampere-seconds (that is, the product of tube current and exposure time, with units mAs). "Tube voltage" may refer to a voltage output by a high voltage generator to an X-ray tube, and represents a penetrating capability of X-rays emitted by the X-ray tube. The higher the tube voltage, the greater the kinetic energy acquired by electrons emitted by the X-ray tube cathode, and the stronger the capability (that is, penetrating capability) of the X-rays generated. "Tube current" may refer to a current output by a high voltage generator to an X-ray tube, and represents an amount of X-rays emitted by the X-ray tube. The greater the tube current, the greater the number of electrons emitted by the X-ray tube cathode, and the greater the number of electrons striking the surface of the anode target every second, and thus also the more X-rays are generated.

An exposure curve is used for describing the exposure parameter of each exposure point used by the X-ray tube in an operating process, wherein the exposure points correspond to exposure doses of the X-ray tube, the exposure dose being related to the tube voltage, tube current and exposure time of the X-ray tube. The exposure curve comprises one or multiple curves: a voltage curve, a current curve, a time curve and a milliampere-seconds curve. Horizontal coordinates of the voltage curve, the current curve, the time curve and the milliampere-seconds curve represent different exposure points, and the vertical coordinates are respectively used for describing an exposure voltage value, current value, time value or milliampere-second value. The exposure curves are generally calibrated before the medical device is dispatched from the factory.

Adjustment of an exposure parameter is one of the important stages of a workflow of an X-ray imaging device, for example. Choosing a rational and suitable exposure parameter is not only beneficial for optimizing image quality to facilitate diagnosis, but can also prevent a patient from coming into contact with excessive X-ray radiation. In a process of actual use, the exposure parameter of the X-ray imaging device generally can be adjusted by means of a double-exposure method; for example, first, dose adjustment is performed according to a preset exposure curve by means of short pre-exposure once to obtain a relatively suitable exposure parameter, and then this exposure parameter is used to perform exposure. Herein, "pre-exposure" refers to using the X-ray imaging device to perform exposure in advance, before exposure is performed on the patient.

In the related art, dose adjustment according to a preset exposure curve is a main

method for causing a medical device (such as an X-ray imaging device) to obtain a suitable exposure parameter (for example, enabling an image average grayscale value to reach a target value), and provides a fast and direct method for a system to achieve a target incident dose and a target image contrast resolution. However, in a process of actual use of a medical device, there exist multiple types of different interventional imaging techniques, different patients with various cases, and various different parts to be tested of patients. Therefore, in a process of actual use, normally a medical device operator, by means of a human-machine interactive device (such as a touchscreen, keyboard, mouse, etc.), can choose a corresponding organ procedure (OGP) according to an organ/part to be tested, patient body type and posture (such as upright or lateral); thus, the medical device, on the basis of a preset exposure curve corresponding to the organ procedure, can automatically determine a desired X-ray dose corresponding to this organ/part, and determine a tube voltage value, tube current value, exposure time length, etc. of the X-ray tube. An exposure parameter obtained by performing dose adjustment only according to a preset fixed exposure curve might generate an image with poorer contrast and higher noise. In this type of situation, the operator of the medical device must manually adjust the exposure parameter, and estimate a more ideal exposure parameter for the patient according to experience. However, it is difficult to adjust the exposure parameter according to experience; merely simply increasing the incident dose results in an increase of the exposure voltage, whereas the image contrast becomes worse. Manually adjusting the exposure parameter can result in the operator performing exposure repeatedly many times, wasting more operating time. Even then, the operator may not be able to obtain a suitable exposure parameter through adjustment, and the obtained image quality may still be poor.

The present disclosure calculates an initial incident dose and an initial image parameter of the test target by means of the initial exposure parameter used in the initial exposure, and on the basis of the initial exposure parameter, and the calculated initial incident dose and initial image parameter, according to a relationship of the exposure parameter of the medical device with the incident dose and the image parameter, determines an optimized exposure parameter. Firstly, the time of an operator adjusting the exposure parameter can be saved on in a process of actual use of the medical device, and the operation procedure and efficiency of operating the medical device are improved; additionally, the probability of patients re-performing radiological examinations can be reduced, to prevent excessive exposure of patients to radioactive radiation.

Exemplary embodiments of the present disclosure are described in detail below with

reference to the drawings.

Fig. 1 is a flowchart of a parameter optimization method for a medical device according to some exemplary embodiments of the present disclosure. The medical device may be a medical device that performs exposure on the basis of an exposure curve (additionally, requiring exposure multiple times to acquire multiple images), such as an X-ray imaging device (for example, a C-arm X-ray imaging device, etc.). As shown in Fig. 2, a medical device 2000 may comprise a radiation source 201 (such as an X-ray tube), a detector 202 used for receiving rays emitted by the radiation source 201, an examination table 204, a high voltage generator (not shown), etc. In Fig. 2, the medical device 2000 is in a process of actual use, and a test target 205 is located on the examination table 204. As shown in Figs. 1 and 2, a parameter optimization method 1000 may comprise:

Step S101, obtaining a distance from the radiation source 201 of the medical device 2000 to the test target 205;

Step S102, obtaining an initial exposure parameter used for initial exposure performed by the medical device 2000;

Step S103, on the basis of the initial exposure parameter, and a distance B from the radiation source 201 to the test target 205, according to a first association, determining an initial incident dose that is associated with the initial exposure parameter and the distance B from the radiation source 201 to the test target 205;

Step S104, according to a second association, determining an initial image parameter that is associated with the initial exposure parameter and the initial incident dose; and

Step S105, on the basis of at least two of the initial incident dose, the initial image parameter and the initial exposure parameter, determining at least one optimized exposure parameter for the medical device according to the first association and the second association.

In step S101, a distance from the radiation source of the medical device to the test target is obtained.

The distance from the radiation source to the test target is specifically the distance from the focus of the radiation source to the surface of the test target, the distance

B from the focus of the radiation source 201 to the test target 205 as shown in Fig. 2. For example, by means of a camera (such as a 3D camera or a depth camera, etc.) attached onto the radiation source or an added camera that is independent of the radiation source, images are collected to obtain the distance from the focus of the radiation source to the surface of the test target, for calculating the incident dose of a medical device in a process of actual use.

In step S102, an initial exposure parameter used for initial exposure performed by the medical device is obtained.

Herein, "initial exposure" may refer to any one instance of exposure performed by the medical device. For example, "initial exposure" may be exposure performed on a patient on the basis of a selected organ procedure, and also may be "pre-exposure", that is, exposure performed in advance using the medical device before exposure is performed on the patient. In the process of initial exposure, for example, a C-arm X-ray imaging device may perform dose adjustment according to a preset exposure curve to obtain a relatively suitable exposure parameter. In some embodiments, the initial exposure parameter may comprise one or more of initial exposure voltage, initial exposure current, initial exposure milliampere-seconds and initial exposure filter parameters, etc. In some embodiments, the initial exposure parameter may be an exposure parameter of the medical device at the instant that the initial exposure stage ends, that is, an exposure parameter that has been adjusted according to a preset exposure curve.

In step S103, on the basis of the initial exposure parameter, and the distance from the radiation source to the test target, according to a first association, an initial incident dose that is associated with the initial exposure parameter and the distance from the radiation source to the test target is determined.

The first association is used for indicating a relationship of an exposure parameter used for exposure performed by the medical device and the distance from the radiation source to the test target with the corresponding obtained incident dose. Herein, "association" may comprise a function relationship, a data table relationship, a linear graph relationship, etc. In some embodiments, the first association may be used for indicating a relationship of the exposure voltage and the exposure current used for exposure performed by the medical device with the corresponding obtained incident dose at the test target (specifically, a surface thereof).

In some embodiments, before the medical device is dispatched from a factory, the first association between the exposure parameter and the incident dose at the test target can be determined by means of system calibration. Alternatively, in a process of actual use of the medical device, that is, in the process of the medical device being actually used to photograph a test target after being dispatched from the factory, the association between the exposure parameter and the incident dose is determined by means of system calibration in advance, the system calibration being achievable, for example, by means of exposure multiple times. That is, the parameter optimization method 1000 also may comprise a step for determining the first association by means of system calibration.

In some embodiments, the distance from the radiation source to the test target is a first distance from the radiation source to the test target, and the first association may be obtained by the following solution: obtaining a second distance from the radiation source (specifically, the focus thereof) to a detector (specifically, a surface thereof); in a scenario without a test target, by means of device calibration, determining a calibration relationship of the exposure parameter used for exposure performed by the medical device with a dose at the detector; and determining the first association on the basis of the first distance, the second distance and the calibration relationship. Specifically, for example, the following steps can be used to perform system calibration to obtain the calibration relationship: under conditions of no test target on the examination table, a fixed filter parameter (for example, no filter or 0.1 mm Cu) and fixed exposure milliampere-seconds (for example, 0.02 mAs), using multiple exposure voltages (which change in set increments between a minimum exposure voltage and a maximum exposure voltage allowed by the X-ray generator) to respectively perform exposure multiple times, to respectively obtain multiple doses received at the detector. Thus, the calibration relationship of the dose received at the detector with the exposure parameter (for example, an exposure voltage and milliampere-seconds) can be obtained, so that the first association can subsequently be obtained by conversion.

Here it will be understood that different filter parameters can result in different associations between the exposure parameter and the incident dose, and accordingly different calibration relationships can be demarcated for different filter parameters (for example, no filter or 0.1 mm Cu), to obtain different first associations; moreover, in the process of actual use of the medical device, the corresponding first association is used according to the selected filter parameter. Alternatively, if a filter is not selected in the process of actual use of the medical device (that is, there is only one or no filter), an effect of the filter parameter need

not be considered with regard to the first association at this time.

Thus, the calibration conditions used during system calibration are no test target being on the examination table, what is obtained during system calibration being the dose received at the detector; therefore, when determining the first association between the exposure parameter and the incident dose, it is further necessary, on the basis of the first distance, the second distance and the calibration relationship, to determine, that is consider, a distance SID from the radiation source (specifically, the focus thereof) to the detector (specifically, a surface thereof) and a distance from the radiation source (specifically, the focus thereof) to the test target (specifically, a surface thereof) when the test target is on the examination table, so as to convert the association between the exposure parameter obtained by system calibration and the dose received at the detector into the first association between the exposure parameter and the incident dose at the test target. The specific conversion relation is as follows:

$$ED_B = A^2/B^2 * ED_A.$$

ED_A is a dose received at the detector determined according to a calibration relationship obtained by system calibration; ED_B is an actual incident dose when the test target 205 is located on the examination table 204; A is the distance from the radiation source 201 to the detector 202, and is an intrinsic parameter of the medical device; and B is the distance from the radiation source 201 to the test target 205, and must be obtained during actual use of the medical device, for example, by collecting an image with a camera, and is related to the volume, photographed part, etc. of the test target.

The calibration relationship obtained by system calibration may be the curve relationship shown in Fig. 3. In Fig. 3, the horizontal coordinates represent exposure points, and the vertical coordinates represent values of parameters of the corresponding curves. The curve 301 is an exposure voltage curve; the curve 302 is a curve of the dose received at the detector obtained by system calibration; the curve 303 is a milliampere-seconds curve. In the curve relationships shown in Fig. 3, it is possible, on the basis of the initial exposure parameter (for example, initial exposure voltage and milliampere-seconds), according to the exposure voltage curve, the incident dose curve and the milliampere-seconds curve, to find the corresponding dose received at the detector, and then, according to the conversion relation that is determined by the distance from the radiation source to the detector and the distance from the radiation source to the test target, convert the dose found

at the detector to obtain the initial incident dose.

Alternatively or in addition, the first association may be a function relationship. For example, when the exposure milliampere-seconds are 0.02 mAs, and the conversion relation between the dose and distance, and a linear relationship between the exposure milliampere-seconds and incident dose have been considered, the first association can be expressed by the following formula (when the influence of the field of view on the incident dose is relatively small, this variable need not be considered in the following formula):

$$ED = f(filter, \left(\frac{Sys\_mAs}{0.02\ mAs}\right) \times \left(\frac{(Sys\_SID)^2}{(Sys\_Distance)^2}\right) \times (a \times Sys\_kV^2 + b \times Sys\_kV + c))$$

(formula 1).

where ED is the incident dose, which is a function of the exposure parameter, the distance from the focus of the radiation source to the surface of the test target, and the filter parameter, wherein the exposure parameter comprises exposure milliampere-seconds and exposure voltage; Sys_mAs is one of the inputs of the first association, that is, exposure milliampere-seconds of the current system, and Sys_kV is one of the inputs of the first association, that is, exposure voltage of the current system; Sys_SID is the distance from the focus of the radiation source to the surface of the detector that is used under the condition where there is no test target during system calibration, and $Sys\_Distance$ is one of the inputs of the first association, that is, the current distance from the focus of the radiation source to the surface of the test target; a, b, c is a function determined by means of system calibration; and $filter$ is one of the inputs of the first association, that is, the filter parameter selected by the current system, for example, absence or presence of filter, filter type, etc.

For example, when the initial exposure voltage is $kV1$, the initial exposure milliampere-seconds are $mAs1$, $Sys\_SID = A$、$Sys\_Distance$ = B, and when the filter parameter is $filter1$, the initial incident dose is $ED1 = f(filter1, \left(\frac{mAs1}{0.02\ mAs}\right) \times \left(\frac{A^2}{B^2}\right) \times (a \times kV1^2 + b \times kV1 + c))$.

Thus, during actual use of the medical device, on the basis of the initial exposure parameter for initial exposure in step S102, the first association is used (for example, substituting the initial exposure parameter, and the distance from the

radiation source to the test target into formula 1) to determine the initial incident dose associated with this initial exposure parameter.

In step S104, according to a second association, an initial image parameter that is associated with the initial exposure parameter and the initial incident dose is determined.

The second association is used for indicating, with the exposure parameter used for exposure performed by the medical device being applied, a relationship between the corresponding obtained incident dose and the image parameter of a corresponding generated medical image. The image parameters may be parameters used for representing image quality (such as contrast resolution), and may comprise: contrast-to-noise ratio CNR, signal-to-noise SNR, etc. Herein, "association" may comprise a function relationship, a data table relationship, a linear graph relationship, etc. In some embodiments, the second association may be used for indicating a relationship of an exposure voltage and exposure current used for exposure performed by the medical device, and the distance from the radiation source to the test target, with the corresponding obtained image quality, or a relationship of the exposure voltage used for exposure performed by the medical device with the corresponding obtained incident dose and image parameter.

In some embodiments, the second association can be determined by means of system calibration before the medical device is dispatched from the factory. Alternatively, during actual use of the medical device (that is, during actual use of the medical device after being dispatched from the factory), the second association is determined by means of system calibration in advance (in advance by means of exposure multiple times). That is, the parameter optimization method 1000 also may comprise a step for determining the second association by means of system calibration. In some embodiments, the step for determining the second association may be similar to the step for determining the first association mentioned above, and is not described in further detail here. In some other embodiments, a relationship between the incident dose and CNR can be obtained by system calibration first, and thus a trend of variation of CNR is obtained in situations where exposure voltage changes. It will be understood that, in the process of system calibration, it is not necessary to perform image processing on the image obtained by exposure, to ensure an accurate image parameter is obtained.

When the second association is used for representing the relationship of the exposure voltage with the incident dose and the image parameter, and the image

parameter is CNR, the second association obtained by system calibration may be the curve relationship 401 between CNR and exposure voltage shown in Fig. 4 (wherein the incident dose does not change). In Fig. 4, the horizontal coordinates represent exposure voltage, and the vertical coordinates represent values of corresponding CNR. At this time, on the basis of the initial exposure parameter, according to the curve relationship between CNR and exposure voltage, the initial CNR can be found.

Alternatively or in addition, the second association obtained by system calibration may also be a function relationship. For example, the second association, obtained by system calibration, of the exposure voltage with the incident dose and CNR may expressed with the following function relationship:

$ED/E\_CNR = d \times kV^e$ (formula 2).

where ED is incident dose; E_CNR is CNR; and kV is an input of the second association, that is, exposure voltage of the current system. d, e are coefficients of the function determined by system calibration. For example, when the initial exposure voltage is $kV1$, and the initial exposure milliampere-seconds are $mAs1$, $Sys\_SID = A$、$Sys\_Distance$ =B, the initial incident dose is $E\_CNR1 = ED1/(d \times kV1^e)$.

Alternatively, when the second association is used for representing the relationship of exposure voltage and exposure current with the image parameter, and the image parameter is CNR, the second association may be expressed with the following formula (conditions during demarcation being milliampere-seconds being 0.02 mAs):

$$E\_CNR = f(filter, \left(\frac{Sys\_mAs}{0.02mAs}\right) \times \left(\frac{(Sys\_SID)^2}{(Sys\_Distance)^2}\right) \times (a \times Sys\_kV^2 + b \times Sys\_kV + c))/(d \times kV^e)$$ (formula 3).

That is, formula 1 of the above-mentioned incident dose is substituted into formula 2 to obtain formula 3 mentioned above. The characteristics of the various parameters in formula 3 are the same as formulas 1 and 2, and are not described in further detail here. For example, when the initial exposure voltage is $kV1$, the initial exposure milliampere-seconds are $mAs1$, $Sys\_SID = A$、$Sys\_Distance$ =B, and the filter parameter is $filter1$, the initial incident dose is $E\_CNR1 = f(filter1, \left(\frac{mAs1}{0.02\ mAs}\right) \times (\frac{A^2}{B^2}) \times (a \times kV1^2 + b \times kV1 + c))/(d \times kV1^e)$.

Thus, during actual use of the medical device, on the basis of the initial exposure parameter for initial exposure, according to the second association, an initial image parameter that is associated with this initial exposure parameter can be determined. For example, substituting the initial exposure parameter and initial incident dose into formula 2, or substituting the initial exposure parameter, and the distance from the radiation source to the test target into formula 3, the initial CNR is calculated.

In step S105, on the basis of at least two of the initial incident dose, the initial image parameter and the initial exposure parameter, at least one optimized exposure parameter for the medical device is determined according to the first association and the second association.

Specifically, the initial image parameter or initial incident dose associated with the initial exposure parameter may act as a standard for comparison. For example, by means of the incident dose not changing (that is, being equal to the initial incident dose) while increasing the image parameter, the corresponding exposure parameter is determined, via the above-mentioned first association and second association, to act as the optimized exposure parameter. As another example, by means of the image parameter not changing (that is, being equal to the initial image parameter) while reducing the incident dose, the corresponding exposure parameter is determined, via the above-mentioned first association and second association, to act as the optimized exposure parameter.

By means of the above-mentioned embodiments, the procedure of adjusting the exposure parameter for the medical device can be improved, and time for adjusting the exposure parameter can be saved on; moreover, a better image quality and a lower radiation dose can be obtained, and performing repeated exposure on a patient can be prevented as much as possible. In addition, the above-mentioned embodiments not only adjust the exposure parameter by means of the incident dose but also consider the influence of the image parameter; moreover, a capability of a ray generator is maximally utilized without being restricted by an exposure curve, so as to achieve a better image quality and less radiation.

In some embodiments, step S105 may comprise: on the basis of the initial incident dose and the initial image parameter, determining at least one optimized exposure parameter for the medical device according to the first association and the second association. For example, by means of the incident dose not changing (that is, being

equal to the initial incident dose) while increasing the image parameter, the corresponding exposure parameter is determined, via the above-mentioned first association and second association, to act as the optimized exposure parameter. As another example, by means of the image parameter not changing (that is, being equal to the initial image parameter) while reducing the incident dose, the corresponding exposure parameter is determined, via the above-mentioned first association and second association, to act as the optimized exposure parameter. Thus, the initial image parameter and initial incident dose associated with the initial exposure parameter may act as a standard for comparison, and a target image parameter or incident dose is set to directly determine the corresponding exposure parameter, to simplify the amount of computation and improve computation efficiency.

In some embodiments, the optimized exposure parameter can be determined by means of maintaining the initial incident dose and setting a target image parameter. Specifically, at least one optimized exposure parameter comprises a first optimized exposure parameter, and the step of determining, on the basis of the initial incident dose and initial image parameter, according to the first association and the second association, at least one optimized exposure parameter for the medical device comprises: determining a target image parameter on the basis of the initial image parameter, the target image parameter being greater than the initial image parameter; on the basis of the initial incident dose and the target image parameter, according to the first association and the second association, determining a first candidate exposure voltage and a first candidate exposure current; and in response to a first preset condition being satisfied, the first candidate exposure voltage and the first candidate exposure current acting as the first optimized exposure parameter, and the first preset condition stipulating that the first candidate exposure current is less than or equal to a maximum exposure current allowed by a ray generator. In some examples, the maximum exposure current allowed by the ray generator may be related to the exposure voltage. That is, the maximum exposure current allowed by the ray generator changes with the exposure voltage currently used by the ray generator. At this time, a third preset condition is specifically that the first candidate exposure current may be less than or equal to the maximum exposure current allowed by the ray generator with the first candidate exposure voltage.

Where the first association and the second association are respectively formulas 1 and 2 mentioned above, the target CNR, that is T_CNR, may be set to be $T\_CNR = m * E\_CNR1$, wherein m is greater than 1 (that is, $T\_CNR > E\_CNR1$), specifically

between 1.1 and 1.2 for example. Where the incident dose does not change (that is, a new incident dose $ED2$ is equal to the initial incident dose, $ED2 = ED1$), $ED1/T\_CNR = d \times kV2^e$ can be obtained according to formula 2, and thus it is possible to calculate the first candidate exposure voltage $kV2$. Subsequently, according to formula 1, it is possible to calculate the first candidate exposure current $mAs2 = ED1 \times 0.02\,mAs \times f^{-1}(filter1, (\frac{A^2}{B^2}) \times (a \times kV2^2 + b \times kV2 + c))$. If the first candidate exposure current $mAs2$ is less than or equal to the maximum exposure current L_mAs2 allowed by the ray generator at the first candidate exposure voltage $kV2$, then the first candidate exposure current $mAs2$ and the first candidate exposure voltage $kV2$ act as the first optimized exposure parameter. It will be understood that, although in the means for determining the first candidate exposure voltage and current mentioned above, the set filter parameter $filter$ does not change (that is, is equal to the filter parameter $filter1$ during initial exposure), a combined value of the first candidate exposure voltage, first candidate exposure current and first candidate filter parameter can be determined on the basis of the first association and the second association. The above-mentioned embodiment can obtain a better image quality without the incident dose changing, for example, with a CNR that is 10% to 20% higher than the initial CNR, and can ensure that the obtained optimized exposure parameter is an exposure parameter which can be achieved by the ray generator.

Additionally or alternatively, the optimized exposure parameter can be determined by means of maintaining the initial image parameter and setting a target incident dose. Specifically, at least one optimized exposure parameter comprises a second optimized exposure parameter, and the step of determining, on the basis of the initial incident dose and initial image parameter, according to the first association and the second association, at least one optimized exposure parameter for the medical device may comprise: determining a target incident dose on the basis of the initial incident dose, the target incident dose being less than the initial incident dose; on the basis of the initial image parameter and the target incident dose, according to the first association and the second association, determining a second candidate exposure voltage and a second candidate exposure current; and in response to a second preset condition being satisfied, the second candidate exposure voltage and the second candidate exposure current acting as a second optimized exposure parameter, the second preset condition stipulating that the second candidate exposure current is less than or equal to a maximum exposure current allowed by a ray generator, wherein the maximum exposure current allowed by the ray generator has the same characteristics as the maximum exposure current in the

above-mentioned embodiment, and is not described in further detail here.

Where the first association and the second association are respectively formulas 1 and 2 mentioned above, the target incident dose TD may be set to be $TD = n * ED1$, wherein n is less than 1 (that is, $TD < ED1$), specifically between 0.8 and 0.9 for example. Where the CNR does not change (that is, a new CNR E_CNR2 is equal to the initial CNR, that is $E\_CNR2 = E\_CNR1$), $TD/E\_CNR1 = d \times kV3^e$ can be obtained according to formula 2, and thus it is possible to calculate the second candidate exposure voltage $kV3$. Subsequently, according to formula 1, it is possible to calculate the second candidate exposure current $mAs3 = TD \times 0.02\,mAs \times f^{-1}(filter1, (\frac{A^2}{B^2}) \times (a \times kV3^2 + b \times kV3 + c))$. If the second candidate exposure current $mAs3$ is less than or equal to the maximum exposure current L_mAs3 allowed by the ray generator at the second candidate exposure voltage $kV3$, then the second candidate exposure current $mAs3$ and the second candidate exposure voltage $kV3$ act as the second optimized exposure parameter. It will be understood that, although in the means for determining the second candidate exposure voltage and current mentioned above, the set filter parameter $filter$ does not change (that is, is equal to the filter parameter $filter1$ during initial exposure), a combined value of the second candidate exposure voltage, second candidate exposure current and second candidate filter parameter can be determined on the basis of the first association and the second association. The above-mentioned embodiment can obtain a lower incident dose (that is, less radiation) without the image parameter changing, for example, with an incident dose that is 10% to 20% lower than the initial incident dose, and can ensure that the obtained optimized exposure parameter is an exposure parameter which can be achieved by the ray generator.

It will be understood that the method 1000 may comprise the steps of determining both the first optimized exposure parameter and the second optimized exposure parameter. Moreover, the first optimized exposure parameter and the second optimized exposure parameter are both sent to an operator, for the operator to select a suitable exposure parameter according to needs.

In some other embodiments, on the basis of formula 2, it can be seen that, with the initial incident dose maintained, the exposure voltage reduces, which can increase the CNR, and, without the initial CNR changing, the exposure voltage reduces, which can reduce the incident dose. Therefore, the optimized exposure parameter can be determined by means of maintaining the initial incident dose and/or initial image parameter, and reducing the exposure voltage. Specifically, at least one

optimized exposure parameter comprises a third optimized exposure parameter and/or a fourth optimized exposure parameter, and step S105 may comprise: on the basis of the initial incident dose and initial exposure parameter, according to the first association and the second association, determining the third optimized exposure parameter; and/or on the basis of the initial image parameter and the initial exposure parameter, according to the first association and the second association, determining the fourth optimized exposure parameter. The above-mentioned embodiment can facilitate acquisition of an optimized exposure parameter with the greatest reduction in incident dose and/or greatest increase in image parameter.

In some embodiments, the optimized exposure parameter can be calculated by means of maintaining the initial incident dose and reducing the exposure voltage. Specifically, the step of determining, on the basis of the initial incident dose and the initial exposure parameter, according to the first association and the second association, the third optimized exposure parameter may comprise: determining at least one third candidate exposure voltage on the basis of the initial exposure voltage, each of the at least one third candidate exposure voltage being greater than or equal to a minimum exposure voltage allowed by the ray generator and being less than the initial exposure voltage (that is, the third candidate exposure voltage not exceeding the minimum exposure voltage allowed by the ray generator, and being lower by a certain degree compared to the initial exposure voltage); for each of the at least one third candidate exposure voltage, on the basis of the initial incident dose and the third candidate exposure voltage, according to the first association and the second association, determining a candidate image parameter and a third candidate exposure current corresponding to the third candidate exposure voltage; and in response to a third preset condition being satisfied, determining the third optimized exposure parameter from the at least one third candidate exposure voltage and the third candidate exposure current corresponding to the at least one third candidate exposure voltage, the third preset condition stipulating that the third candidate exposure current corresponding to at least some third candidate exposure voltages from the at least one third candidate exposure voltage is less than or equal to the maximum exposure current allowed by the generator, and a ratio of a candidate image parameter corresponding to at least some of the third candidate exposure voltages to the initial image parameter is greater than a first preset threshold value, wherein the maximum exposure current allowed by the ray generator has the same characteristics as the maximum exposure current in the above-mentioned embodiment, and is not described in further detail here. The first preset threshold value may be greater than 1, for example, between 1.1 and 1.2.

In the examples in formulas 1 and 3 mentioned above, supposing the minimum exposure voltage allowed by the ray generator $kVmin$, the initial exposure voltage $kV1$, at this time at least one third candidate exposure voltage kVp (wherein$p = 2, 3. ...$), set as $kVmin < kVp < kV1$, and correspondingly, the maximum exposure current allowed by the ray generator is respectively L_mAsp (wherein $p = 2, 3, ...$). Without the incident dose changing (that is, the new incident dose $ED2$ is equal to the initial incident dose, $ED2 = ED1$), and substituting in each one of the third candidate exposure voltages from the at least one third candidate exposure voltage kVp into formula 1, at least one third candidate exposure current $mAsp =$ $ED1 \times 0.02\ mAs \times f^{-1}(filter1, (\frac{A^2}{B^2}) \times (a \times kVp^2 + b \times kVp + c))$ can respectively be obtained (wherein $p = 2,3, ...$). Moreover, on the basis of formula 3, the corresponding candidate CNR can be obtained, that is $E\_CNRp =$ $f(filter1, (\frac{mAsp}{0.02\ mAs}) \times (\frac{A^2}{B^2}) \times (a \times kVp^2 + b \times kVp + c))/(d \times kVp^e)$. For one third candidate exposure voltage therein kVp, if the third candidate exposure current $mAsp$ is less than or equal to the maximum exposure current L_mAsp allowed when the ray generator has the third candidate exposure voltage kVp, and $E\_CNRp/E\_CNR1 > t1$ (wherein t1 is a first preset threshold value), then the third candidate exposure current $mAsp = ED1$ and the first candidate exposure voltage kVp can act as a third optimized exposure parameter. In the above embodiment, multiple third candidate exposure voltages and third candidate exposure currents corresponding thereto that satisfy the third preset condition can be found (for example, the candidate exposure current curve 501 in Fig. 5, and the curves 301, 302 and 303 in Fig. 5 being the corresponding curves 301, 302 and 303 in Fig. 3), and have the same incident dose (for example, incident dose curve 502 in Fig. 5) and multiple corresponding CNRs (for example, candidate CNR curve 503 in Fig. 5). In some examples, the third candidate exposure voltage and the third candidate exposure current that satisfy the third preset condition may all act as the third optimized exposure parameter. Alternatively, the third candidate exposure voltage and the third candidate exposure current with the most increase in candidate CNR can act as the third optimized exposure parameter. The above-mentioned embodiment can obtain a better image quality without the incident dose changing, and in particular can find the best optimized exposure parameter, and can ensure that the obtained optimized exposure parameter is an exposure parameter which can be achieved by the ray generator.

Alternatively or in addition, the optimized exposure parameter can be calculated by

means of maintaining the initial image parameter and reducing the exposure voltage. The step of determining the fourth optimized exposure parameter, on the basis of the initial image parameter and the initial exposure parameter, according to the first association and the second association, may comprise: determining at least one fourth candidate exposure voltage on the basis of the initial exposure voltage, each of the at least one fourth candidate exposure voltage being greater than or equal to a minimum exposure voltage allowed by the ray generator and being less than the initial exposure voltage; for each of the at least one fourth candidate exposure voltage, on the basis of the initial image parameter and the fourth candidate exposure voltage, according to the first association and the second association, determining a candidate incident dose and a fourth candidate exposure current corresponding to the fourth candidate exposure voltage; and in response to a fourth preset condition being satisfied, determining the fourth optimized exposure parameter from the at least one fourth candidate exposure voltage and the fourth candidate exposure current corresponding to the at least one fourth candidate exposure voltage, the fourth preset condition stipulating that the fourth candidate exposure current corresponding to at least some fourth candidate exposure voltages from the at least one fourth candidate exposure voltage is less than or equal to the maximum exposure current allowed by the ray generator, and a ratio of a candidate incident dose corresponding to at least some of the fourth candidate exposure voltages to the initial incident dose is less than a second preset threshold value, wherein the maximum exposure current allowed by the ray generator has the same characteristics as the maximum exposure current in the above-mentioned embodiment, and is not described in further detail here. In addition, values of the fourth candidate exposure voltage may be the same as the third candidate exposure voltage, or some may be the same, or all may be different. The second preset threshold value may be less than 1, for example, between 0.8 and 0.9.

In the examples in formulas 1 and 3 mentioned above, supposing the minimum exposure voltage allowed by the ray generator $kVmin$, the initial exposure voltage $kV1$, at this time at least one fourth candidate exposure voltage may be the same as the value of the at least one third candidate exposure voltage, that is, both being kVp, and $kVmin < kVp < kV1$, and correspondingly, the maximum exposure current allowed by the ray generator is respectively L_mAsp. Without CNR changing (that is, the new CNR E_CNRp is equal to the initial CNR, that is $E\_CNRp = E\_CNR1$), and substituting each of the at least one fourth candidate exposure voltage kVp into formula 3, at least one fourth candidate exposure current $mAs'p =$

$E\_CNR1 \times d \times kVp^e \times 0.02\,mAs \times f^{-1}(filter1, (\frac{A^2}{B^2}) \times (a \times kVp^2 + b \times kVp + c))$ can

respectively be obtained. Moreover, on the basis of formula 1, the corresponding candidate incident dose can be obtained, that is $EDp = f(filter1, \left(\frac{mAs'p}{0.02\ mAs}\right) \times (\frac{A^2}{B^2}) \times (a \times kVp^2 + b \times kVp + c))$. For one fourth candidate exposure voltage therein kVp, if the fourth candidate exposure current $mAs''p$ is less than or equal to the maximum exposure current L_mAsp allowed when the ray generator has the fourth candidate exposure voltage kVp, and $\frac{EDp}{ED1} < t2$ (wherein t2 is a second preset threshold value), then the fourth candidate exposure current $mAs''p$ and the fourth candidate exposure voltage kVp can act as a fourth optimized exposure parameter. In the above embodiment, multiple fourth candidate exposure voltages and fourth candidate exposure currents corresponding thereto that satisfy the fourth preset condition can be found, and have the same CNR (for example, CNR curve 601 in Fig. 6, and curves 301, 302 and 303 in Fig. 6 being corresponding curves 301, 302 and 303 in Fig. 3) and multiple corresponding incident doses (for example, incident dose-CNR curve 602 in Fig. 6). In some examples, the fourth candidate exposure voltage and the fourth candidate exposure current that satisfy the fourth preset condition may all act as the fourth optimized exposure parameter. Alternatively, referring to Fig. 6, the fourth candidate exposure voltage and the fourth candidate exposure current with the greatest reduction in candidate incident dose may act as the fourth optimized exposure parameter. The above-mentioned embodiment can obtain a lower incident dose without the image parameter changing, and in particular can find the best optimized exposure parameter, and can ensure that the obtained optimized exposure parameter is an exposure parameter which can be achieved by the ray generator.

In some embodiments, the parameter optimization method 1000 may further comprise: in response to the radiation source aligning with a part to be tested (for example, an organ) of the test target, causing the camera to carry out photography to obtain the distance from the focus of the radiation source to the test target. As stated above in step S103, since no test target is on the examination table in the process of system calibration, it is necessary to consider a distance SID from the focus of the radiation source to the surface of the detector, and a distance from the focus of the radiation source to the surface of the test target when the test target is on the examination table, so as to convert the association between the exposure parameter obtained by system calibration and the dose received at the detector into the first association between the exposure parameter and the incident dose at the test target. Therefore, in response to an operator operating the medical device to cause the radiation source to align with the part to be tested of the test target, the

camera carries out photography to obtain the distance from the focus of the radiation source to the test target. This camera, for example, is a 3D camera or depth camera that is mounted at the radiation source, or is an added 3D camera or depth camera that is independent of the radiation source, etc.

In some embodiments, the parameter optimization method 1000 may further comprise: sending at least one optimized exposure parameter to a display unit for a user to select. Additionally, the parameter optimization method 1000 may further comprise: in response to receiving a user selection instruction, on the basis of the user selection instruction, updating the initial exposure parameter, and the user selection instruction being used for indicating an optimized exposure parameter selected by the user from the at least one optimized exposure parameter. Thereafter, the medical device performs exposure using an updated initial exposure parameter, thereby causing radiation generated by subsequent exposure to be lower and/or obtained image quality to be better.

In some embodiments, the parameter optimization method 1000 may further comprise: in response to not receiving a user selection instruction, continuing to use the initial exposure parameter to perform exposure.

Fig. 7 is a schematic block diagram of a parameter optimization apparatus 7000 for a medical device according to some exemplary embodiments of the present disclosure. As shown in Fig. 7, the parameter optimization apparatus 7000 may comprise: a first acquisition module 701, a second acquisition module 702, a first determination module 703, a second determination module 704 and a third determination module 705. The first acquisition module 701 is configured to acquire a distance from a radiation source of the medical device to a test target. The second acquisition module 702 is configured to acquire an initial exposure parameter used for initial exposure performed by the medical device. The first determination module 703 is configured, on the basis of the initial exposure parameter and the distance from the radiation source to the test target, according to a first association, to determine an initial incident dose that is associated with the initial exposure parameter and the distance from the radiation source to the test target, wherein the first association is used for indicating a relationship of an exposure parameter used for exposure performed by the medical device and the distance from the radiation source to the test target with the corresponding obtained incident dose. The second determination module 704 is configured, according to a second association, to determine an initial image parameter that is associated with the initial exposure parameter and the initial incident dose, wherein the second association is used for

indicating, with the medical device performing exposure, a relationship between the corresponding obtained incident dose and the image parameter of a corresponding generated medical image. The third determination module 705 is configured to determine at least one optimized exposure parameter for the medical device, on the basis of at least two of the initial incident dose, the initial image parameter and the initial exposure parameter, according to the first association and the second association.

It should be understood that the modules of the apparatus 7000 shown in Fig. 7 may correspond to the steps in the method 1000 described with reference to Fig. 1. Thus, the operations, features and advantages described above for the method 1000 likewise apply to the apparatus 7000 and the modules comprised therein. For conciseness, some operations, features and advantages are not described again here.

According to another aspect of the present disclosure, a medical device is provided, comprising: at least one processor; and a memory in communicative connection with the at least one processor, wherein the memory stores a computer program which, when executed by the at least one processor, implements the steps according to the method 1000 described above. The medical device may be an X-ray imaging device, etc.

According to another aspect of the present disclosure, an electronic device is provided, comprising: at least one processor; and a memory in communicative connection with the at least one processor, wherein the memory stores a computer program which, when executed by the at least one processor, implements the steps according to the method 1000 described above. The X-ray imaging device comprises this type of electronic device.

According to another aspect of the present disclosure, a non-transitory computer-readable storage medium storing a computer program is provided, wherein the computer program, when executed by a processor, implements the steps according to the method 1000 described above.

According to another aspect of the present disclosure, a computer program product is provided, comprising a computer program which, when executed by a processor, implements the steps according to the method 1000 described above.

Illustrative examples of such an electronic device, non-transitory computer-readable storage medium and computer program product are described below with reference

to Fig. 8.

Fig. 8 shows an exemplary configuration of an electronic device 8000 that may be used to implement the methods described herein. The electronic device 8000 may be a variety of different types of device, e.g. a server of a service provider, a device associated with a client (e.g. a client device), a system on a chip, and/or any other suitable computer device or computing system. Examples of the electronic device 8000 include but are not limited to: a desktop computer, a server computer, a notebook computer or netbook computer, a mobile device (for example, a tablet computer, cellular or other wireless telephone (e.g. smartphone), notepad computer, mobile station), etc.

The electronic device 8000 may comprise the following, capable of communicating with each other for example by means of a system bus 814 or other suitable connection: at least one processor 802, a memory 804, (multiple) communication interface(s) 806, a display device 808, another input/output (I/O) device 810 and one or more large-capacity storage device 812.

The processor 802 may be a single processing unit or multiple processing units, and all of the processing units may comprise a single or multiple computing units or multiple cores. The processor 802 may be implemented as one or more microprocessor, microcomputer, microcontroller, digital signal processor, central processing unit, state machine, logic circuit and/or any device which controls signals on the basis of operating instructions. Besides other abilities, the processor 802 may be configured to acquire and execute computer-readable instructions stored in the memory 804, large-capacity storage device 812 or other computer-readable medium, such as program code of an operating system 816, program code of an application program 818, program code of another program 820, etc.

The memory 804 and large-capacity storage device 812 are examples of computer-readable storage media used to store instructions, which are executed by the processor 802 to implement the various functions described above. As an example, the memory 804 may generally comprise both a volatile memory and a non-volatile memory (e.g. RAM, ROM, etc.). In addition, the large-capacity storage device 812 may generally comprise a hard disk drive, solid state drive, removable media, including external and removable drives, memory cards, flash memory, floppy disks, optical disks (e.g. CD, DVD), storage arrays, network attached storage, storage area networks, etc. The memory 804 and large-capacity storage device 812 may both be collectively referred to as memory or computer-readable storage media herein, and

may be non-transitory media capable of storing computer-readable, processor-executable program instructions as computer program code, which may be executed by the processor 802 as a specific device configured to implement the operations and functions described in the examples herein.

Multiple program modules may be stored on the large-capacity storage device 812. These programs comprise the operating system 816, one or more application program 818, other program 820 and program data 822, and they may be loaded to the memory 804 for execution. Examples of such application programs or program modules may include, for example, computer program logic for realizing the following components/functions (e.g. computer program code or instructions): the apparatus 7000 (including the first acquisition module 701, second acquisition module 702, first determination module 703, second determination module 704 and third determination module 705), the method 1000 (including any suitable steps of the method 1000) and/or other embodiments described herein.

Although shown in Fig. 8 as being stored in the memory 804 of the computer device 8000, the modules 816, 818, 820 and 822 or parts thereof may be implemented using any form of computer-readable media that can be accessed by the computer device 8000. As used herein, "computer-readable media" include at least two types of computer-readable media: computer storage media and communication media.

Computer storage media include volatile and non-volatile, removable and non-removable media implemented by any method or technology used to store information such as computer-readable instructions, data structures, program modules or other data. Computer storage media include but are not limited to RAM, ROM, EEPROM, flash memory or other memory technologies, CD-ROM, digital versatile disks (DVD) or other optical storage means, magnetic cartridges, magnetic tape, magnetic disk storage means or other magnetic storage devices, or any other non-transmitting medium that can be used to store information for access by a computer device.

In contrast, communication media may specifically realize computer-readable instructions, data structures, program modules or other data in modulated data signals such as carriers or other transmission mechanisms. As defined herein, computer storage media do not include communication media.

The electronic device 8000 may further comprise one or more communication interface 806 for exchanging data with another device, for example by means of a

network, direct connection, etc., as discussed above. Such a communication interface may be one or more of the following: any type of network interface (e.g. a network interface card (NIC)), wired or wireless (e.g. IEEE 802.11 wireless LAN (WLAN)) interface, Worldwide Interoperability for Microwave Access (Wi-MAX) interface, Ethernet interface, universal serial bus (USB) interface, cellular network interface, BluetoothTM interface, near-field communication (NFC) interface, etc. The communication interface 806 can promote communication in various network and protocol types, including wired networks (e.g. LAN, electric cable, etc.) and wireless networks (e.g. WLAN, cellular, satellite, etc.), internet, etc. The communication interface 806 may also provide communication with an external storage apparatus (not shown) in, for example, a storage array, network attached storage, storage area network, etc.

In some examples, a display device 808 such as a monitor may be included, for displaying information and images to a user. Other I/O devices 810 may be devices that receive various inputs from the user and provide various outputs to the user, and may include a touch input device, gesture input device, camera, keyboard, remote controller, mouse, printer, audio input/output device, etc.

The above are merely embodiments of the present disclosure, which are not intended to limit it. Any amendments, equivalent substitutions or improvements, etc. made within the spirit and principles of the present disclosure shall be included in the scope of protection thereof.

CLAIMS

1. A parameter optimization method for a medical device, the method comprising:

obtaining a distance from a radiation source of the medical device to a test target;

obtaining an initial exposure parameter used for initial exposure performed by the medical device;

on the basis of the initial exposure parameter and the distance from the radiation source to the test target, according to a first association, determining an initial incident dose that is associated with the initial exposure parameter and the distance from the radiation source to the test target, wherein the first association is used for indicating a relationship of an exposure parameter used for exposure performed by the medical device and the distance from the radiation source to the test target with the corresponding obtained incident dose;

according to a second association, determining an initial image parameter that is associated with the initial exposure parameter and the initial incident dose, wherein the second association is used for indicating, with the exposure parameter used for exposure performed by the medical device being applied, a relationship between the corresponding obtained incident dose and the image parameter of a corresponding generated medical image; and

on the basis of at least two of the initial incident dose, the initial image parameter and the initial exposure parameter, determining at least one optimized exposure parameter for the medical device according to the first association and the second association.

2. The parameter optimization method as claimed in claim 1, wherein the exposure parameter used for exposure performed by the medical device comprises an exposure voltage and an exposure current, the first association being used for indicating a relationship between the exposure voltage and exposure current that are used for exposure performed by the medical device and the corresponding obtained incident dose, and the second association being used for indicating a relationship between the exposure voltage used for exposure performed by the medical device and the corresponding obtained incident dose and an image parameter.

3. The parameter optimization method as claimed in claim 2, wherein on the basis of at least two of the initial incident dose, the initial image parameter and the initial exposure parameter, the step of determining at least one optimized exposure

parameter for the medical device according to the first association and the second association comprises:

on the basis of the initial incident dose and the initial image parameter, determining at least one optimized exposure parameter for the medical device according to the first association and the second association.

4. The parameter optimization method as claimed in claim 3, wherein the at least one optimized exposure parameter comprises a first optimized exposure parameter, and the medical device comprises a ray generator having the radiation source, and on the basis of the initial incident dose and the initial image parameter, the step of determining at least one optimized exposure parameter for the medical device according to the first association and the second association comprises:

determining a target image parameter on the basis of the initial image parameter, the target image parameter being greater than the initial image parameter;

on the basis of the initial incident dose and the target image parameter, determining a first candidate exposure voltage and a first candidate exposure current according to the first association and the second association; and

in response to a first preset condition being satisfied, the first candidate exposure voltage and the first candidate exposure current acting as the first optimized exposure parameter, the first preset condition stipulating that the first candidate exposure current is less than or equal to a maximum exposure current allowed by the ray generator.

5. The parameter optimization method as claimed in claim 3 or 4, wherein the at least one optimized exposure parameter comprises a second optimized exposure parameter, and the medical device comprises a ray generator having the radiation source, and on the basis of the initial incident dose and the initial image parameter, the step of determining at least one optimized exposure parameter for the medical device according to the first association and the second association comprises:

determining the target incident dose on the basis of the initial incident dose, the target incident dose being less than the initial incident dose;

on the basis of the initial image parameter and the target incident dose, determining a second candidate exposure voltage and a second candidate exposure current according to the first association and the second association; and

in response to a second preset condition being satisfied, the second candidate exposure voltage and the second candidate exposure current acting as the second optimized exposure parameter, the second preset condition stipulating that the second candidate exposure current is less than or equal to a maximum exposure

current allowed by the ray generator.

6. The parameter optimization method as claimed in claim 2, wherein the at least one optimized exposure parameter comprises at least one of a third optimized exposure parameter and a fourth optimized exposure parameter, and on the basis of at least two of the initial incident dose, the initial image parameter and the initial exposure parameter, the step of determining at least one optimized exposure parameter for the medical device according to the first association and the second association comprises:

on the basis of the initial incident dose and the initial exposure parameter, determining the third optimized exposure parameter according to the first association and the second association; and/or

on the basis of the initial image parameter and the initial exposure parameter, determining the fourth optimized exposure parameter according to the first association and the second association.

7. The parameter optimization method as claimed in claim 6, wherein the medical device comprises a ray generator having the radiation source, and the initial exposure parameter comprises the initial exposure voltage, and

wherein the step of, on the basis of the initial incident dose and the initial exposure parameter, determining the third optimized exposure parameter according to the first association and the second association comprises:

determining at least one third candidate exposure voltage on the basis of the initial exposure voltage, each of the at least one third candidate exposure voltage being greater than or equal to the maximum exposure voltage allowed by the ray generator and less than the initial exposure voltage;

for each of the at least one third candidate exposure voltage, on the basis of the initial incident dose and the third candidate exposure voltage, determining a candidate image parameter and a third candidate exposure current corresponding to the third candidate exposure voltage according to the first association and the second association; and

in response to a third preset condition being satisfied, determining the third optimized exposure parameter from the at least one third candidate exposure voltage and the third candidate exposure current corresponding to the at least one third candidate exposure voltage, the third preset condition stipulating that the third candidate exposure current corresponding to at least some of the third candidate exposure voltages in the at least one third candidate exposure voltage is less than or equal to the maximum exposure current allowed by the ray generator, and a ratio between the candidate image parameter corresponding to the at least

some of the third candidate exposure voltages and the initial image parameter is greater than a first preset threshold value.

8. The parameter optimization method as claimed in claim 6, wherein the medical device comprises a ray generator having the ray source, and the initial exposure parameter comprises the initial exposure voltage, and

wherein the step of, on the basis of the initial image parameter and the initial exposure parameter, determining the fourth optimized exposure parameter according to the first association and the second association comprises:

determining at least one fourth candidate exposure voltage on the basis of the initial exposure voltage, each of the at least one fourth candidate exposure voltage being greater than or equal to the minimum exposure voltage allowed by the ray generator and less than the initial exposure voltage;

for each of the at least one fourth candidate exposure voltage, on the basis of the initial image parameter and the fourth candidate exposure voltage, determining a candidate incident dose and a fourth candidate exposure current corresponding to the fourth candidate exposure voltage according to the first association and the second association; and

in response to a fourth preset condition being satisfied, determining the fourth optimized exposure parameter from the at least one fourth candidate exposure voltage and the fourth candidate exposure current corresponding to the at least one fourth candidate exposure voltage, the fourth preset condition stipulating that the fourth candidate exposure current corresponding to at least some of the fourth candidate exposure voltages in the at least one fourth candidate exposure voltage is less than or equal to the maximum exposure current allowed by the ray generator, and a ratio between the candidate incident dose corresponding to the at least some of the fourth candidate exposure voltages and the initial incident dose is less than a second preset threshold value.

9. The parameter optimization method as claimed in any one of claims 1 to 4 and 6 to 8, wherein the medical device comprises a radiation source and a detector for receiving a ray emitted by the radiation source, a distance from the radiation source to the test target being a first distance from the radiation source to the test target, and the first association being obtained by means of the following solution:

obtaining a second distance from the radiation source to the detector;

in a scenario without a test target, by means of device calibration, determining a calibration relationship between the exposure parameter used for exposure performed by the medical device and a dose at the detector; and

on the basis of the first distance, the second distance and the calibration

relationship, determining the first association.

10. The parameter optimization method as claimed in any one of claims 1 to 4 and 6 to 8, wherein the medical device comprises a display unit, and the parameter optimization method further comprises:

sending the at least one optimized exposure parameter to the display unit, for a user to select.

11. The parameter optimization method as claimed in claim 10, further comprising: in response to receiving a user selection instruction, on the basis of the user selection instruction, updating the initial exposure parameter, and the user selection instruction being used for indicating an optimized exposure parameter selected by the user from the at least one optimized exposure parameter.

12. A parameter optimization apparatus for a medical device, the apparatus comprising:

a first acquisition module, the first acquisition module being configured to acquire a distance from a radiation source of the medical device to a test target;

a second acquisition module, the second acquisition module being configured to acquire an initial exposure parameter used for initial exposure performed by the medical device;

a first determination module, the first determination module being configured, on the basis of the initial exposure parameter and the distance from the radiation source to the test target, according to a first association, to determine an initial incident dose that is associated with the initial exposure parameter and the distance from the radiation source to the test target, wherein the first association is used for indicating a relationship of an exposure parameter used for exposure performed by the medical device and the distance from the radiation source to the test target with the corresponding obtained incident dose;

a second determination module, the second determination module being configured, according to a second association, to determine an initial image parameter that is associated with the initial exposure parameter and the initial incident dose, wherein the second association is used for indicating, with the exposure parameter used for exposure performed by the medical device being applied, a relationship between the corresponding obtained incident dose and the image parameter of a corresponding generated medical image; and

a third determination module, the third determination module being configured, on the basis of at least two of the initial incident dose, the initial image parameter and the initial exposure parameter, to determine at least one optimized

exposure parameter for the medical device according to the first association and the second association.

13. A medical device, comprising:

at least one processor; and

a memory in communicative connection with the at least one processor, wherein

the memory stores a computer program, and the computer program implements the parameter optimization method as claimed in any one of claims 1-11 when executed by the at least one processor.

14. A non-transient computer-readable storage medium that stores a computer program, wherein the computer program implements the parameter optimization method as claimed in any one of claims 1-11 when executed by a processor.

15. A computer program product, comprising a computer program, wherein the computer program implements the parameter optimization method as claimed in any one of claims 1 - 11 when executed by a processor.

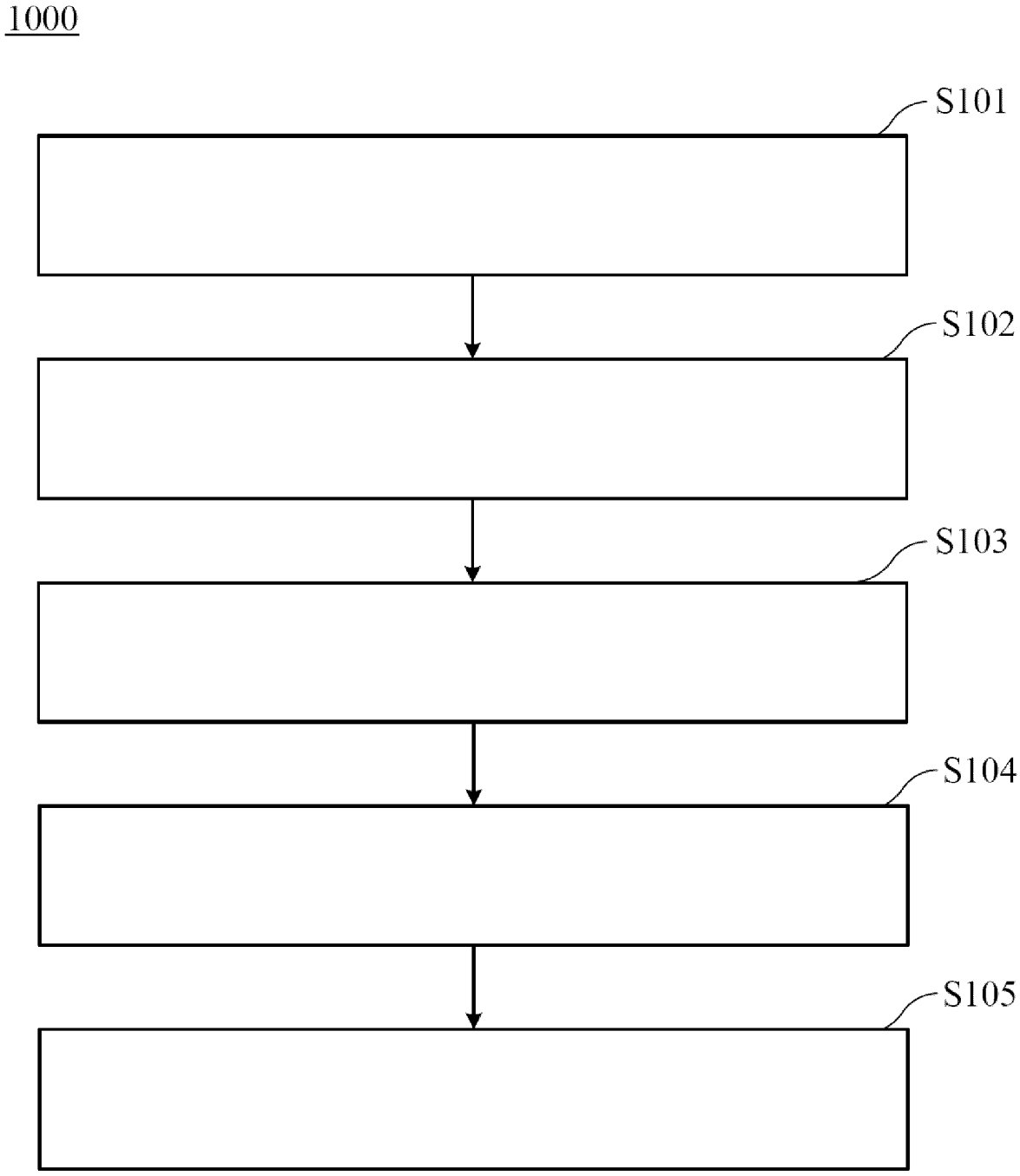

Fig. 1

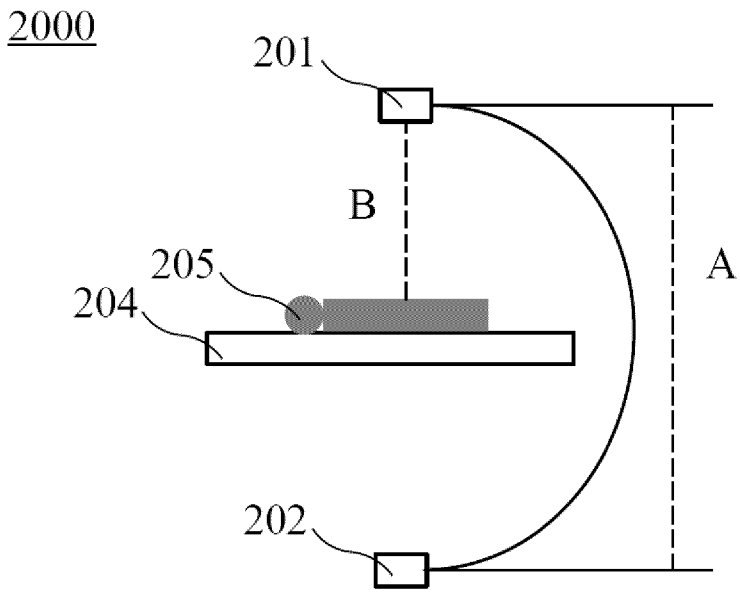

Fig. 2

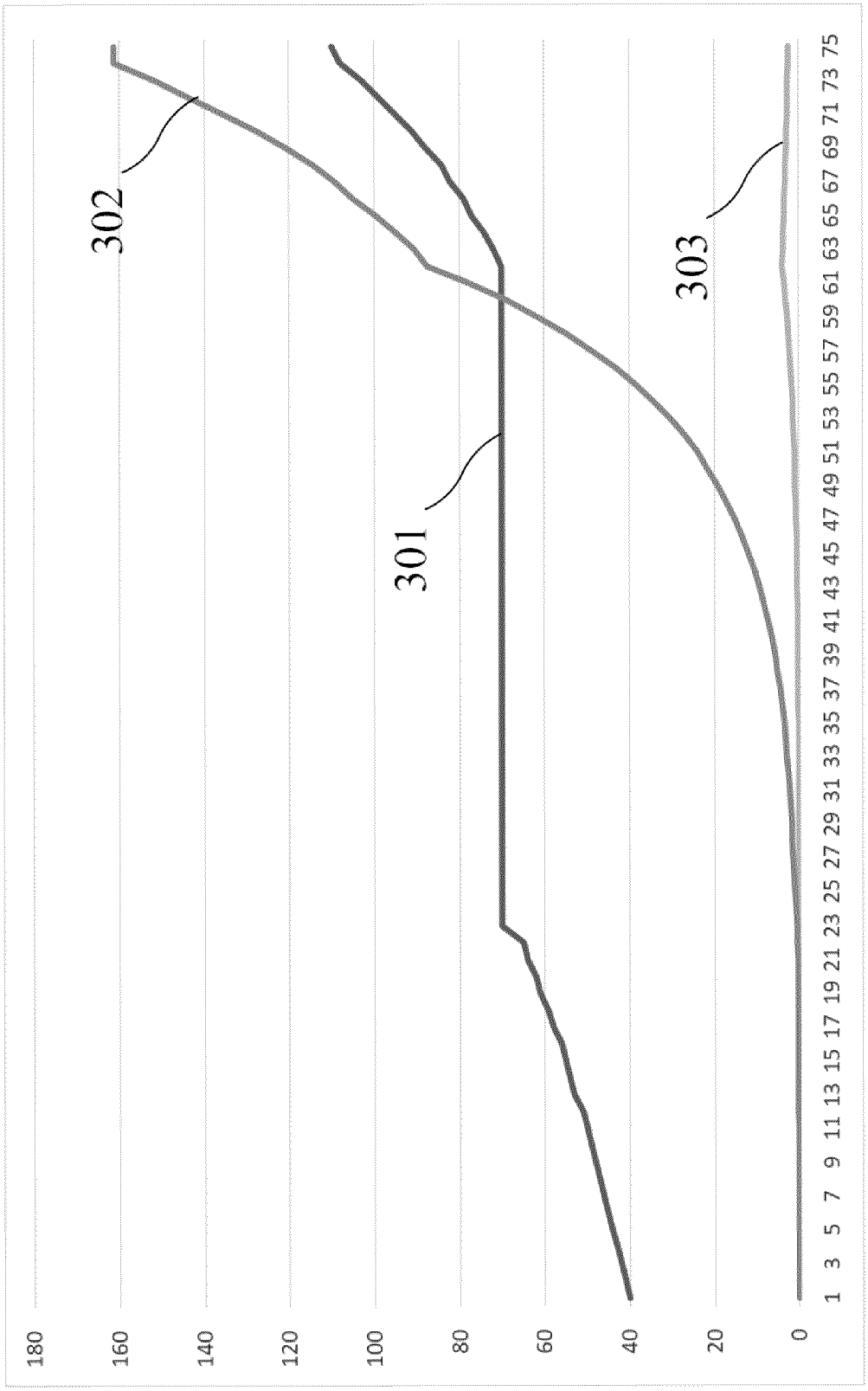
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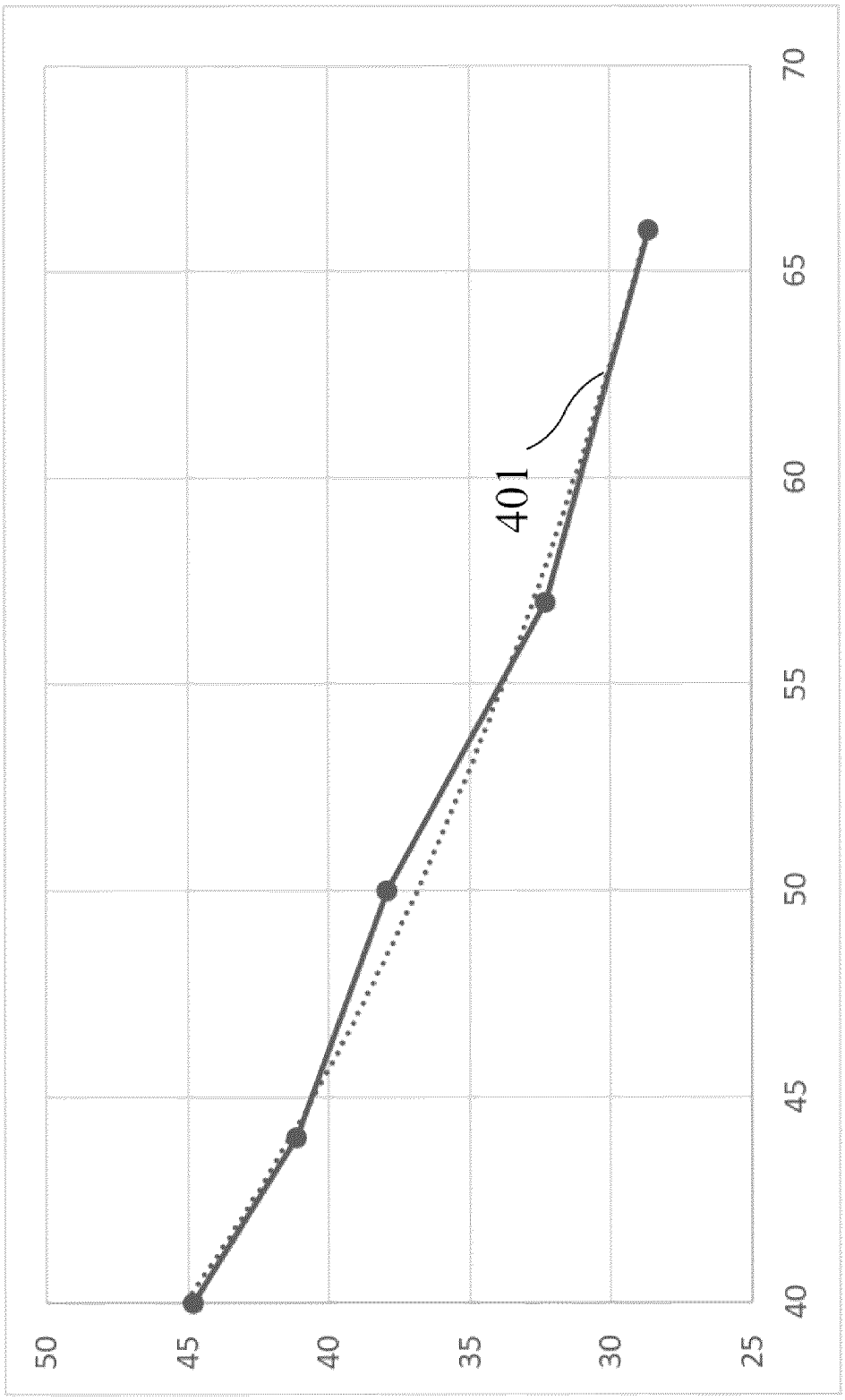
Fig. 3



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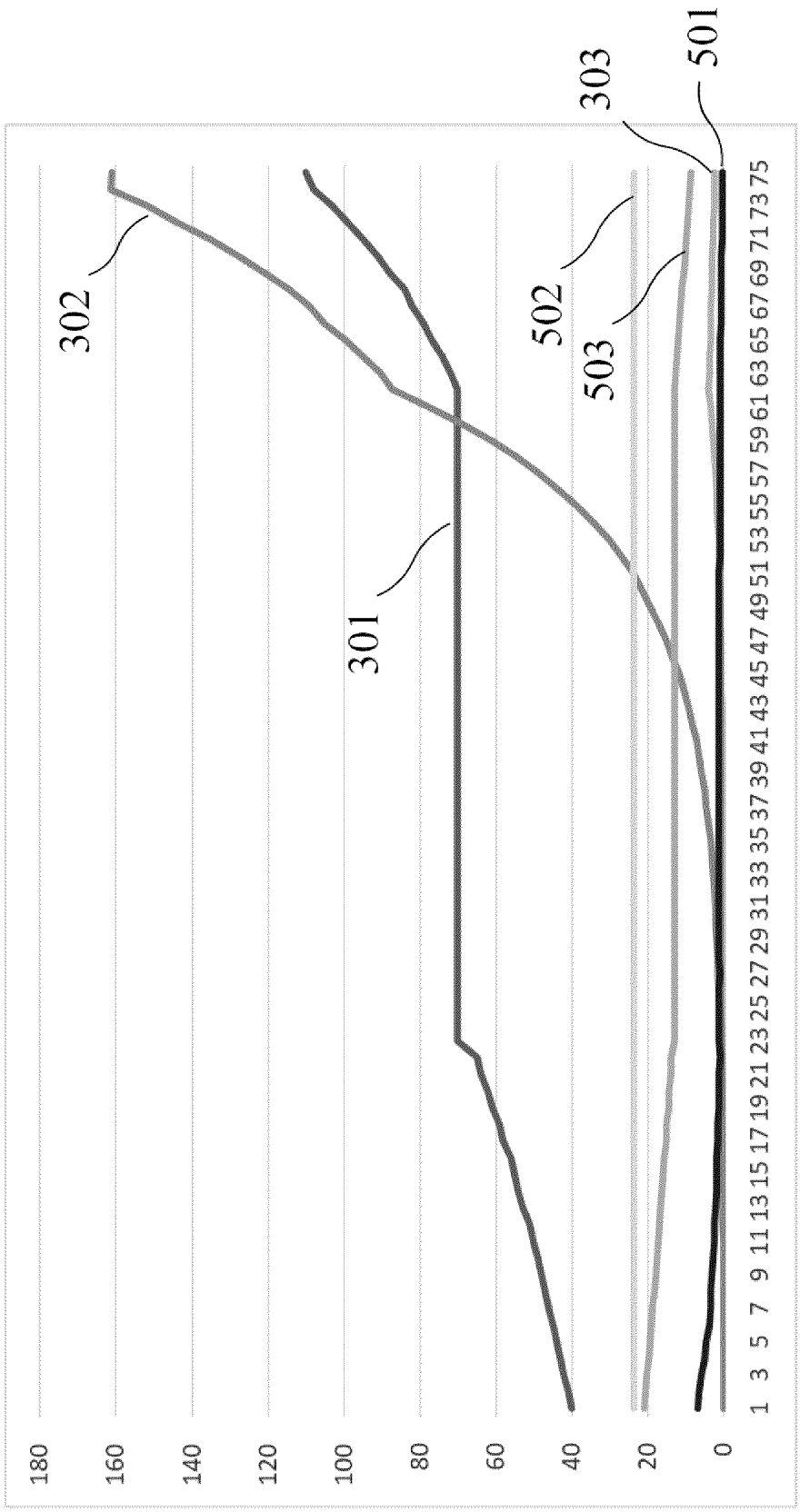
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Fig. 5

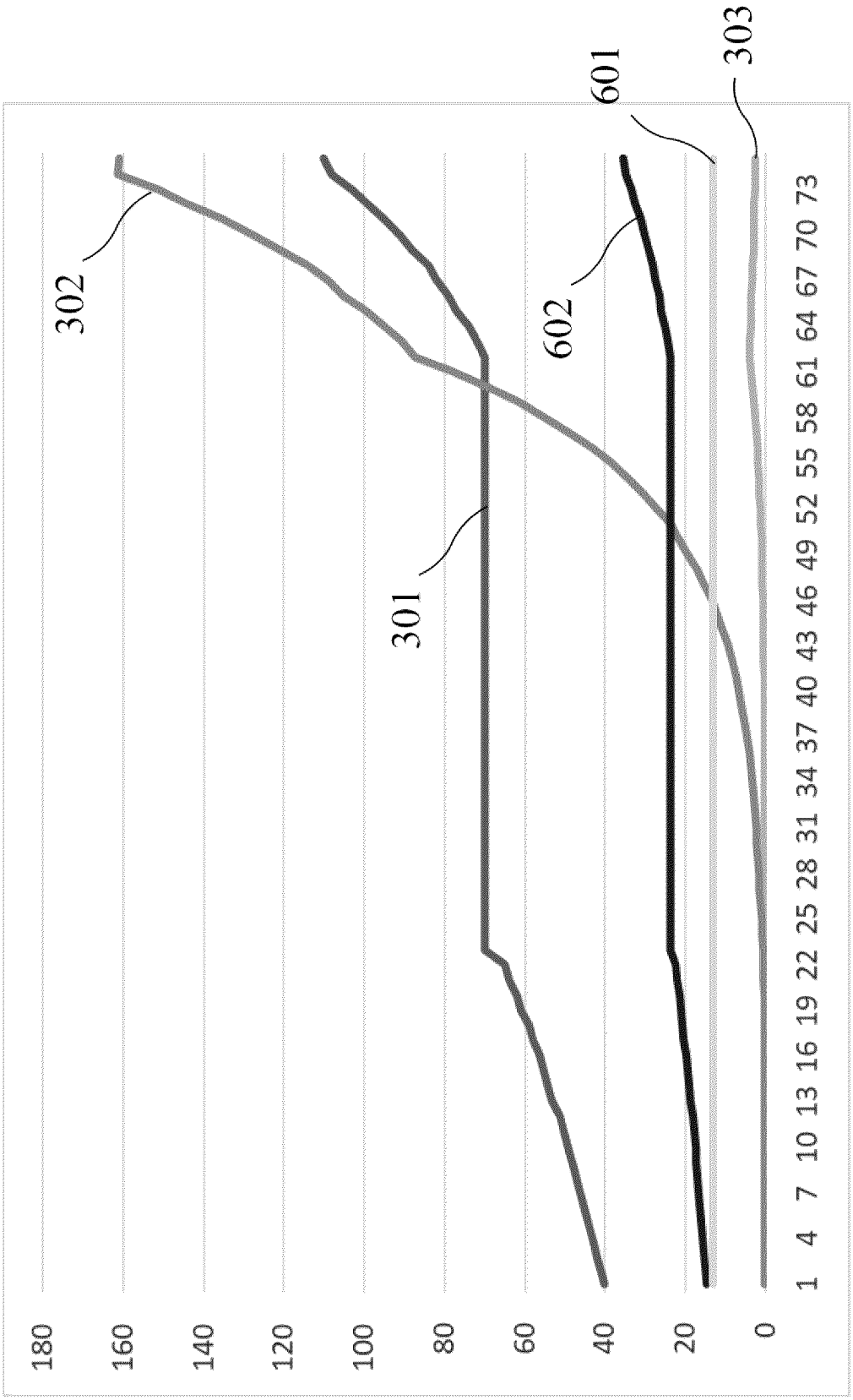
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Fig. 6

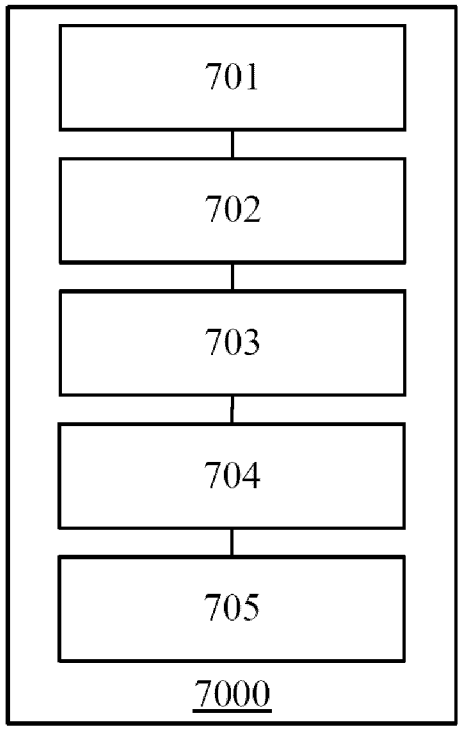
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Fig. 7

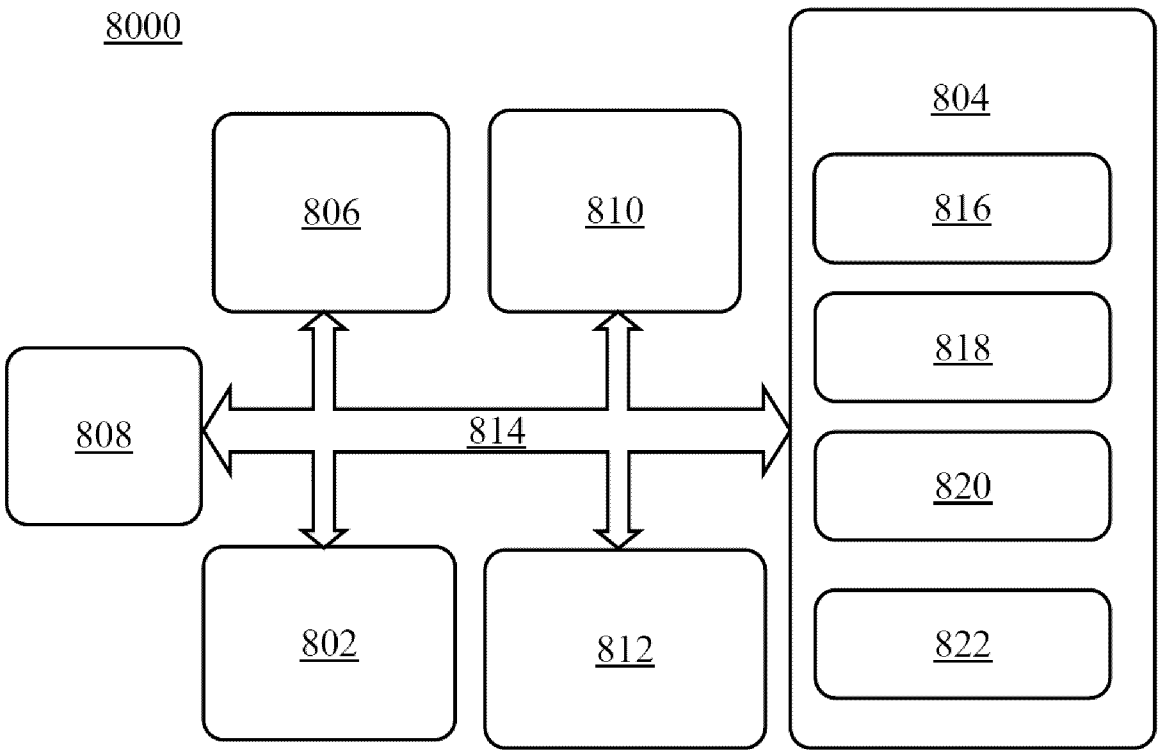
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Fig. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/068680

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61B6/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 222 907 B1 (GORDON III CLARENCE L [US] ET AL) 24 April 2001 (2001-04-24) abstract column 1, line 46 - line 54 column 2, line 40 - line 61 column 4, line 34 - line 64 column 5, line 10 - line 33 column 5, line 55 - column 6, line 37 figures 4,5	1-15

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[x] Further documents are listed in the continuation of Box C.

[x] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 September 2024	09/10/2024

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Montes, Pau

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/068680

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	Poletti J.L.: "Chapter 6: Projection Radiography" In: "Diagnostic Radiology Physics. A Handbook for Teachers and Students.", 30 September 2014 (2014-09-30), International Atomic Energy Agency, XP093208608, section "6.2.1. Components of an imaging system" section "6.2.3.3. Inverse square law" section "6.2.3.4. Geometrical unsharpness" section "6.2.7.1. Effect of tube voltage on contrast, noise and dose" -----	1-15
A	US 2009/086911 A1 (VENUGOPAL MANOHARAN [IN] ET AL) 2 April 2009 (2009-04-02) abstract paragraph [0001] paragraph [0005] paragraph [0018] paragraph [0028] - paragraph [0030] paragraph [0032] -----	1-15
A	US 2006/269044 A1 (FEHRE JENS [DE] ET AL) 30 November 2006 (2006-11-30) abstract paragraph [0002] paragraph [0015] - paragraph [0017] paragraph [0023] figures 1,2 -----	1-15

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Information on patent family members

International application No
PCT/EP2024/068680

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