

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
27 July 2006 (27.07.2006)

PCT

(10) International Publication Number
WO 2006/078085 A1

(51) International Patent Classification:
A61B 6/03 (2006.01)

(74) Agent: **DYNE PATENT & LAW FIRM**; #205 Bubjun
Bldg, 81-6, Wonchun-dong, Youngtong-gu, Suwon-si,
Gyeonggi-do 443-821 (KR).

(21) International Application Number:

PCT/KR2005/001815

(22) International Filing Date: 14 June 2005 (14.06.2005)

(25) Filing Language: Korean

(26) Publication Language: English

(30) Priority Data:
10-2005-0005831 21 January 2005 (21.01.2005) KR

(71) Applicants and

(72) Inventors: **CHO, Min-Hyoung** [KR/KR]; 803-1603
Byoukjeok Doosan A.P.T., Youngtong-dong, Young-
tong-gu, Suwon-si, Gyeonggi-do 122-050 (KR). **LEE,
Soo-Yeol** [KR/KR]; 04-304 Hayan maeul Grand villa,
Gumi-dong, Bundang-gu, Sungnam-si, Gyeonggi-do
463-793 (KR). **CHUN, In-Kon** [KR/KR]; 109-1006
Mugunghwa Joogong A.P.T., Geumjeong-dong, Gunpo-si,
Gyeonggi-do 435-050 (KR). **LEE, Sang-Chul** [KR/KR];
#613 Daelim Rezion A.P.T., Seocho 1-dong, Seocho-gu,
Seoul 137-071 (KR).

(81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,
AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN,
CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI,
GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE,
KG, KM, KP, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD,
MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM,
PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM,
SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN,
YU, ZA, ZM, ZW.

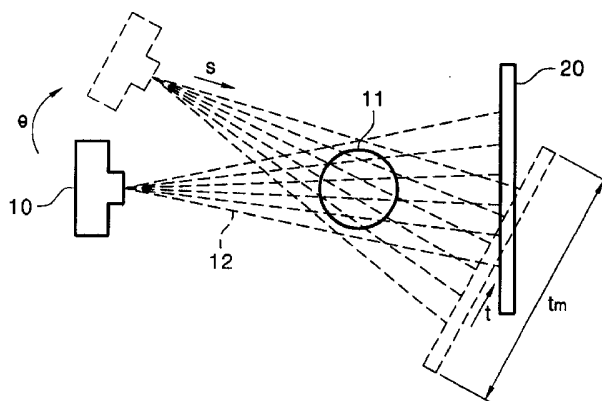
(84) Designated States (unless otherwise indicated, for every
kind of regional protection available): ARIPO (BW, GH,
GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM,
ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM),
European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI,
FR, GB, GR, HU, IE, IS, IT, LT, LU, MC, NL, PL, PT, RO,
SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN,
GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— with international search report

[Continued on next page]

(54) Title: METHOD FOR RECONSTRUCTING A LOCAL HIGH RESOLUTION X-RAY CT IMAGE AND APPARATUS FOR RECONSTRUCTING A LOCAL HIGH RESOLUTION X-RAY CT IMAGE



(57) Abstract: The present invention relates to a method and apparatus for reconstructing an X-ray CT (computerized tomography) image, and more particularly, to a method and apparatus for reconstructing a local high resolution X-ray CT image. Further, the apparatus of the present invention can control the resolution of an X-ray CT image to be reconstructed by changing the distance between a target object and an X-ray generator. A method for reconstructing a CT image including a high resolution X-ray CT image for a local region of interest according to an aspect of the present invention comprises the steps of acquiring projection data by means of irradiation of X-rays on a target object at a position close to an X-ray generator such that a portion of the target object including a local region of interest exists within a range of irradiation angles of X-rays; calculating virtual projection data on the assumption that the X-rays are irradiated on the entire target object at the close position, based on projection data acquired through irradiation of the X-rays on the entire target object at a position where the entire target object exists within the range of irradiation angles of X-rays; combining the virtual projection data on the entire target object except data on the local region of interest with the projection data acquired at the position close to the X-ray generator; and reconstructing the combined projection data.



WO 2006/078085 A1



For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

METHOD FOR RECONSTRUCTING A LOCAL HIGH RESOLUTION X-RAY CT
IMAGE AND APPARATUS FOR RECONSTRUCTING A LOCAL HIGH
RESOLUTION X-RAY CT IMAGE

5

Technical Field

The present invention relates to a method and apparatus for reconstructing an X-ray CT (computerized tomography) image, and more particularly, to a method and apparatus for reconstructing an X-ray CT image having high resolution locally. Further,
 10 the apparatus of the present invention can control the resolution of an X-ray CT image to be reconstructed by changing the distance between a target object and an X-ray generator.

Background Art

When X-rays pass through an object, they show a property by which the intensity
 15 thereof decreases according to the physical property and length of the object. The property of the X-rays is described by "Lambert-Beer's Law" that is expressed as the following equation:

$$I = I_0 e^{-\mu L} \quad \cdots (1)$$

where I_0 is the initial intensity of X-rays, μ is a unique X-ray attenuation coefficient of an
 20 object, and L is the length of the object through which the X-rays pass. This equation shows a relationship in which upon irradiation of X-rays with an initial intensity of I_0 , the X-rays are attenuated according to the attenuation coefficient and distance of the object through which the X-rays pass. This equation is applied to a case where the object comprises a single substance. In case of an object with a variety of substances mixed
 25 therein, the following equation is applied thereto:

$$I = I_0 e^{-\int_0^L \mu(s) ds} \quad \cdots (2)$$

where s is a path of X-rays, and $\mu(s)$ is an X-ray attenuation coefficient and is a function of a path since it varies according to locations in an object.

An X-ray system, which has been widely used for a nondestructive inspection for

diagnosing the interior of a human body or finding a defect within an object, obtains a projection image by catching the intensity of X-rays, which varies according to locations on an object through which the X-rays pass, on a two-dimensional film. When X-rays pass through an object, the intensity of the X-rays varies according to the unique
 5 attenuation coefficient of the object and the path on which the X-rays travel, as expressed by the equations. The varying values are detected by a photosensitive film. Since such an X-ray projection photograph represents a final cumulative value obtained during passage of X-rays on a path within an object, it shows information on the interior of the object but has a disadvantage in that it cannot show information on the depth of the object,
 10 i.e., cross-sectional images.

On the contrary, an apparatus for reconstructing an X-ray CT image obtains several ten to several hundred projection images at various angles by rotating an object through 360 degrees or rotating an X-ray generator and a detector through 360 degrees around an object, and mathematically reconstructs the images using a computer to create
 15 information on the depth of the object, i.e., cross-sectional images. Fig. 1 is a schematic view illustrating an operational principle of a conventional apparatus for reconstructing an X-ray CT image. The conventional apparatus for reconstructing an X-ray CT image is configured to reconstruct CT images by rotating an X-ray generator 10 and an X-ray
 20 detector 20, which are installed to be spaced apart from a target object 11 of which CT images will be obtained and to face the target object, through 360 degrees around the target object 11, by generating X-rays 12 from the X-ray generator 10 at a predetermined angular interval, and by causing the X-ray detector 20 to detect the X-rays 12 that have passed through the target object 11. The most general method for creating cross-sectional images from data detected by the X-ray detector 20 is a back projection method, and its associated
 25 equations are as follows:

$$\mu(x, y) = \frac{1}{2} \int_0^{2\pi} \int_{-\frac{1}{2}t_m}^{\frac{1}{2}t_m} P_\theta(t) h(x \cos \theta + y \sin \theta - t) dt d\theta \quad \cdots (3)$$

$$P_\theta(t) = -\log \frac{I}{I_0} = \int_0^{L(t)} \mu(s, t) ds \quad \cdots (4)$$

where θ and t are geometric conditions for acquisition of projection data and indicate a

rotational angle and coordinates along the length of the X-ray detector 20, respectively, and t_m is the total length of the detector 20. $P_\theta(t)$ is projection data obtained in the direction of θ . The function $h(x\cos\theta+y\sin\theta-t)$ indicates a back projection filtering function. Generally, a Ram-Lak filter, a Shepp-Logan or the like is widely used. A
5 function $\mu(x,y)$ that is desired to be obtained through calculation of such a back projection process is an attenuation coefficient at each of locations of a target object, which represents how much X-rays are attenuated upon passage thereof through the object. The function means desired cross-sectional images. Consequently, the apparatus for reconstructing an X-ray CT image quantitatively calculates unique attenuation coefficients
10 at respective locations according to the kind of object when X-rays pass through cross sections of an object, and shows the calculated results as images.

Fig. 2 is a schematic view showing a basic configuration of an apparatus for reconstructing an X-ray CT image, which is mainly used at present. As shown in Fig. 2, the conventional apparatus for reconstructing an X-ray CT image has an X-ray generator
15 10 and an X-ray detector 20, which are secured on a rotatably installed gantry 30. The X-ray generator 10 and the X-ray detector 20 are fixedly installed at opposite positions with respect to a rotational center of the gantry 30 such that they are equidistantly spaced apart from the rotational center. An X-ray detector 20 of an early apparatus for reconstructing a CT image is constructed in a one-dimensional arrangement in the form of a line to mainly
20 obtain two-dimensional cross-sectional images. Recently, with the development of hardware technology, the X-ray detector 20 is developed from the one-dimensional arrangement in the form of a line to a limited two-dimensional arrangement in the form of several to several tens of lines. Thus, an obtained image is developed to a limited three-dimensional image. Further, there is a recent tendency for an X-ray detector to be
25 gradually developed to a complete two-dimensional arrangement.

The resolution R of a cross-sectional image obtained by the apparatus for reconstructing an X-ray CT image constructed as above is determined according to a relative ratio of the distance from the X-ray generator 10 to the X-ray detector 20, i.e., a source to detector distance (SD), and the distance from the X-ray generator 10 to the center
30 of a target object 11, i.e., a source to object distance (SOD). The resolution R can be

expressed as the following equation. Here, "DS" is a pixel size of the X-ray detector 20.

$$R = \frac{SOD \times DS}{SD} \quad \dots (5)$$

In the conventional apparatus for reconstructing an X-ray CT image, an X-ray detector with a fixed pixel size is used, the distance between the X-ray generator and the X-ray detector is fixed, and the center of a target object is placed at the center between the X-ray generator and the X-ray detector. Therefore, the conventional apparatus for reconstructing an X-ray CT image always provides only a cross-sectional image with a fixed pixel size.

To obtain a high resolution cross-sectional image using the apparatus for reconstructing a CT image with a fixed pixel size, it is possible to utilize magnification effects that are obtained by moving the target object toward the X-ray generator to obtain a cross-sectional image. As shown in Fig. 3, the magnification effects refer to effects by which the resolution of data projected on the X-ray detector is improved since X-rays passing through the interior of the target object 11 placed close to the X-ray generator are denser than those passing through the interior of the target object 11 placed close to the X-ray detector 20. That is, a portion of the target object is placed close to the X-ray detector and thus is magnified and projected on the X-ray detector, thereby improving the resolution.

However, there is a problem in that the movement of the target object toward the X-ray generator for improving the resolution through the magnification effects causes a portion of the target object to deviate from a range of irradiation angles between the X-ray generator and the X-ray detector. Basically, in a method for reconstructing a CT image, the entire target object of which an image is to be reconstructed should be included in the range of irradiation angles of X-rays between the X-ray generator and the X-ray detector. Therefore, if a portion of the target object 11 deviates from the range of irradiation angles of X-rays as shown in Fig. 3, projection data acquired by the X-ray detector 20 do not include projection data on the portion of the target object that deviates from the range of irradiation angles, so that a complete cross-sectional image cannot be reconstructed. Accordingly, if it is intended to obtain a high resolution cross-sectional image using the

magnification effects, there is a problem in that a target object is limited to a small target object which can be fully included in a range of irradiation angles of X-rays even though the target object is placed close to an X-ray generator. This problem is common to both an apparatus with a fan-beam X-ray generator and an apparatus with a cone-beam X-ray generator if it is intended to improve the resolution of a cross-sectional image using the magnification effects.

Meanwhile, U.S. Patent No. 6,246,742 entitled "Local CT image reconstruction with limited x-ray exposure" discloses a method for obtaining a CT image by locally exposing only a desired portion of a target object to X-rays while controlling an irradiation angle of X-rays of an X-ray generator so that a CT image for the portion exposed to the X-rays can be obtained. However, as for the resolution of a local CT image obtained by means of the method disclosed in the patent, the CT image is a cross-sectional image with a resolution predetermined upon manufacture of an apparatus. It is not possible to obtain a local high resolution CT image.

There is a case where a local high resolution CT image is required for an accurate diagnosis of a specific part of a patient or clinical study. However, as discussed above, all the conventional apparatuses for reconstructing an X-ray CT image have limitations in that they can provide only a cross-sectional image with a resolution predetermined upon manufacture of the apparatuses and thus cannot provide a local cross-sectional image with a proper resolution as desired.

Disclosure of Invention

Technical Problem

A primary object of the present invention is to provide a method for reconstructing an X-ray CT image for a target object, wherein it is possible to include a high resolution CT image for a local region of interest on the target object.

A secondary object of the present invention is to provide an apparatus for reconstructing an X-ray CT image, wherein the distance between a target object and an X-ray generator can be controlled to reconstruct a high resolution CT image for a local region of interest on the target object.

Technical Solution

A method for reconstructing a CT image including a high resolution X-ray CT image for a local region of interest according to an aspect of the present invention comprises the steps of acquiring projection data by means of irradiation of X-rays on a target object at a position close to an X-ray generator such that a portion of the target object including a local region of interest exists within a range of irradiation angles of X-rays; calculating virtual projection data on the assumption that the X-rays are irradiated on the entire target object at the close position, based on projection data acquired through irradiation of the X-rays on the entire target object at a position where the entire target object exists within the range of irradiation angles of X-rays; combining the virtual projection data on the entire target object except data on the local region of interest with the projection data acquired at the position close to the X-ray generator; and reconstructing the combined projection data.

Further, the step of calculating the virtual projection data may comprise the steps of reconstructing cross-sectional image data on the entire target object, based on the projection data acquired through irradiation of the X-rays on the entire target object at the position where the entire target object exists within the range of irradiation angles of X-rays; and calculating the virtual projection data through line integral for the reconstructed cross-sectional image data on the entire target object on the assumption that the X-rays are irradiated on the entire target object at the close position.

An apparatus capable of reconstructing a high resolution X-ray CT image for a local region of interest on a target object according to another aspect of the present invention includes a rotatably installed gantry, an X-ray generator installed on the gantry, an X-ray detector installed on the gantry to output projection data by detecting X-rays radiated from the X-ray generator and passed through the target object, and an imaging system for reconstructing an image of the target object by receiving the projection data from the X-ray detector. The apparatus further comprises a moving means for relatively moving any one of the X-ray generator and the target object. The imaging system receives projection data acquired by means of irradiation of the X-rays on the target object at a position close to the X-ray generator such that a portion of the target object

including a local region of interest exists within a range of irradiation angles of X-rays, calculates virtual projection data on the assumption that the X-rays are irradiated on the entire target object at the close position, based on projection data acquired through irradiation of the X-rays on the entire target object at a position where the entire target
5 object exists within the range of irradiation angles of X-rays, combines the virtual projection data on the entire target object except data on the local region of interest with the projection data acquired by means of the irradiation on the target object at the position close to the X-ray generator, and reconstructing the combined projection data into an image.

10 Moreover, in the apparatus for reconstructing an X-ray CT image according to the present invention, the imaging system performs may reconstruct cross-sectional image data on the entire target object, based on the projection data acquired through the irradiation of the X-rays on the entire target object at the position where the entire target object exists within the range of irradiation angles of X-rays, and calculate the virtual projection data
15 through line integral for the reconstructed cross-sectional image data on the entire target object on the assumption that the X-rays are irradiated on the entire target object at the close position.

Furthermore, in the apparatus for reconstructing an X-ray CT image according to the present invention, the moving means may be a linearly moving means capable of
20 moving the X-ray generator relative to the target object along a line passing through a rotational center of the gantry. Alternatively, the linearly moving means may simultaneously move the X-ray generator and the X-ray detector such that the X-ray generator and the X-ray detector are not moved relative to each other.

An apparatus capable of controlling resolution for reconstructing an X-ray CT
25 image according to a further aspect of the present invention includes a rotatably installed gantry, an X-ray generator installed on the gantry, an X-ray detector installed on the gantry to output projection data by detecting X-rays radiated from the X-ray generator and passed through a target object, and an imaging system for reconstructing an image of the target object by receiving the projection data from the X-ray detector. The apparatus further
30 comprises a linearly moving means for relatively moving at least one of the X-ray

generator, the target object and the X-ray detector along a line passing through a rotational center of the gantry, thereby controlling the resolution of the X-ray CT image.

In the apparatus capable of controlling resolution for reconstructing an X-ray CT image according to the present invention, the linearly moving means may be configured to
5 move the X-ray generator and the X-ray detector relative to the target object.

Further, the X-ray detector of the apparatus for reconstructing an X-ray CT image according to the present invention may be constructed in either of a one-dimensional arrangement and a two-dimensional arrangement.

10 Brief Description of Drawings

Fig. 1 is a view illustrating an operational principle of an apparatus for reconstructing an X-ray CT image.

Fig. 2 is a schematic view showing a basic configuration of a conventional apparatus for reconstructing an X-ray CT image.

15 Fig. 3 is a view illustrating a principle of acquisition of a high resolution image for a local region of interest.

Figs. 4 to 7 are views illustrating processes for reconstructing a local high resolution X-ray CT image according to the method of the present invention.

Fig. 8 is a flowchart illustrating a method for reconstructing a local high resolution
20 X-ray CT image according to an aspect of the present invention.

Fig. 9 is a schematic view showing an embodiment of an apparatus for reconstructing a local high resolution X-ray CT image according to another aspect of the present invention.

Fig. 10 is a schematic view illustrating the procedure for reconstructing a local
25 high resolution X-ray CT image using the apparatus of Fig. 9.

Fig. 11 shows local high resolution tomograms obtained by means of the method and apparatus of the present invention.

<Brief Explanation of Reference Numerals in the Drawings>

10: X-ray generator	20: X-ray detector
30: Gantry	40: X-ray control unit
50: Gantry motor control unit	60: Data acquisition unit
70: Computer	80: Linear actuator control unit
90: Linear actuator	

10 Best Mode for Carrying Out the Invention

Hereinafter, preferred embodiments of the present invention will be described in detail with reference to the accompanying drawings.

15 Figs. 4 to 7 schematically show a method for reconstructing a CT image including a local high resolution X-ray CT image for a local region of interest according to the present invention.

First, as shown in Fig. 4, an object 11 is placed close to an X-ray generator 10 such that X-rays can be irradiated on a local region of interest (ROI) 11a of which a high resolution CT image is desired to be obtained on the object 11, and the X-rays are irradiated thereon, thereby acquiring high resolution projection data 25 through 360° scanning. Since the high resolution projection data 25 thus acquired do not include projection data on a portion 11b of the target object 11 existing outside a range of irradiation angles of X-rays, reconstruction of a CT image from the projection data causes severe image distortion.

25 Next, in order to complement such a distortion phenomenon, the projection data on the portion 11b of the target object 11 existing outside the range of irradiation angles of X-rays are acquired as follows. That is, as shown in Fig. 5, the target object 11 is moved from the X-ray generator 10 toward the X-ray detector 20 such that the entire target object 11 is included within the range of irradiation angles of X-rays, and the X-rays are irradiated thereon, thereby acquiring low resolution projection data 26 through 360° scanning. Next, a CT image for the entire target object 11 is reconstructed based on the

low resolution projection data 26 on the entire target object. The CT image obtained through the reconstruction based on the projection data acquired in the state shown in Fig. 5 has low resolution due to reduced magnification effects, but is a complete CT image without distortion since the entire target object is included within the range of irradiation angles of X-rays.

Then, projection data on the assumption that X-rays are irradiated on the target object at the same position as the case of Fig. 4 are calculated by a computer from the reconstructed low resolution CT image data. Subsequently, projection data on the portion existing outside the range of irradiation angles in Fig. 4 are extracted from the virtual projection data calculated by the computer and are then combined with the high resolution projection data on the portion within the range of irradiation angles, thereby acquiring projection data on the entire target object without distortion. This will be specifically described below with reference to Figs. 6 and 7.

First, assume that the projection data 26 acquired under the conditions shown in Fig. 5 are defined as $P_{\theta}^1(t)$, and the projection data 25 acquired under the conditions shown in Fig. 4 are defined as $P_{\theta}^2(t)$. As described above, the former is low resolution projection data on the entire target object, and the latter is high resolution projection data on a portion including the local region of interest 11a on the target object. Here, θ indicates a rotational angle around the target object, and t indicates coordinates along the length of the X-ray detector. Since $P_{\theta}^2(t)$ is projection data acquired in the state where the target object is not fully included within the range of irradiation angles of X-rays, reconstruction of an image based on these projection data causes data distortion. To complement this, $P_{\theta}^1(t)$ is used. First, a CT image is reconstructed using $P_{\theta}^1(t)$. In order to supplement the projection data on the portion of the target object existing outside the range of irradiation angles, virtual projection data 27 are acquired from a reconstructed CT image 11' shown in Fig. 6 on the assumption that X-rays are irradiated under the same geometrical conditions as $P_{\theta}^2(t)$. The method for acquiring the virtual projection data 27 on the portion existing outside the range of irradiation angles is performed using a virtual X-ray generator 10' and a virtual X-ray detector 20' in a virtual space defined by a computer. The virtual projection data 27 are acquired from the CT image 11' obtained in Fig. 5 by

performing line integral for the values of image pixels through which virtual X-rays 12' pass. This directly uses a principle by which upon passage of actual X-rays through an object, values attenuated according to the physical property and length of the object are subjected to line integral and then detected by an X-ray detector. As compared with the
 5 actual X-ray generator 10, the virtual X-ray generator 10' used in this case is assumed to have a range of irradiation angles for allowing projection data on the entire target object to be included. The projection data acquired through the calculation are defined as $P_{\theta}^r(t)$. The virtual projection data acquired through the calculation have low resolution but have information on the portion of the target object existing outside the range of irradiation
 10 angles. Therefore, when two pieces of projection data $P_{\theta}^2(t)$ and $P_{\theta}^r(t)$ are combined with each other according to the following equation, it is possible to acquire new projection data 28, which have high resolution at the local region of interest 11a on the target object and low resolution at the portion 11b except the local region of interest, as shown in Fig. 11.

$$15 \quad P_{\theta}^c(t) = \begin{cases} P_{\theta}^2(t) & -\frac{t_m}{2} \leq t \leq \frac{t_m}{2} \\ P_{\theta}^r(t) & |t| \geq \frac{t_m}{2} \end{cases} \quad \dots (6)$$

When the projection data thus acquired are reconstructed by means of a general method for reconstructing a CT image, it is possible to obtain an image that has high resolution at a local region of interest without distortion. Fig. 11 shows cross-sectional images reconstructed by means of the method for reconstructing a CT image including a
 20 high resolution X-ray CT image for a local region of interest according to the present invention. Fig. 11 (a) is a tomogram of an image obtained by reconstructing $P_{\theta}^l(t)$ (in the tomogram, a portion designated by a dotted line is a local region of interest that is desired to be reconstructed with high resolution), and Fig. 11 (b) is a tomogram of an image obtained by reconstructing $P_{\theta}^2(t)$. As described above, image distortion is
 25 observed in Fig. 11 (b). Fig. 11 (c) is a tomogram of an image reconstructed by means of the method proposed by the present invention. It can be understood that a high resolution image for a local region of interest can be obtained without distortion according to the method of the present invention. Further, the method proposed by the present invention is

applicable to an X-ray detector constructed either in a one-dimensional arrangement or in a two-dimensional arrangement.

Fig. 8 is a flowchart illustrating a method for obtaining a local high resolution X-ray CT image according to the present invention (the method for reconstructing a high resolution image according to the present invention will be referred to as “zoom-in method”). First, low resolution projection data are acquired to obtain a cross-sectional image by means of general tomography. Then, high resolution projection data on a local region of interest on a target object are acquired (S10). Subsequently, a low resolution CT image is reconstructed from low resolution projection data on the entire target object (S20). Thereafter, based on data on the low resolution CT image, virtual projection data are calculated under conditions for high resolution (S30). Then, the low resolution virtual projection data are combined with the high resolution projection data (S40). Then, a CT image is reconstructed from the combined projection data, thereby obtaining a CT image without distortion.

Next, an embodiment of an apparatus for obtaining a local high resolution X-ray CT image according to the present invention will be described with reference to Figs. 9 and 10.

Referring to Fig. 9, an apparatus for reconstructing an X-ray CT image according to an embodiment of the present invention comprises a rotatably installed gantry 30, a linearly moving means 90 secured on the gantry 30, and an X-ray generator 10 and an X-ray detector 20 movably installed at opposite positions on the linearly moving means 90. The X-ray detector 20 detects X-rays that have been radiated from the X-ray generator 10 and passed through a target object, and outputs projection data. Further, the apparatus for reconstructing an X-ray CT image comprises an imaging system for reconstructing an image for the target object by receiving the projection data from the X-ray detector 20. The imaging system comprises a data acquisition unit 60 for acquiring the projection data, a computer 70 for performing image reconstruction, and a display means (not shown) for displaying a reconstructed image thereon. In addition, the apparatus for reconstructing an X-ray CT image comprises a gantry control unit 50 for controlling the operation of the gantry 30, an X-ray control unit 40 for controlling the X-ray generator 10, and a linear

actuator control unit 80 for controlling the linearly moving means 90.

The linearly moving means 90 is configured to move the X-ray generator 10 relative to the target object 11 along a line L that passes through a rotational center O of the gantry. Further, the linearly moving means 90 is configured to simultaneously move the
5 X-ray generator 10 and the X-ray detector 20 such that they are not moved relative to each other. The linearly moving means 90 is preferably a ball screw and a servomotor but is not limited thereto. The apparatus for reconstructing an X-ray CT image according to this embodiment is different from a conventional apparatus in that contrary to the conventional
10 apparatus in which the X-ray generator 10 and the X-ray detector 20 are secured on the gantry 30 to be simply rotated around the target object 11, they can be moved relative to each other by the linearly moving means along the line L with respect to the gantry. Moreover, the linearly moving means 90 is secured on the gantry 30 so that it can be rotated together with the gantry 30 around the target object.

That is, the distance between the target object 11 and the X-ray generator 10 can be
15 controlled while consistently maintaining the distance between the X-ray generator 10 and the X-ray detector 20, so that the resolution of an image can be controlled by means of magnification effects. As described above, when the target object approaches the X-ray generator 10, a high resolution image can be obtained by means of the magnification effects. On the contrary, when the target object is moved away from the X-ray generator
20 10 and approaches the X-ray detector 20, a low resolution image can be obtained due to reduced magnification effects.

In an existing apparatus for reconstructing an X-ray CT image with a conventional gentry structure, a high resolution image can be obtained by causing a target object to approach an X-ray generator. However, since there is a limitation on the size of the target
25 object, the target object is generally placed at the center between the X-ray generator and the X-ray detector. Further, an obtained image is magnified using digital zooming, i.e., interpolation. This is simply magnify the size of the image without improvement of the resolution of the image, resulting in a disadvantage in that contrary to a high resolution image, it is not possible to grasp a detailed structure of the target object. However, with
30 the use of the apparatus of the present invention, it is possible to overcome a problem of

limited size, which occurs in case of high resolution imaging, and simultaneously to reconstruct a high resolution image for a local region on the target object without distortion, using the zoom-in method.

Fig. 10 illustrates a method for using the apparatus of Fig. 9 to reconstruct a high resolution cross-sectional image for a local region of interest according to the method of the present invention described above. When only a relative distance between the X-ray generator and the target object is simply changed so far as the entire target object 11 is included within a range of irradiation angles defined by the X-ray generator 10, it is possible to reconstruct a CT image while finely controlling the resolution of the entire target object. If it is intended to reconstruct a high resolution image for the local region of interest 11a to such an extent that the target object approaches the X-ray generator to cause a portion of the target object to deviate from the range of irradiation angles, low resolution projection data are acquired at a position shown in Fig. 10 (a), and high resolution projection data are sequentially acquired at a position shown in Fig. 10 (b). Then, the computer 70 of the imaging system combines the high resolution projection data with the low resolution projection data according to the method described with reference to Figs. 4 to 8, thereby reconstructing a high resolution image for the local region of interest without distortion.

20 Industrial Applicability

According to the present invention, there is provided a method and apparatus capable of reconstructing an image for a local region of interest without distortion by combining high resolution projection data with low resolution projection data.

In an apparatus for reconstructing an X-ray CT image according to the present invention, the distance between an X-ray generator and a target object can be controlled so that the resolution of an X-ray CT image can be controlled. Further, the apparatus for reconstructing an X-ray CT image according to the present invention can provide a local high resolution CT image without distortion by acquiring low resolution projection data for the entire target object and by acquiring high resolution projection data for a local region of interest while causing the target object to approach the X-ray generator.

It should not be construed that the embodiments of the present invention described above and illustrated in the drawings limit the technical spirit of the present invention. The scope of the present invention should be defined only by the appended claims. It is apparent to those skilled in the art that various modifications and changes can be made
5 thereto within the technical spirit of the invention. Therefore, the modifications and changes will fall within the scope of the present invention so long as they are apparent to those skilled in the art.

CLAIMS

1. A method for reconstructing a local high resolution X-ray CT image, comprising the steps of:
 - 5 acquiring projection data by means of irradiation of X-rays on a target object at a position close to an X-ray generator such that a portion of the target object including a local region of interest exists within a range of irradiation angles of X-rays;
calculating virtual projection data on the assumption that the X-rays are irradiated on the entire target object at the close position, based on projection data acquired through
10 irradiation of the X-rays on the entire target object at a position where the entire target object exists within the range of irradiation angles of X-rays;
combining the virtual projection data on the entire target object except data on the local region of interest with the projection data acquired at the position close to the X-ray generator; and
15 reconstructing the combined projection data.
2. The method according to Claim 1,
wherein the step of calculating the virtual projection data comprises the steps of:
reconstructing cross-sectional image data on the entire target object, based on the
20 projection data acquired through irradiation of the X-rays on the entire target object at the position where the entire target object exists within the range of irradiation angles of X-rays; and
calculating the virtual projection data through line integral for the reconstructed cross-sectional image data on the entire target object on the assumption that the X-rays are
25 irradiated on the entire target object at the close position.
3. An apparatus for reconstructing an X-ray CT image, including a rotatably installed gantry, an X-ray generator installed on the gantry, an X-ray detector installed on the gantry to output projection data by detecting X-rays radiated from the X-ray generator and passed
30 through a target object, and an imaging system for reconstructing an image of the target

object by receiving the projection data from the X-ray detector, the apparatus comprising:

a moving means for relatively moving any one of the X-ray generator and the target object,

wherein the imaging system receives projection data acquired by means of
5 irradiation of the X-rays on the target object at a position close to the X-ray generator such
that a portion of the target object including a local region of interest exists within a range
of irradiation angles of X-rays, calculates virtual projection data on the assumption that the
X-rays are irradiated on the entire target object at the close position, based on projection
data acquired through irradiation of the X-rays on the entire target object at a position
10 where the entire target object exists within the range of irradiation angles of X-rays,
combines the virtual projection data on the entire target object except data on the local
region of interest with the projection data acquired by means of the irradiation on the target
object at the position close to the X-ray generator, and reconstructing the combined
projection data into an image.

15

4. The apparatus according to Claim 3,

wherein the imaging system performs the calculation of the virtual projection data
by reconstructing cross-sectional image data on the entire target object, based on the
projection data acquired through the irradiation of the X-rays on the entire target object at
20 the position where the entire target object exists within the range of irradiation angles of X-
rays, and by calculating the virtual projection data through line integral for the
reconstructed cross-sectional image data on the entire target object on the assumption that
the X-rays are irradiated on the entire target object at the close position.

25 5. The apparatus according to Claim 3 or 4,

wherein the moving means is a linearly moving means capable of moving the X-
ray generator relative to the target object along a line passing through a rotational center of
the gantry.

30 6. The apparatus according to Claim 5,

wherein the linearly moving means can simultaneously move the X-ray generator and the X-ray detector such that the X-ray generator and the X-ray detector are not moved relative to each other.

- 5 7. The apparatus according to Claim 6,
 wherein the X-ray detector is constructed in a one-dimensional arrangement.
8. The apparatus according to Claim 6,
 wherein the X-ray detector is constructed in a two-dimensional arrangement.
- 10 9. An apparatus for reconstructing an X-ray CT image, including a rotatably installed
 gantry, an X-ray generator installed on the gantry, an X-ray detector installed on the gantry
 to output projection data by detecting X-rays radiated from the X-ray generator and passed
 through a target object, and an imaging system for reconstructing an image of the target
15 object by receiving the projection data from the X-ray detector, the apparatus comprising:
 a linearly moving means for relatively moving at least one of the X-ray generator,
 the target object and the X-ray detector along a line passing through a rotational center of
 the gantry, thereby controlling the resolution of the X-ray CT image.
- 20 10. The apparatus according to Claim 9,
 wherein the linearly moving means is configured to move the X-ray generator and
 the X-ray detector relative to the target object.
11. The apparatus according to Claim 10,
25 wherein the X-ray detector is constructed in a one-dimensional arrangement.
12. The apparatus according to Claim 10,
 wherein the X-ray detector is constructed in a two-dimensional arrangement.
- 30 13. The apparatus according to any one of Claims 9 to 12,

wherein the imaging system receives projection data acquired by means of irradiation of the X-rays on the target object at a position close to the X-ray generator such that a portion of the target object including a local region of interest exists within a range of irradiation angles of X-rays, calculates virtual projection data on the assumption that the

5 X-rays are irradiated on the entire target object at the close position, based on projection data acquired through irradiation of the X-rays on the entire target object at a position where the entire target object exists within the range of irradiation angles of X-rays, combines the virtual projection data on the entire target object except data on the local

10 region of interest with the projection data acquired by means of the irradiation on the target object at the position close to the X-ray generator, and reconstructing the combined projection data into an image.

14. The apparatus according to Claim 13,

wherein the imaging system reconstructs cross-sectional image data on the entire

15 target object, based on the projection data acquired through the irradiation of the X-rays on the entire target object at the position where the entire target object exists within the range of irradiation angles of X-rays, and calculates the virtual projection data through line integral for the reconstructed cross-sectional image data on the entire target object on the assumption that the X-rays are irradiated on the entire target object at the close position.

Drawings

FIG. 1

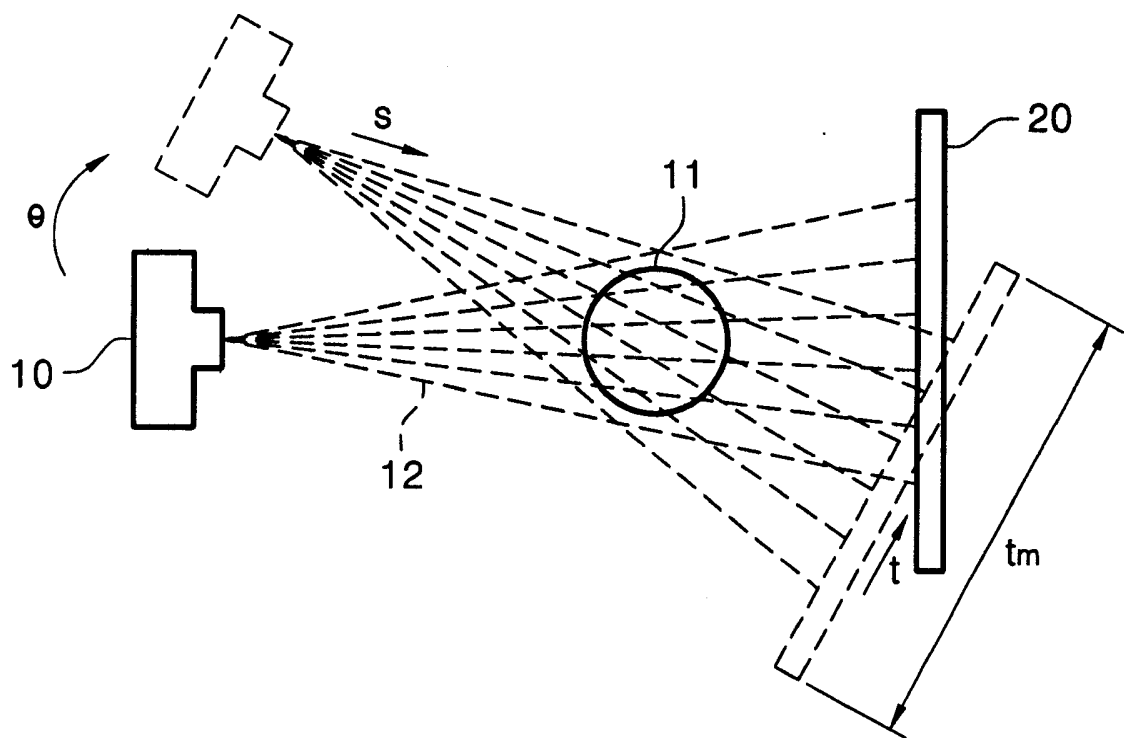


FIG. 2

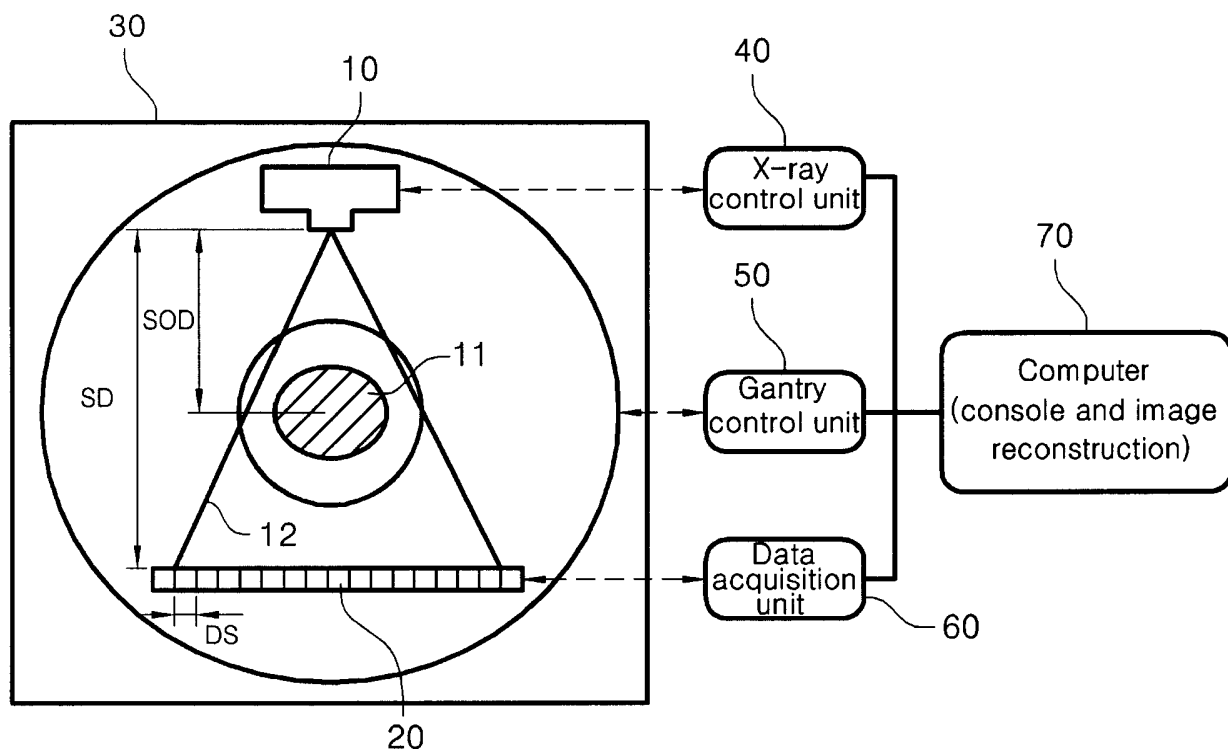


FIG. 3

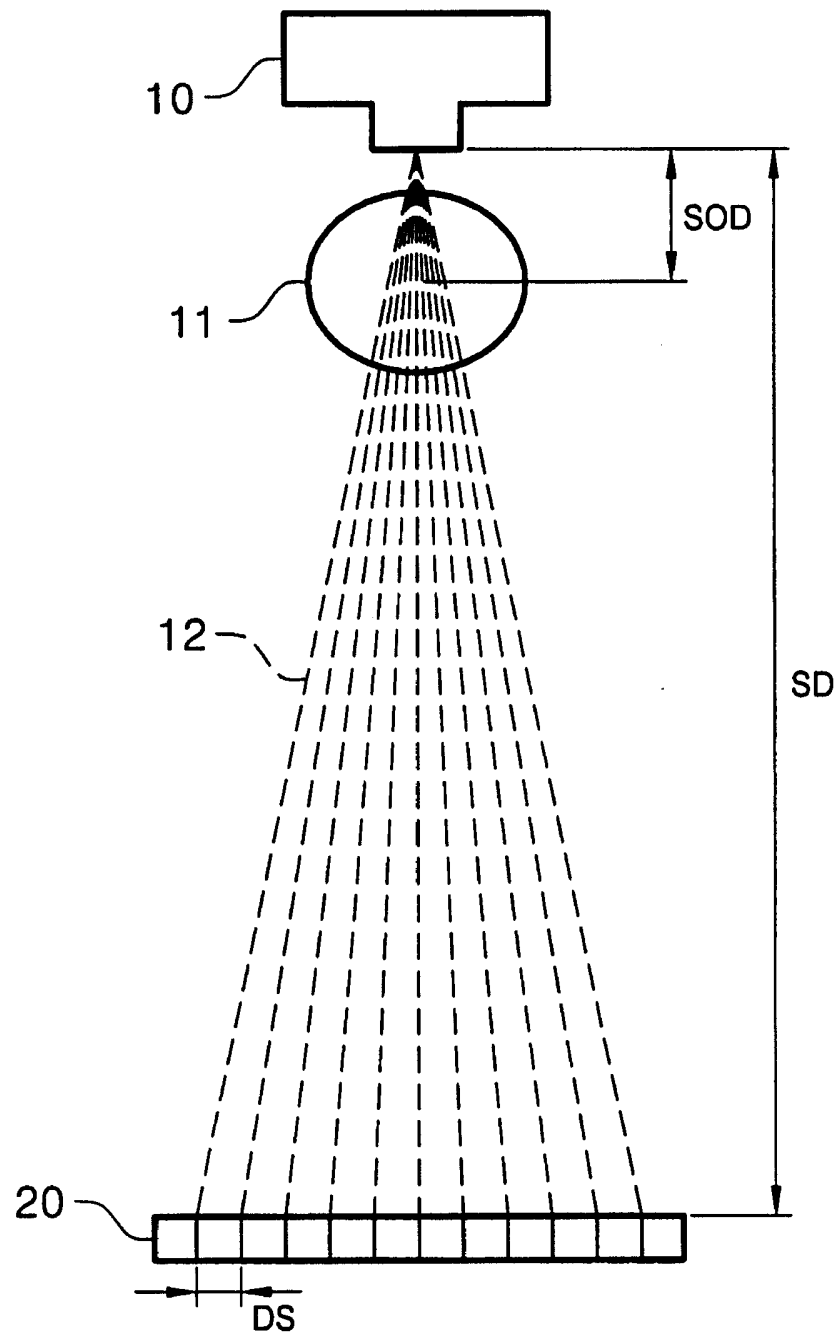


FIG. 4

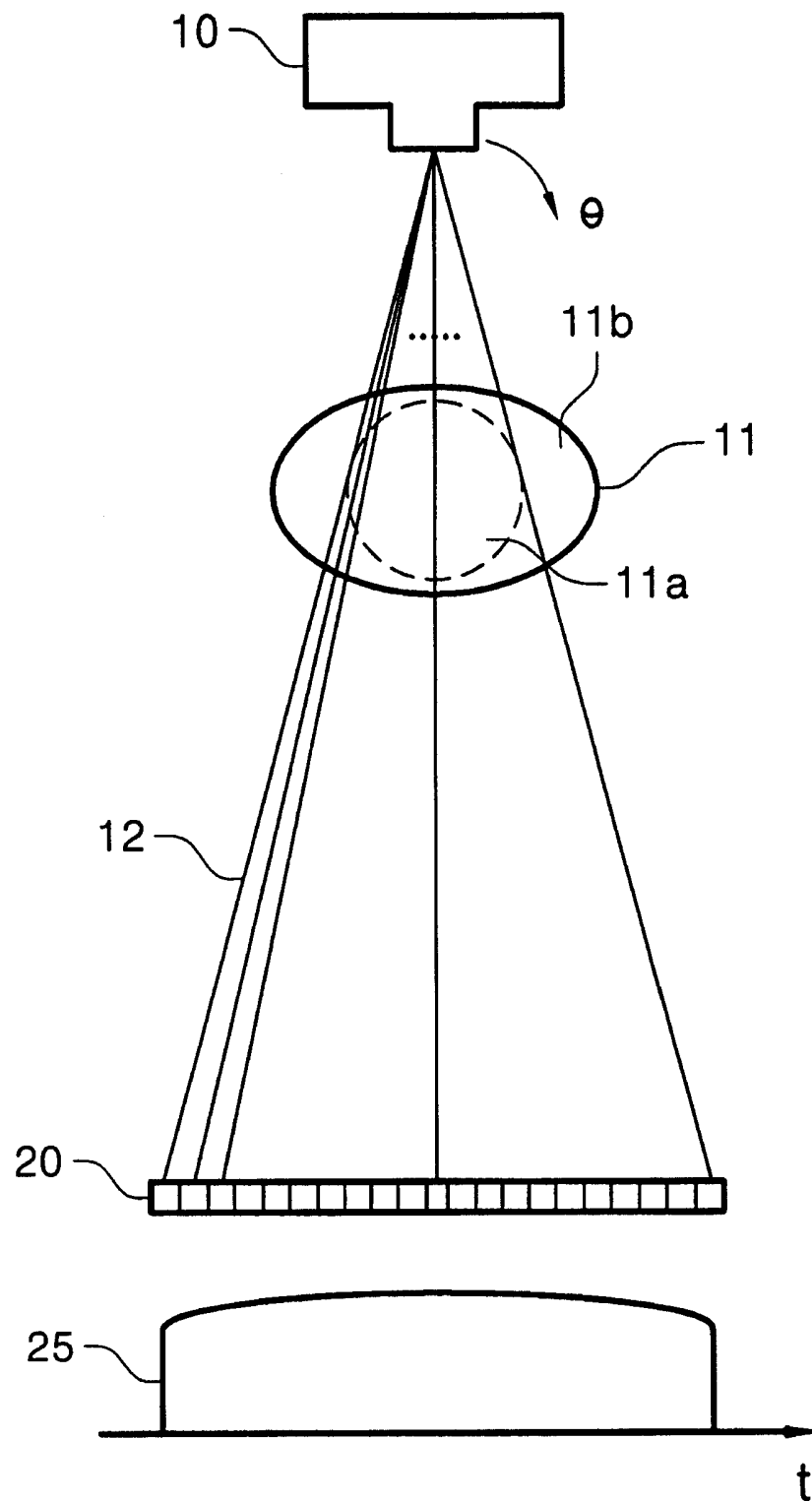


FIG. 5

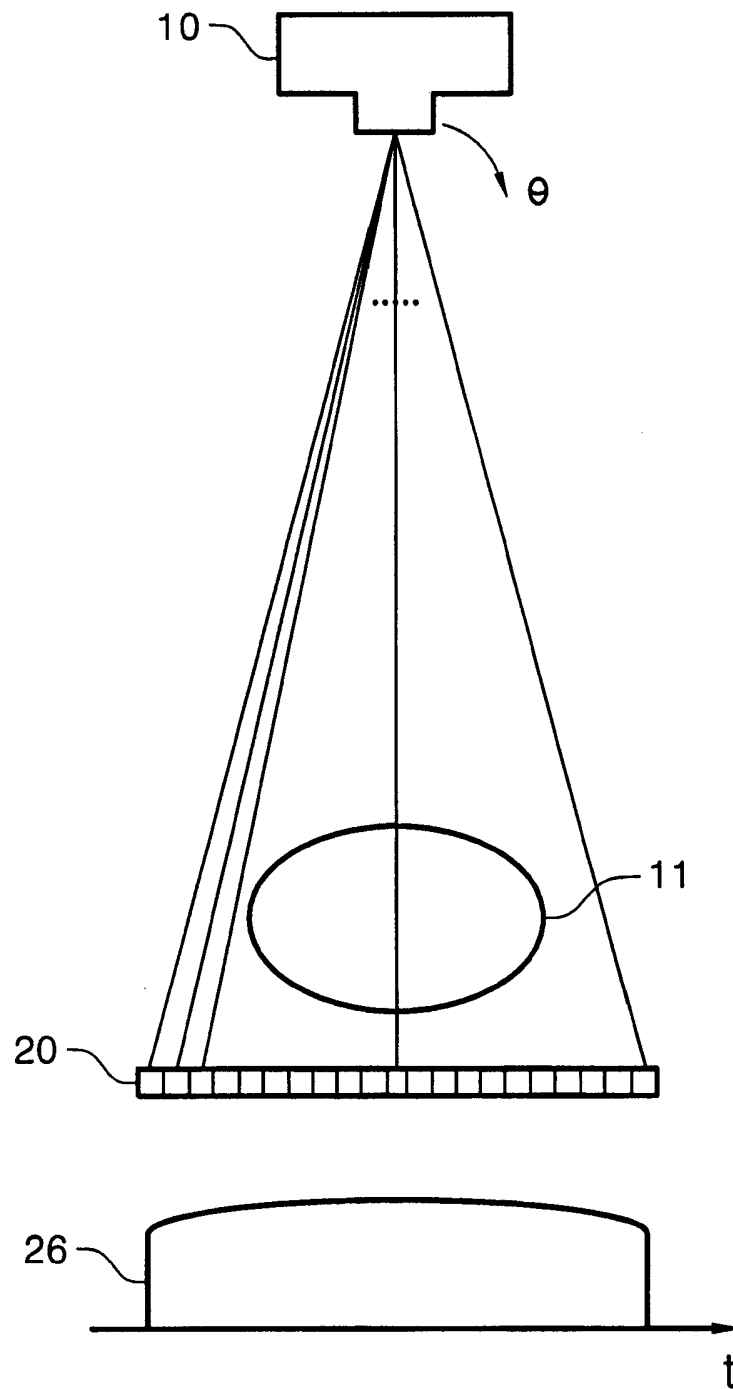


FIG. 6

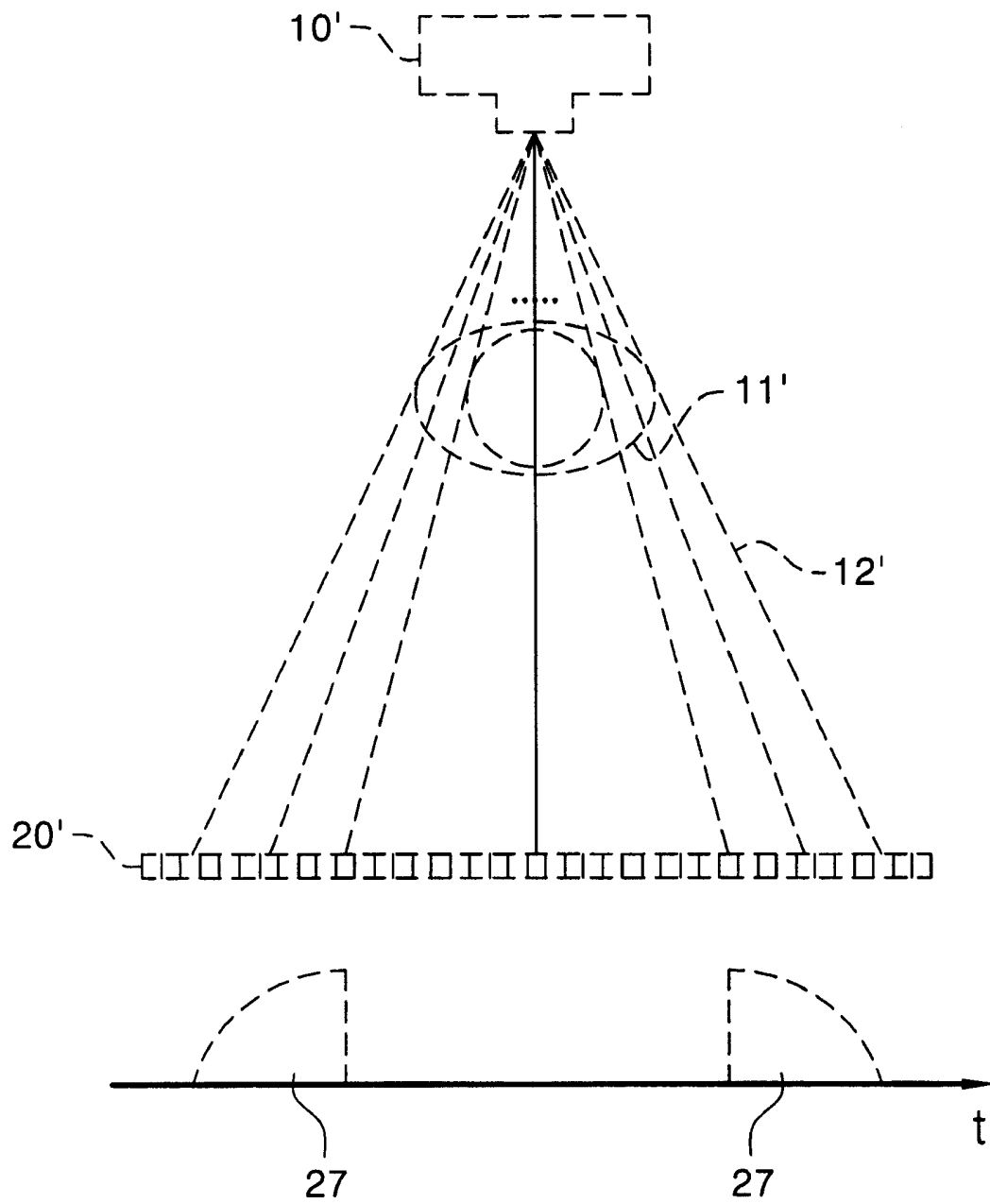


FIG. 7

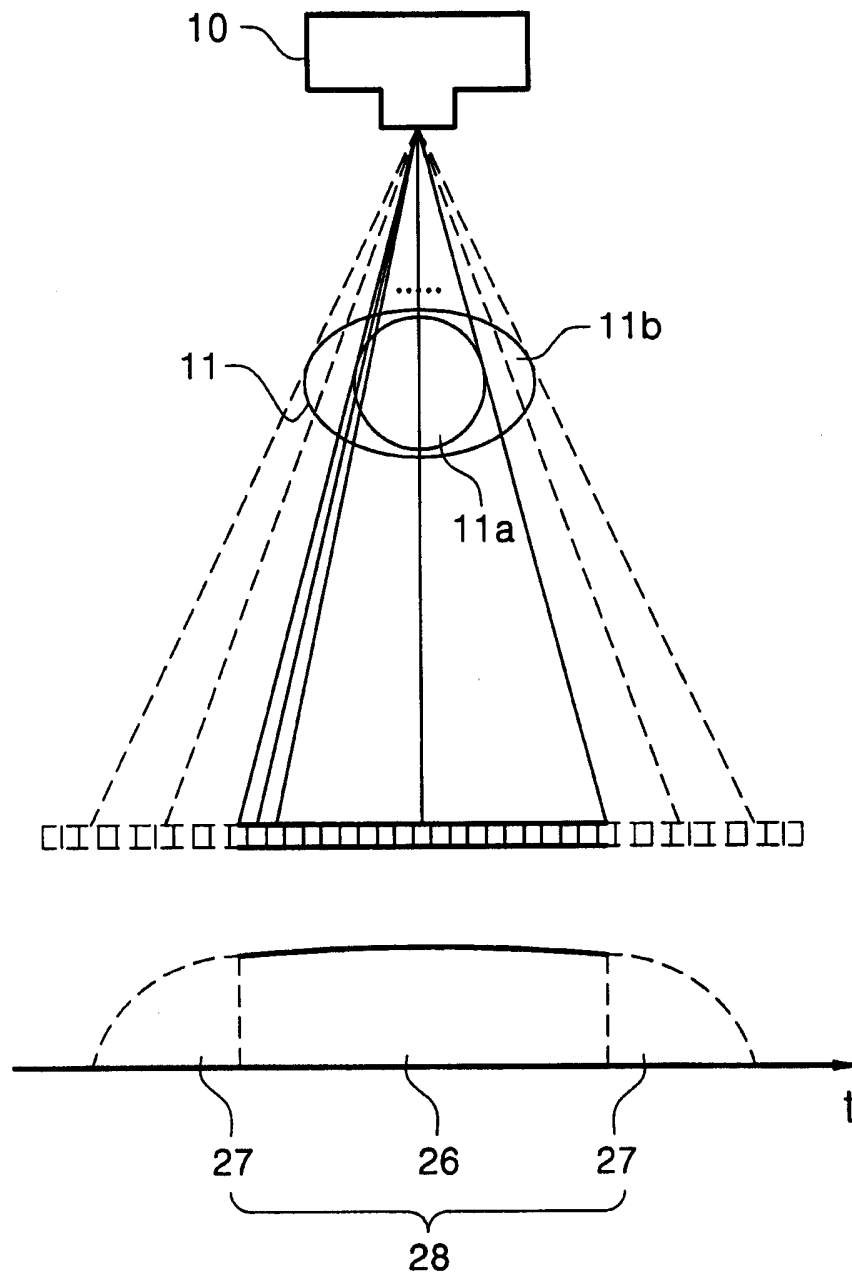


FIG. 8

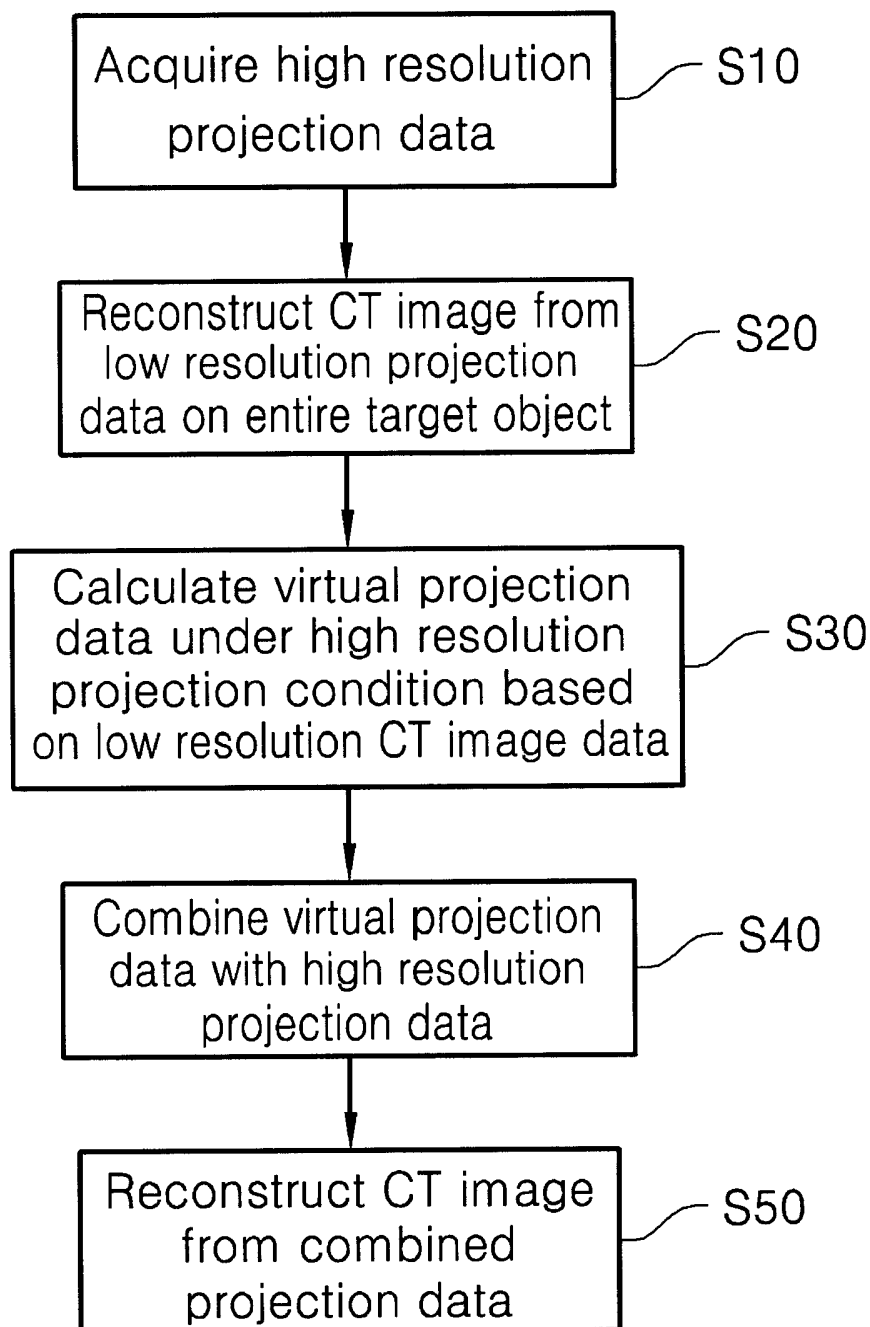


FIG. 9

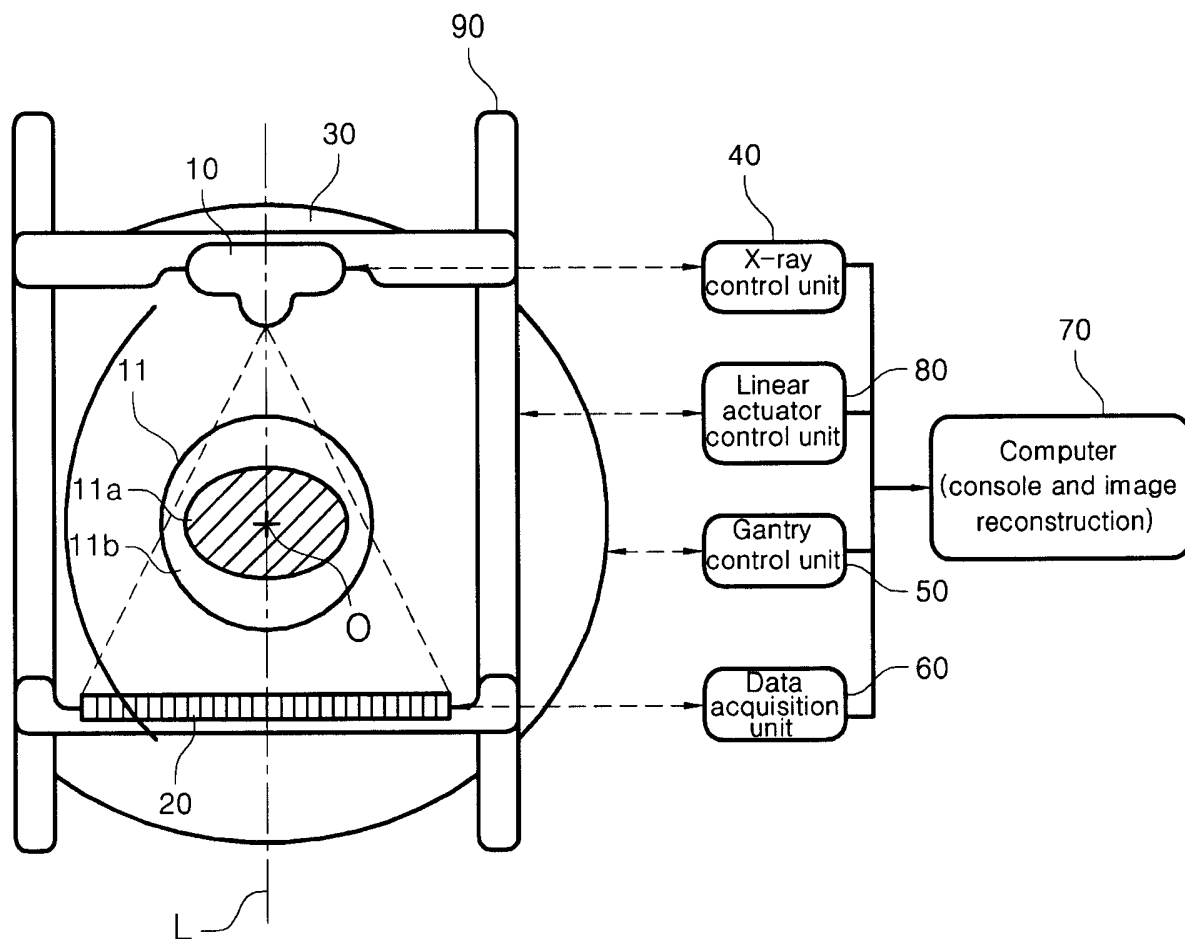
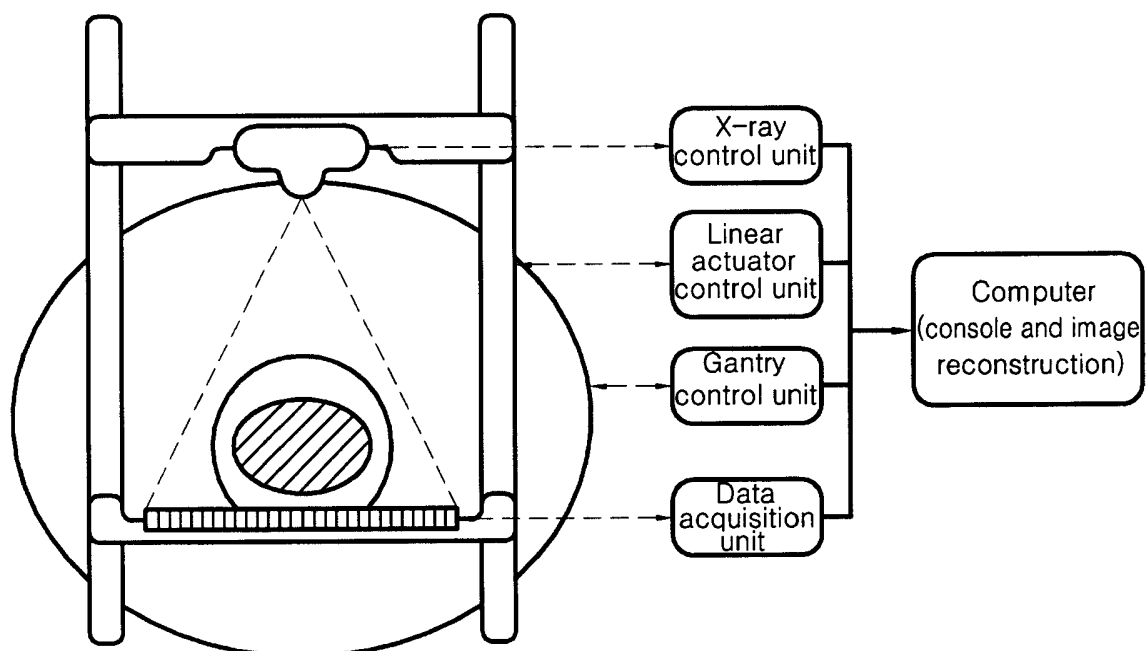


FIG. 10

(a)



(b)

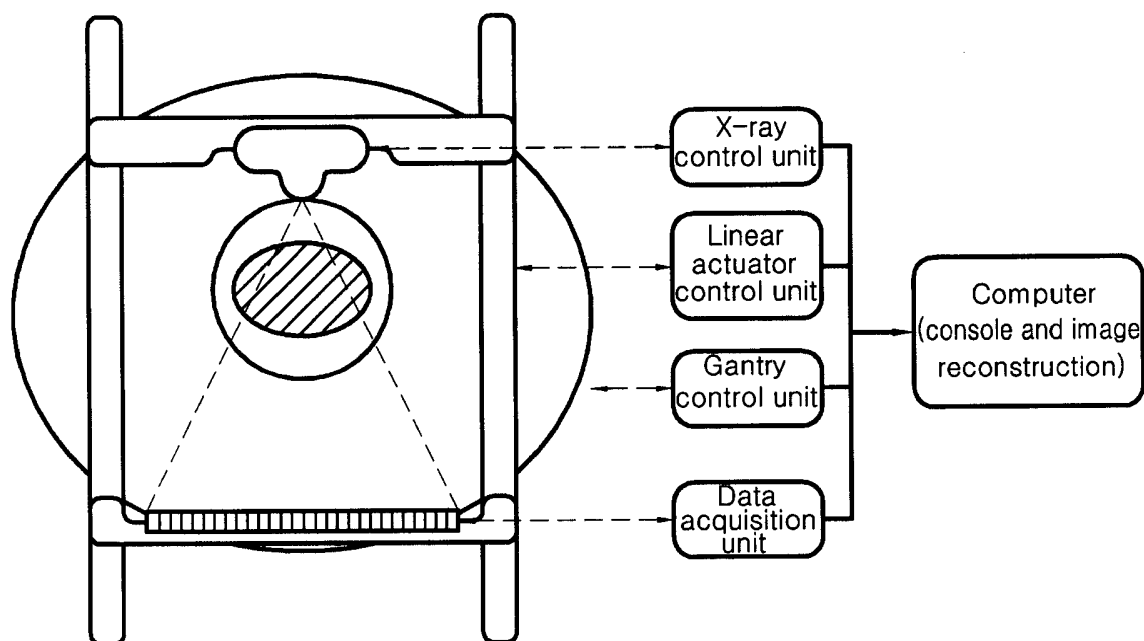
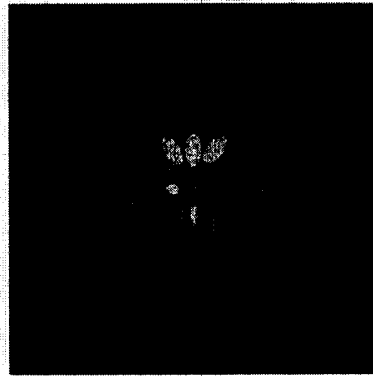
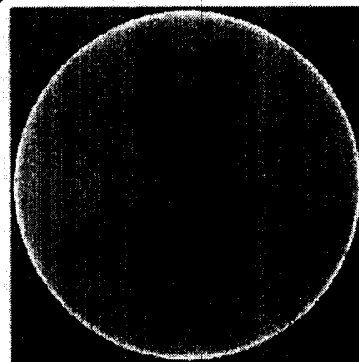


FIG. 11

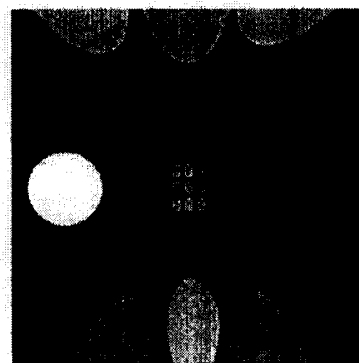
(a)



(b)



(c)



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2005/001815

A. CLASSIFICATION OF SUBJECT MATTER**IPC7 A61B 6/03**

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)

IPC7 A61B

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

Korean Patents and applications for inventions since 1947

Korean Utility models and applications for Utility models since 1947

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 12-325338 A (GENERAL ELECTRIC CO) 28 NOVEMBER 2000 abstract	1
A	US 6826251 B1 (Hitachi Medical Corporation) 30 NOVEMBER 2004 the entire document	1



Further documents are listed in the continuation of Box C.



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 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

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

25 OCTOBER 2005 (25.10.2005)

Date of mailing of the international search report

27 OCTOBER 2005 (27.10.2005)

Name and mailing address of the ISA/KR



Korean Intellectual Property Office
920 Dunsan-dong, Seo-gu, Daejeon 302-701,
Republic of Korea

Facsimile No. 82-42-472-7140

Authorized officer

KIM, Tae Geun

Telephone No. 82-42-481-8118



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/KR2005/001815

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP12325338	28.11.2000	DE10018707A1 JP12325338 US6256370B1	28.12.2000 28.11.2000 03.07.2001
US06826251	30.11.2004	JP2001346794A2 W0200128425A1	18.12.2001 26.04.2001